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FOREWORD

This gives me much pleasure to know that the Annual Research Report of the Bangladesh Institute of Nuclear Agriculture (BINA) for the year 2013-14 is going to be published. The research activities performed by the Institute during this period are reported here. Like other Institutes under the National Agricultural Research System (NARS), BINA has been working for agricultural development and conducting research covering eleven different research areas, specially with the aid of nuclear and other advance techniques.

A substantial progress was made towards the development of new crop varieties. The major research achievements during this period were: two lines as Ciherang-sub1 and Samba mahsuri-sub1for submergence tolerance (under 25-days of complete submergence), higher yield (5.5 and 4.5 t ha^{-1}, respectively) and early maturity (110 and 120 days, respectively) were selected and were already released as Binadhan-11 and Binadhan-12, respectively for T. aman season. A premium quality T. aman rice line IR-50 and a early maturing (100-105 days) T. aman rice line OMCS-2007 were released as Binadhan-15 and Binadhan-16, respectively; one rapeseed mutant line MM-51 and another rapeseed line RC-5 with higher seed yield (1700-1800 kg ha^{-1}) and short duration (78-82 days) were also registered by the National Seed Board (NSB) as Binasarish-9 and Binasarish-10; a Green Super Rice line BINA-GSR-3 of 3-4 days early maturity with higher grain yield (7.2 t ha^{-1}) over the check variety (BRRI dhan39) was selected and was applied to NSB for releasing as a T. aman variety. Two mutant lines of boro rice (RM(1)-200(c)-1-17 and RM(1)-50C-2-1-1), one having late transplanting potentials with average grain yield of 6.85 t ha^{-1} and another derived from BRRI dhan 29, having 9-days early maturing with similar grain yield were selected: one elite wheat mutant line (L-880-43) with salinity tolerance and higher yield potentials, three promising sesame mutant lines (SM-08, SM-09 and SM 067) and four soybean lines (SBM-9, SBM-15, SBM-18 and SBM-22) were selected. A mutant line (MBM-07-3Y-1) of summer mungbean was found to perform well in respect of seed coat color, seed yield and tolerance to cercospora leaf spot disease. Two lentil mutant lines (LM-75-4 and LM-132-7) and one onion mutant line for its higher yield in Khrif-II season were also selected as promising for release.

Fertilizer recommendations were made for some elite mutants of mustard, rice and sesame. Phosphatic biofertilizer with 50% P from TSP could be used for cultivation of lentil and chickpea as an alternate of 100% P from TSP alone. Studies on physiological aspect were done on some elite mutant lines of rice, mungbean, lentil and tomato. Screening of different mutant lines were done against insects, pest and diseases. It was found that under the prevailing climatic condition in Magura, the highest seed yield and water productivity of mungbean could be obtained with one irrigation at flowering stage, in addition to one pre-sowing irrigation. For technology transfer and promotional activities; 1101 demonstrations were laid out, 1585 farmers, DAE and NGOs personnel were trained and 40 field days were organized. Besides, BINA scientists supervised considerable numbers of MS and PhD students of BAU, Mymensingh.

I hope that the report would be useful for the scientists, planners, policy makers and those having academic interest. I sincerely congratulate and thank those who worked hard in publishing this report.

(Dr. Md. Shamsher Ali)
Director General

BINA'S OBJECTIVES

- *To develop high yielding and better quality crop varieties using both mutation and conventional breeding techniques.*
- *To assess the fertilizer status of the soils of Bangladesh and efficiency of utilization of applied nutrients by crop plants using radioisotopic techniques.*
- *To develop means of water use efficiency for optimization of crop yields through radioisotopes and radiation techniques.*
- *To evolve control measure against major pests and diseases of crop plants.*
- *To assist national and international research programmes through cooperative support.*
- *To provide facilities to students of the Bangladesh Agricultural University for carrying out research leading to Masters and Ph.D. degree in Agriculture.*
- *To arrange training programmes for the research scientists on the peaceful use of atomic energy in agriculture.*

PLANT BREEDING DIVISION

RESEARCH HIGHLIGHTS

Rice

The mutant RM(2)-40(C)-1-1-10 matured 10-15 days earlier than its parent BRRI dhan29 and produced significantly higher grain yield. Three mutants selected from Carbon Ion Beams irradiated NERICA-10 matures 20-25 days earlier and simultaneously produced higher grain yield (5.0-5.5 t ha^{-1}) in Aus season than the parent variety. Additionally, selected deep water rice mutant LD-20-1-1-1 could grow up to 3.0 m with rising water and produced double grain yield than its parent Luxmidigha in T. aman season.

Wheat

The line L-880-43 produced significantly higher grain yield in the saline areas of Satkhira and Patuakhali than check variety, BARI Gom-25. This line also produced significantly higher grain yield than BARI Gom-25 in the non-saline area Ishurdi.

Rapeseed-Mustard

One rapeseed mutant, MM-51 and one line, RC-5 having higher seed yield and early maturity period were registered by National Seed Board of Bangladesh as Binasarisha-9 and Binasarisha-10, respectively. Other two rapeseed mutant/line (MM-64 and RC-9) were also identified with higher seed yield and shorter maturity period. In addition, some mutant lines having higher seed yield potentials are under different trials for further evaluation.

Groundnut

A F_{10} line GC(1)-24-1-1-2 and two mutant lines (D1/20/17-1 and RS/25/3-1) were selected based on enhanced tolerance against *Cercospora* leaf spot diseases, jassid and jute hairy caterpillar and produced significantly higher pod yield than Dacca-1 and Zhingabadam in both of saline and non-saline areas.

Sesame

Three mutants (SM-08, SM-09 and SM-067) were selected based on their better performance in respect of seed yield. At least two of them are expected to be registered as varieties after further evaluation both in research and farmers' field. In addition, there were some other advanced mutants at various generations which will be evaluated in the next growing season.

Soybean

Four mutants (SBM-9, SBM-15, SBM-18 and SBM-22) were selected based on their better performance in respect of seed yield. At least two of them are expected to be registered as varieties after further evaluation both in research and farmers' fields. In addition, there are some other mutants at various generations, which will be evaluated in the next growing season.

Mungbean

One mutant (MBM-07-3Y-1) performed well in respect of seed-coat color, seed yield and tolerance to *Cercospora* leaf spot disease at different agro-ecological zones. Application will be made to the NSB for registration as a variety. In addition, some promising mutants were selected for earliness, seed yield and tolerance to diseases which will be evaluated further in the next growing season.

Chickpea

Some desirable mutant lines were selected for earliness, bolder seed size and higher seed yield potential. Those mutants will be further evaluated through different yield trials.

Lentil

Two mutant lines (LM-75-4 and LM-132-7) were found promising for seed yield (average seed yield of 2647 and 2418 kg ha^{-1}, respectively) with other desirable agronomic characters. Besides these two lines, a germplasm line (GL-208) was identified as drought tolerant in pre-field screening in hydroponic media. Application will be made for registration of these lines after further field evaluation. In addition, a good number of advanced mutant lines are in different trials for further evaluation.

Onion

The mutant BP2/100/2 produced significantly higher fresh and dry bulb yields followed by BP2/75/2 than the mother variety, BARI Piaj-2 in Kharif-II season.

RICE

Zonal yield trial with M_7 high yielding mutant lines of T. aman rice

This experiment was carried out with four early maturing and high yielding Boro mutant lines along with a check variety BRRI dhan49 to assess their performance over different locations of Bangladesh. Seeds were sown during 07 July to 17 July 2013 and transplanted during 29 July to 15 August 2013 at different locations (Table 1). The experiment was followed by RCB design with three replications. The size of the unit plots was 4.5 m × 3.0 m. Seedlings were transplanted at 15 cm distance within rows of 20 cm apart. Recommended doses of nitrogen, phosphorus, potassium, sulphur and zinc were applied in the form of Urea, TSP, MOP, Gypsum and Zinc Sulphate. Cultural and intercultural practices were followed as and when necessitated. Data on plant height, number of effective tillers hill^{-1}, panicle length, filled and unfilled grains panicle^{-1} were recorded after harvest from five randomly selected competitive plants. Maturity was assessed by plot basis. Grain yield were recorded from an area of 1.0 m^2 which was later converted to t ha^{-1}. All the recorded data were subjected to proper statistical analyses and are presented in Table 2.

It appears that the plant height differed significantly between the mutants and the check variety at all locations. The check variety was shorter than the mutants. Of the mutants, RM(2)-40(C)-4-2-4 produced the shortest plants at all locations except farmers' field at Mymensingh and Magura followed by the mutant RM(2)-40(C)-3-1-7. The number of effective tiller also differed significantly among the mutant lines and the check variety at all locations except Ishurdi and Magura sub-station farms. Mutant RM(2)-40(C)-3-1-7 had the highest number of effective tillers plant^{-1} at farmers' field, Magura followed by RM(2)-40(C)-4-2-4 at BINA Headquarters farm.

There were significant differences for panicle length among the mutants and the check variety. At all the locations, the check variety had shortest panicle than the mutants. Longest panicle was found at Rangpur farmers' field in RM(2)-50(C)-2-1-1 followed by RM(2)-40(C)-4-2-7. From the combined means RM(2)-50(C)-2-1-1 had the longest panicle over eight locations followed by RM(2)-40(C)-4-2-7 and RM(2)-40(C)-3-1-7.

Table 1. Date of sowing and transplanting of the mutants and check variety at different locations of Bangladesh

Location	Date of sowing	Date of transplanting	Seedling age (days)
Mymensingh Headquarters farm	7 July 2013	29 July 2013	22
Mymensingh farmer's field	7 July 2013	6 August 2013	30
Ishurdi sub-station farm	10 July 2013	10 August 2013	30
Magura sub-station farm	9 July 2013	2 August 2013	24
Magura farmer's field	9 July 2013	2 August 2013	24
Rangpur sub-station farm	17 July 2013	8 August 2013	22
Rangpur farmer's field	17 July 2013	15 August 2013	42

Number of filled grains panicle^{-1} differed significantly at all the locations except BINA Headquarters farm, Mymensingh and sub-station farm at Ishurdi. Highest number of filled grains were found at Magura in the mutant RM(2)-50(C)-2-1-1. This mutant also had the highest number of filled grains from the combined means followed by RM(2)-40(C)-4-2-7 and RM(2)-40(C)-3-1-7. Unfilled grains also differed significantly for the mutants and the check variety at all locations.

Two mutants, RM(2)-40(C)-4-2-4 and RM(2)-40(C)-3-1-7 matured 13-16 days earlier than the check variety. At BINA Headquarters farm, Mymensingh and sub-station farm at Magura, the mutant RM(2)-40(C)-4-2-7 produced significantly higher grain yield than the check variety (Table 2). But at Rangpur sub-station farm, all the mutants produced significantly higher yield than BRRI dhan49. Apart from Rangpur sub-station farm, the mutant RM(2)-50(C)-2-1-1 produced significantly higher yield at farmers' field at Rangpur. From the combined means, it was observed that the mutant RM(2)-50(C)-2-1-1 produced the highest yield and had mostly similar maturity period with the check variety. Therefore, the mutants RM(2)-50(C)-2-1-1 and RM(2)-40(C)-4-2-4 could be selected for further evaluation.

Table 2. Yield and yield attributes of four early maturing mutant lines of T. aman rice along with the check variety BRRI dhan49

Mutant/check variety	Days to maturity	Plant height (cm)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Grain yield (t ha^{-1})
Mymensingh Headquarters farm							
RM(2)-40(C)-4-2-4	110	114.3	9.7	27.9	101.3	43.3	4.0
RM(2)-40(C)-3-1-7	110	117.1	7.3	27.9	103.9	37.3	4.0
RM(2)-40(C)-4-2-7	123	124.9	8.2	27.2	87.7	30.5	4.3
RM(2)-50(C)-2-1-1	123	122.9	9.0	26.9	110.0	26.1	4.0
BRRI dhan49	127	101.9	8.9	23.0	104.7	25.8	3.8
$LSD_{(0.05)}$	-	8.7	1.3	2.7	NS	5.4	0.3
Mymensingh farmer's field							
RM(2)-40(C)-4-2-4	116	106.9	7.6	23.9	87.4	19.5	3.4
RM(2)-40(C)-3-1-7	113	102.4	6.0	22.9	63.7	15.1	3.1
RM(2)-40(C)-4-2-7	126	118.8	6.9	23.7	72.9	35.3	3.7
RM(2)-50(C)-2-1-1	126	121.9	7.6	24.7	100.4	27.1	4.1
BRRI dhan49	129	98.0	6.7	21.0	103.9	17. 7	4.1
$LSD_{(0.05)}$	-	3.5	1.2	2.4	8.4	4.8	0.3
Ishurdi							
RM(2)-40(C)-4-2-4	110	100.4	8.3	20.3	74.1	16.9	3.4
RM(2)-40(C)-3-1-7	108	102.3	9.2	21.5	74.2	18.1	3.4
RM(2)-40(C)-4-2-7	125	110.7	8.3	21.7	86.8	17.9	2.8
RM(2)-50(C)-2-1-1	125	107.5	8.3	23.6	80.4	9.7	3.5
BRRI dhan49	125	82.9	8.4	17.9	81.3	19.5	3.0
$LSD_{(0.05)}$	-	8.2	NS	2.9	NS	4.1	0.6

Table 2 Contd.

Mutant/check variety	Days to maturity	Plant height (cm)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Grain yield (t ha^{-1})
Magura sub-station farm							
RM(2)-40(C)-4-2-4	109	124.3	8.5	24.9	107.7	16.5	3.5
RM(2)-40(C)-3-1-7	102	124.3	8.5	26.5	103.5	32.7	3.0
RM(2)-40(C)-4-2-7	116	130.8	7.3	25.7	134.7	14.2	4.1
RM(2)-50(C)-2-1-1	116	128.1	8.0	26.9	136.5	17.1	3.5
BRRI dhan49	116	93.3	7.7	22.3	77.1	14.5	3.2
$LSD_{(0.05)}$	-	10.4	NS	2.8	10.2	8.7	0.7
Magura farmers' field							
RM(2)-40(C)-4-2-4	109	104.3	8.3	23.9	55.7	23.5	3.2
RM(2)-40(C)-3-1-7	101	102.3	14.6	26.2	58.7	17.1	3.1
RM(2)-40(C)-4-2-7	117	122.4	9.4	24.1	79.9	20.4	2.7
RM(2)-50(C)-2-1-1	117	127.0	7.9	24.7	81.7	21.4	2.5
BRRI dhan49	117	83.0	9.9	21.7	83.2	14.5	3.2
$LSD_{(0.05)}$	-	3.6	2.7	3.4	9.3	8.7	0.3
Rangpur sub-station farm							
RM(2)-40(C)-4-2-4	109	118.2	9.0	23.8	84.1	16.4	5.7
RM(2)-40(C)-3-1-7	104	120.4	9.5	25.1	115.0	14.5	5.6
RM(2)-40(C)-4-2-7	118	130.3	9.1	24.7	73.5	18.7	5.0
RM(2)-50(C)-2-1-1	118	137.5	7.7	26.0	114.0	18.9	5.6
BRRI dhan49	118	103.9	9.1	22.6	122.0	14.0	4.5
$LSD_{(0.05)}$	-	1.3	1.0	1.1	4.4	1.8	0.4
Rangpur farmer's field							
RM(2)-40(C)-4-2-4	106	103.8	7.6	25.9	77.3	18.0	3.6
RM(2)-40(C)-3-1-7	101	104.3	8.9	25.2	75.7	22.6	3.6
RM(2)-40(C)-4-2-7	114	118.8	7.7	28.2	100.5	18.6	4.4
RM(2)-50(C)-2-1-1	114	124.5	8.2	28.6	136.1	18.9	5.5
BRRI dhan49	114	92.5	9.0	22.9	114.7	14	4.5
$LSD_{(0.05)}$	-	3.7	0.8	1.3	3.2	1.8	0.5
Combined means over eight locations							
RM(2)-40(C)-4-2-4	110	110.3	8.4	24.4	83.9	22.0	3.8
RM(2)-40(C)-3-1-7	106	110.4	9.2	25.0	84.9	22.5	3.7
RM(2)-40(C)-4-2-7	120	122.4	8.1	25.0	90.9	22.2	3.9
RM(2)-50(C)-2-1-1	120	124.2	8.1	25.9	108.4	19.9	4.0
BRRI dhan49	121	93.6	8.5	21.6	98.1	17.1	3.8
$LSD_{(0.05)}$	-	5.4	1.3	2.1	20.1	4.7	0.4

NS = not significant

Advanced yield trial with F_7 lines of fine grain and higher iron containing rice in T. aman season

An experiment was carried out with seven high yielding and iron containing T. aman rice lines. These lines were derived from hybridization between an exotic line introduced from Vietnam having high iron content and Binadhan-7 or Binasail to assess performance over different locations of Bangladesh. Binadhan-7 was used as a check variety. Seeds were sown during 07 July and 17 July 2013 and transplanted during 30 July and 08 August 2013 at different locations (Table 3). The experiment followed by RCB design with three replications. The size of the unit plots were 3.0 m × 2.0 m. Seedlings were transplanted at 15 cm distance within rows of 20 cm apart. Recommended doses of nitrogen, phosphorus, potassium, sulphur and zinc were applied in the form of Urea, TSP, MOP, Gypsum and Zinc Sulphate. Cultural and intercultural practices were followed as and when necessitated. Data on plant height, number of effective tiller, panicle length, filled as well as unfilled grains panicle^{-1} were recorded after harvest from five randomly selected competitive plants. Maturity was assessed by plot basis. Grain yield data were recorded from an area of 1.0 m^2 which was later converted to tha^{-1}. Finally, all the recorded data were subjected to proper statistical analyses and are presented in Table 4.

Table 3. Date of seed sowing and seedling transplanting of seven advanced lines and the check variety

Locations	Date of sowing	Date of transplanting	Seedling age (days)
Mymensingh	7 July 2013	30 July 2013	23
Magura	9 July 2013	2 August 2013	24
Rangpur	17 July 2013	8 August 2013	22
Comilla	10 July 2013	8 August 2013	29

It appears that all the seven lines had significantly taller height than the check variety, Binadhan-7 at all locations (Table 4). Number of effective tillers did not differ significantly among the lines than the check variety at Mymensingh and Magura. The highest number of effective tillers were found in RC(3)-4-1-8 despite with non-significant difference from the check variety. At Comilla, none of the lines had significantly higher number of tillers than the check variety, Binadhan-7. At Mymensingh, one line had significantly longer panicle length than the check variety, Binadhan-7 while each of Magura and Rangpur two lines and at Comilla four lines had significantly longer panicle length. Number of filled grains also differed significantly at all locations between the lines and check variety. At Mymensingh, four lines had significantly higher filled grains than the check variety while at Comilla two and Magura five lines had higher filled grains. In contrast, at Rangpur, all the lines had significantly higher filled grains than the check variety. Significantly lower unfilled grains were observed at Mymensingh in five lines while at Magura only in one line. Only one line, RC(2)-2-4-1-4 produced significantly higher grain yield than the check variety at Mymensingh. However, the lines that produced statistically as per yield with the check variety but with higher iron content could be put into AYT in the next Boro season.

Table 4. Yield and yield attributes of seven advanced lines with check variety, Binadhan-7

Lines/Variety	Days to maturity (days)	Plant height (cm)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains plant^{-1} (no.)	Unfilled grains plant^{-1} (no.)	Grain yield (t ha^{-1})
Mymensingh							
RC(1)-3-2-1	123	145.5	8.3	26.1	103.7	26.6	4.1
RC(1)-3-5-5	116	120. 7	11.3	24.5	98.5	11.4	3.4
RC(2)-2-2-1-7	119	119.4	8.9	24.9	86.2	11.7	4.1
RC(2)-2-4-1-2	123	119.3	8.5	26.4	99.7	14.1	4.9
RC(2)-2-4-1-4	123	120.5	7.9	26.1	87.2	10.5	4.8
RC(2)-2-4-3-1	123	124.7	8.3	27.9	99.9	10.9	5.2
RC(3)-4-1-8	118	127.5	8.9	28.9	83.7	31.6	3.5
Binadhan-7	113	102.9	10.5	26.1	77.4	27.2	4.8
$LSD_{(0.05)}$	-	3.7	NS	2.0	11.0	5.0	0.2
Magura							
RC(1)-3-2-1	116	149.8	8.1	25.7	134.9	14.7	4.2
RC(1)-3-5-5	116	132.9	9.8	24.3	109.8	12.3	4.3
RC(2)-2-2-1-7	115	126.9	7.7	26.5	130.4	13.9	3.7
RC(2)-2-4-1-2	115	130.8	7.4	25.4	95.9	9. 7	4.4
RC(2)-2-4-1-4	115	149.8	9.5	24.2	129.7	14.7	4.3
RC(2)-2-4-3-1	114	129.2	7.4	25.5	108.5	17.1	4.2
RC(3)-4-1-8	115	144.8	9.1	27.7	98.1	24.5	3.6
Binadhan-7	113	102.1	10.3	23.8	95.3	12.6	4.8
$LSD_{(0.05)}$	-	4.8	NS	1.7	7.8	4.9	0.7
Rangpur							
RC(1)-3-2-1	119	144.1	8.1	25.1	134.2	21.3	5.5
RC(1)-3-5-5	119	126.3	9.2	26.3	124.9	33.3	5.5
RC(2)-2-2-1-7	119	121.1	8.4	20.4	121.1	25.7	4.9
RC(2)-2-4-1-2	119	121.7	7.2	25.0	108.3	21.4	5.6
RC(2)-2-4-1-4	120	138.3	8.2	23.8	112	25.3	5.9
RC(2)-2-4-3-1	119	125.0	8.8	26.0	113.3	26.2	5.9
RC(3)-4-1-8	119	133.5	10.0	27.1	119.1	39.7	5.1
Binadhan-7	114	98.2	9.7	22.6	89.1	20.1	5.7
$LSD_{(0.05)}$	-	3.49	0.6	1.3	1.8	1.4	0.5
Comilla							
RC(1)-3-2-1	119	143.5	9.1	23.9	93.7	26.1	3.4
RC(1)-3-5-5	119	129.9	10.5	24.8	96.9	23.9	3.5
RC(2)-2-2-1-7	119	122.7	11.9	26.6	77.8	21.1	3.6
RC(2)-2-4-1-2	119	122.1	8.3	25.8	73.9	18.9	3.7
RC(2)-2-4-1-4	119	127.3	9.5	27.7	108.9	18.9	3.5
RC(2)-2-4-3-1	119	125.9	10.5	26. 7	88.5	26.1	4.2
RC(3)-4-1-8	119	133.1	8. 7	28.2	111. 7	32.3	3.4
Binadhan-7	112	99.1	14.3	23. 7	96.2	14.1	4.4
$LSD_{(0.05)}$	-	6.9	1.1	2.1	7.2	5.1	0.5
Combined means over four locations							
RC(1)-3-2-1	119	145.7	8.4	25.2	116.6	22.2	4.3
RC(1)-3-5-5	118	127.4	10.2	24.9	107.6	20.2	4.2
RC(2)-2-2-1-7	118	122.5	9.2	24.6	103.9	18.1	4.1
RC(2)-2-4-1-2	119	123.5	7.9	25.7	94.5	16.0	4.7
RC(2)-2-4-1-4	119	133.9	8.7	25.5	109.5	17.3	4.6
RC(2)-2-4-3-1	119	126.2	8.8	26.5	102.5	20.1	4.9
RC(3)-4-1-8	118	134.8	9.2	27.9	103.1	32.0	3.9
Binadhan-7	113	100.6	11.2	24.0	89.5	18.5	4.9
$LSD_{(0.05)}$	-	5.1	2.5	1.7	7.1	4.2	0.5

Screening of M_3 population derived from deep water rice cv. Luxmidigha under deep water condition

Seeds of three M_3 bulk populations derived from irradiating the seeds of a local deep water rice cv. Luxmidigha with 200, 250 and 300 Gy doses of gamma rays and six selected plants derived from 200 Gy dose were sown on 10 July 2013 at BINA Headquarters farm, Mymensingh. Seedlings were transplanted on 7 August 2013 at 15 cm distances within rows of 20 cm apart in the Deep Water Rice Screening Tank (DWRST) following non-replicated design. Fertilizers were applied at the rate of N-54 kg, P- 60 kg, K-40 kg ha^{-1} in the form of Urea, TSP and MOP. Urea was applied as top dressing after 10 and 30 days of transplanting. After 35 days of transplanting, water level was increased by 20 cm at every third day till 26 September 2013. The remaining portion of the tank was filled with rain water. The depth of the tank was 2.44 m from the ground level. Recommended cultural and intercultural operations were followed as and when necessitated.

Data on plant height, number of effective tillers $hill^{-1}$, panicle length, filled and unfilled grains $panicle^{-1}$ and grain yield $hill^{-1}$ were recorded. Maturity was recorded population basis while plant height and the other attributes were recorded from each individual hill. Finally, one hill was selected based on longer plant height, higher number of effective tillers, longer panicle length, higher number of filled grains and increased yield per plant (Table 5).

Table 5. Yield and some yield attributes of a M_3 population of deep water rice grown in DWRST in T. aman season

Mutants/check variety	Plant height (cm)	Effective tillers $plant^{-1}$ (no.)	Panicle length (cm)	Maturity (days)	Filled grains $plant^{-1}$ (no.)	Unfilled grains $plant^{-1}$ (no.)	Grain yield $plant^{-1}$ (g)
LD-200-1-1	282	7	32	129	262	23	23.29
Luxmidigha	258	4	22	130	142	4	11.8

Out of six individual plant progenies, only one was selected based on increased plant height, effective tiller number, panicle length, filled grains and grain yield $hill^{-1}$ (Table 5). Unlike the parent the selected plant had awnless spikelet.

Growing carbon ion beam irradiated M_1 generation of Swarna rice in T. aman season

Seeds of a high yielding rice variety, Swarna, were irradiated with carbon ion beams from Japan Atomic Energy Agency (JAEA). Irradiation doses were 0, 20, 40, 60, 80, 100, 120, 140, 160, 180 and 200 Gy. Two hundred seeds per dose were sown on petri dishes. The germinated seedlings were transferred to pot and finally seedlings were transplanted in the field on 18 August 2013. Data on germination, survival, plant height, number of effective tillers, panicle length, filled and unfilled grains $plant^{-1}$, yield $hill^{-1}$ were recorded after harvest from five randomly selected competitive plants. Finally, all the recorded data were subjected to proper statistical analyses and are presented in Table 6 and Table 7.

Germination and survival decreased with the increase of the irradiation doses (Table 6). But the reduction in germination percentages did not follow linear trend after 60 Gy dose. In contrast, survival percentages decreased gradually with increased doses of carbon ion beams and at 100 Gy dose it reduced to zero (Table 6). Plant height, number of effective tillers, panicle length, filled grains and grain yield hill^{-1} decreased gradually with increased doses of carbon ion up to 60 Gy dose (Table 7). As expected unfilled grains plant^{-1} were increased gradually. At maturity the survived plants could produce grains upto 60 Gy dose while that of 80 Gy dose could not produce any seed (Table 7). Finally, the M_1 seeds from the survived plants were bulked dose wise and kept for growing in the M_2 generation in the next T. aman season.

Table 6. Germination and survival percentage of carbon ion irradiated seeds of Swarna

Doses (Gy)	Seeds sown	Seeds germinated	Germination (%)	Survival (%)
0	200	190	95.0	25.3
20	200	122	61.0	17.2
40	200	56	28.0	10.7
60	200	62	31.0	11.3
80	200	52	26.0	5.8
100	200	71	35.5	0
120	200	69	34.5	0
140	200	61	30.5	0
160	200	50	25.0	0
180	200	55	27.5	0
200	200	40	20	0
Mean ± SE	-	-	37.6 ± 6.6	6.4 ± 2.6

Table 7. Yield and yield attributes of the M_1 population of Swarna at different doses

Dose (Gy)	Days to maturity	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	Filled grain plant^{-1} (no.)	Unfilled grain plant^{-1}	Grain yield plant^{-1} (g)
0	136	100.6	12	24	135	23.8	40
20	138	92.6	11.2	25.6	123.2	49.8	30
40	138	97.6	9.4	23.4	110.2	65.0	20
60	138	95.2	9.0	23.2	103.4	29.6	20
Mean ± SE	-	96.5 ± 1.7	10.4 ± 0.7	24 ± 0.5	137.9 ± 15.9	42.0 ± 9.5	27.5 ± 4.8

Zonal yield trial with a M_7 high yielding mutant line of Boro rice

Seedlings of a high yielding short duration mutant line along with its parent BRRI dhan29 were sown on December 2013 to 1 January and transplanted during 9 January to 13 February 2014 (Table 8). The experiments were followed by RCB design with three replications. Seedlings were transplanted at 15 cm distances within rows of 20 cm apart. A unit plot size was 5.0 m × 4.0 m. Recommended doses of fertilizers were applied and cultural and intercultural operations were done as and when necessary. Data on plant height, number of effective tillers, panicle length, filled and unfilled grains panicle^{-1} and grain yield plot^{-1} were recorded. Maturity was recorded plot basis while plant height, effective tillers number, panicle length, filled and unfilled grains panicle^{-1} was recorded from five hills plot^{-1} at harvest. Grain yield was recorded from 1 m^2 area which was later converted to t ha^{-1} at 14% moisture. Moisture data was recorded with a grain moisture meter. Finally, the recorded data were subjected to proper statistical analyses following the design used and are presented in Table 9, Table 10 and Table 11.

Table 8. Seed sowing, transplanting and seedling age of a high yielding short duration Boro mutant along with BRRI dhan29

Location	Date of seed sowing	Date of transplanting	Age of seedlings (days)
BINA farm, Mymensingh	2 December 2013	9 January 2014	39
Maijbari, Mymensingh	2 December 2013	10 January 2014	40
BINA sub-station farm, Magura	2 December 2013	14 January 2014	44
Farmers' Field, Magura	2 December 2013	14 January 2014	44
BINA sub-station farm, Rangpur	1 January 2014	12 February 2014	43
Pakkhifanda, Rangpur	1 January 2014	13 February 2014	44
BINA sub-station farm, Barisal	2 December 2013	31 January 2014	61
Farmers' Field, Barisal	20 December 2013	30 January 2014	42

Yield attributes of the mutant line RM(2)-40C-1-1-10 along with the parent variety BRRI dhan29 averaged over eight locations of Bangladesh are presented in Table 10. It appeared that none of the yield attributes differed significantly between the parent and the mutant.

Table 9. Yield of the mutant and check variety BRRI dhan29 averaged over eight locations

Mutant/variety	Plant height (cm)	Effective tillers (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)
RM(2)-40(C)-1-1-10	101	11.42	24.7	113	33
BRRI dhan29	100	11.87	24.5	111	33
$LSD_{(0.05)}$	NS	NS	NS	NS	NS

NS = not significant

However, the mutant line matured 10-15 days earlier than its parent variety BRRI dhan29 at all locations (Table 10). Additionally, it produced significantly higher grain yield than the parent at four locations and at two other locations it although produced higher grain yield but with non significant difference. The average yield of eight locations of the mutant was 6.46 t ha^{-1} which was 0.41 t ha^{-1} more than the parent variety BRRI dhan29.

The higher grain yield of the mutant than its parent was mostly attributed to its higher 1000-grain weight and longer grain length (Table 11). The decorticated grain length and breadth of the mutant were 7.4 and 2.5 mm, respectively, with a ratio of 2.96 indicating its grains are long and slender.

Table 10. Maturity period and yield of a high yielding short duration Boro mutant along with BRRI dhan29

Location	Maturity period (days)		Grain yield (t ha^{-1})	
	RM(2)-40(C)-1-1-10	BRRI dhan29	RM(2)-40(C)-1-1-10	BRRI dhan29
BINA farm, Mymensingh	150	165	6.9	6.5
Maijbari, Mymensingh	152	165	5.8	6.3
BINA sub-station farm, Magura	157	168	7.6	5.7
Farmer's Field, Magura	155	168	5.8	5.5
BINA sub-station farm, Rangpur	155	165	7.5	7.1
Pakkhifanda, Rangpur	145	160	7.8	7.2
BINA sub-station farm, Barisal	155	170	5.1	4.9
Farmer's Field, Barisal	151	162	5.2	5.2
LSD $_{(0.05)}$	-	-	0.36	-
Average	153	165	6.46	6.05

Table 11. Grain characters of the mutant and the check variety

Mutant/variety	1000-grain weight (g)	Grain length (mm)	Grain breadth (mm)	Length: breadth ratio
RM(1)-40- (C)-1-1-10	26.0	9.0 (7.4)	3.0 (2.5)	3.0 (2.96)
BRRI dhan29	20.6	8.0 (6.5)	2.5 (2.2)	3.2 (2.95)

Figures in the parentheses indicate the values of dehusked grain.

Advanced yield trial with F_7 lines of fine grain and higher iron containing rice in Boro season

An experiment was carried out with three high yielding and iron containing Boro rice lines, derived from hybridization between an exotic higher iron containing rice and Binadhan-7, to assess performance over different locations of Bangladesh. Seeds were sown on 2 December 2013 at Mymensingh, Barisal and Magura and 31 December 2013 at Rangpur and transplanted during during 9 January and 12 February 2014. The experiment was carried out following RCB design with three replications. The size of the unit plots were 5.1 m × 4.0 m. Seedlings were transplanted at 15 cm distance within rows of 20 cm apart. Recommended doses of nitrogen, phosphorus, potassium, sulphur and zinc were applied in the form of Urea, TSP, MOP, Gypsum and Zinc Sulphate. Cultural and intercultural practices were followed as and when necessitated. Data on plant height, number of effective tillers, panicle length, filled and unfilled grains $panicle^{-1}$ were recorded after harvest from five randomly selected competitive plants. Days to maturity was assessed by plot basis. Grain yield was recorded from an area of 1.0 m^2 which was converted to t ha-1. Finally, all the recorded data were subjected to proper statistical analyses and are presented in Table 12.

It appears that plant height differed significantly between the mutants and the check variety at all locations. Only at Magura, all the three lines had shorter plant height. Number of effective tillers also differed significantly at all locations except Mymensingh but the lines had higher number of effective tillers than the check variety only at Rangpur.

All the lines had significantly longer panicle than the check variety at Barisal, Magura and Rangpur. The longest panicle was found in the line RC-2-4-3-1 at Rangpur followed by RC-2-4-1-4. Number of filled grain was higher in all the lines than the check variety at Mymensingh and Barisal but it did not differ significantly at Mymensingh. Number of unfilled grains significantly differed only at Magura and Barisal but unfilled grain number was higher in all the lines than the check variety.

Table 12. Yield and yield attributes of three higher iron containing rice lines along with check variety

Lines/variety	Plant height (cm)	Effective tiller hill^{-1} (no.)	Panicle length (cm)	Maturity (days)	Filled grains panicle^{-1} (no.)	Ufilled grains panicle^{-1} (no.)	Grain yield (t ha^{-1})
Mymensingh							
RC-2-4-1-4	104.9	11.3	26.1	168	103.1	15.9	7.1
RC-2-4-1-2	104.2	11.3	26.7	168	103.0	19.2	7.2
RC-2-4-3-1	104.9	12.5	26.3	168	96.3	21.2	7.1
BRRIdhan28	93.9	13.4	21.9	147	98.9	19.5	5.2
$LSD_{(0.05)}$	6.9	NS	1.9	-	NS	NS	0.4
Barisal							
RC-2-4-1-4	106.7	9.9	24.4	170	86.5	17.8	6.1
RC-2-4-1-2	105.9	9.9	25.5	170	95.7	18.1	6.2
RC-2-4-3-1	109.3	10.4	25.2	170	95.7	18.6	6.4
BRRIdhan28	92.9	11.5	21.3	155	78.5	16.9	4.9
$LSD_{(0.05)}$	4.4	0.7	0.8	-	6.4	NS	0.4
Magura							
RC-2-4-1-4	94.7	13.1	26.9	187	87.2	36.5	4.6
RC-2-4-1-2	90.3	13.1	25.9	187	82.5	46.3	4.9
RC-2-4-3-1	91.8	12.1	25.1	187	78.6	50.2	4.5
BRRIdhan28	117.3	16.9	25.5	153	112.9	12.3	7.7
$LSD_{(0.05)}$	4.7	3.2	NS	-	5.0	7.8	0.9
Rangpur							
RC-2-4-1-4	111.7	12.8	27.5	166	98.6	18.7	7.5
RC-2-4-1-2	113.2	12.7	26.5	166	90.7	18.8	6.3
RC-2-4-3-1	95.0	11.1	28.4	166	103.3	18.1	7.3
BRRIdhan28	104.7	10.9	22.0	140	109	8.1	6.7
$LSD_{(0.05)}$	2.4	0.9	1.3	-	2.9	1.2	1.3
Combined means over four locations							
RC-2-4-1-4	104.5	11.8	26.2	172	93.8	22.2	6.3
RC-2-4-1-2	103.4	11.7	26.2	172	92.9	25.6	6.2
RC-2-4-3-1	100.3	11.5	26.3	172	93.5	27.0	6.3
BRRIdhan28	102.2	13.2	22.7	149	99.8	14.2	6.1
$LSD_{(0.05)}$ for var. × loc.	4.0	1.9	1.4	-	6.4	4.7	NS

NS= not significant

Grain yield differed significantly at all locations. At Mymensingh and Barisal, all the lines and at Rangpur only two lines had higher grain yield than the check variety but the difference was non-significant. Iron content was estimated for the three lines and the check variety (Table 13). The highest iron content was found in the line RC-2-4-1-2 (31.2 mg/100 g grain). This amount is much higher than the other lines and the check variety. This line could be a good solution for mitigating the chronic iron deficiency of pregnant and lactating mother, and also the infants in our country. The line RC-2-4-1-2 was selected based on yield and higher iron content for on-station and on-farm trial for the next T. aman and Boro seasons.

Table 13. Iron content of the three lines and the check variety

Line/variety	Iron content (mg/100 g grain)
RC-2-4-1-4	1.6
RC-2-4-1-2	31.2
RC-2-4-3-1	1.7
BRRIdhan28	5.4

Screening of M_2 population of carbon ion irradiated NERICA-10

An experiment was carried out with nine M_2 mutant populations derived by irradiating the seeds of NERICA-10 with carbon ion beams. Seeds were sown on 6 August and transplanted on 3 September 2013 following non-replicated design at BINA Headquarters farm, Mymensingh. Seedlings were transplanted at 15 cm distance within rows of 20 cm apart. Two rows of 3.0m length comprised a unit plot. Recommended doses of nitrogen, phosphorus, potassium, sulphur and zinc were applied in the form of Urea, TSP, MOP, Gypsum and Zinc Sulphate. Cultural and intercultural practices were followed as and when necessitated. Data on plant height, number of effective tillers, panicle length, filled and unfilled grains panicle^{-1} and grain yield hill^{-1} were recorded after harvest from five randomly selected competitive plants. Maturity period was assessed plot basis. Recorded data were subjected to proper statistical analyses and are presented in Table 14.

Table 14. Mean yield and yield attributes of nine M_2 populations derived from NERICA-10 after carbon ion beam irradiation

Mutants/line	Days to maturity	Plant height (cm)	Effective tillers plant^{-1}	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grain panicle^{-1} (no.)	Grain yield hill^{-1} (g)
RM-N_{10}-40(C)-1-1	105	89	25	23	167	9	52.7
RM-N_{10}-40(C)-1-2	105	91	19	23	109	15	43.2
RM-N_{10}-40(C)-1-3	105	84	11	23	155	9	17.0
RM-N_{10}-40(C)-1-4	105	90	17	21	136	12	39.8
RM-N_{10}-40(C)-1-5	105	86	14	23	152	6	29.4
RM-N_{10}-40(C)-1-6	105	94	15	22	128	65	31.0
RM-N_{10}-40(C)-1-7	105	84	15	22	142	1	26.0
RM-N_{10}-40(C)-1-8	105	89	13	24	180	15	15.7
RM-N_{10}-40(C)-1-9	105	88	10	21	122	40	17.2
NERICA-10	130	100	5	26	150	20	17.0
Mean ± SE	107.5±6.8	89.5±4.1	14.4±4.7	22.8±1.3	144.1±18.3	19.2±16.6	28.9±11.1

It appears that all the mutants had significantly shorter plant height and higher number of effective tillers than the parent NERICA-10. Four mutants had higher number of filled grains and six had lower number of unfilled grains panicle^{-1} than the parent NERICA-10. Moreover, all the mutants matured 25 days earlier than the parent. Grain yield of six mutants were significantly higher than the parental line. These six mutants have been selected for further evaluation in the M_3 generation, in Aus season 2014.

Preliminary yield trial with M_3 mutants of NERICA-10 under rainfed condition in Aus season

This experiment was carried out with seven mutants derived from carbon ion beam irradiation to NERICA-10 to assess earliness and grain yield in Aus season. Seeds were sown on 16 March and transplanted on 10 March 2014 following RCB design at BINA Headquarters farm, Mymensingh. The size of a unit plot was 1.5 m × 0.80 m. Seedlings were transplanted at 15 cm distance within rows of 20 cm apart. Recommended doses of nitrogen, phosphorus, potassium, sulphur and zinc were applied in the form of Urea, TSP, MOP, Gypsum and Zinc Sulphate. Cultural and intercultural practices were followed as and when necessitated. Data on plant height, number of effective tillers, panicle length, filled, unfilled grains panicle^{-1} and grain yield hill^{-1} were recorded after harvest from five randomly selected competitive plants. Maturity was assessed plot basis. Recorded data were subjected to proper statistical analyses and are presented in Table 15.

Table 15. Yield and yield attributes of some M_3 mutants derived from carbon ion beam irradiation to NERICA-10

Mutant/parent	Plant height (cm)	Effective tillers (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Days to maturity	Grain yield (t ha^{-1})
RM-N_{10}-40(C)-1-1	80.4	8.1	21.4	89.5	20.2	106	4.8
RM-N_{10}-40(C)-1-2	78.4	8.8	21.5	87.8	19.9	106	4.7
RM-N_{10}-40(C)-1-3	84.4	9.2	22.2	80.9	27.7	106	4.7
RM-N_{10}-40(C)-1-4	83.1	9.5	22.6	87.8	20.4	106	4.7
RM-N_{10}-40(C)-1-5	80.1	8.3	22.3	86.5	21.5	106	5.1
RM-N_{10}-40(C)-1-6	80.9	9.5	21.5	71.7	35.6	106	4.3
RM-N_{10}-40(C)-1-7	82.1	11.0	22.0	85.1	23.5	106	5.4
NERICA-10	94.0	3.4	24.9	47.8	69.9	126	2.3
$LSD_{(0.05)}$	NS	1.7	1.4	7.1	4.9	-	0.22

NS = not significant

It appeared that there was no significant difference between the mutants and parental line for plant height but for other attributes significant differences were observed. Moreover, all the mutants matured 20 days earlier than the parent NERICA-10. Highest number of filled grains was found in the mutant RM-N_{10}-40(C)-1-1 and lowest in RM-N_{10}-40(C)-1-6. Lowest unfilled grain plant^{-1} was found in the mutant RM-N_{10}-40(C)-1-2 and highest was in RM-N_{10}-40(C)-1-6. All the mutants produced significantly higher grain yield than the parent. Highest grain yield was 5.4 t ha^{-1} and it was found in the mutant RM-N_{10}-40(C)-1-7 followed by RM-N_{10}-40(C)-1-5 (5.1 t ha^{-1}) and RM-N_{10}-40(C)-1-1 (4.8 t ha^{-1}). These three mutants will be put into AYT in the next T. aman season under rainfed condition.

Screening of M_2 population of carbon ion irradiated Kasalath

Seeds of five M_1 populations of carbon ion irradiated Kasalath were sown on 16 March 2014 and transplanted on 03 April 2014 along with the parent. From the M_2 populations only one line was selected based on plant height, effective tillers number, increased panicle length, filled grains and grain yield hill^{-1}.

WHEAT

Zonal yield trial with a promising salt tolerant wheat line

With a view to assess the performance over different locations in the saline and non saline area, this experiment was carried out with L-880-43 along with the only released salt tolerant wheat variety in Bangladesh, BARI Gom-25. The experiment was conducted following by RCB design with three replications and conducted at four locations. Of the locations, three were in saline area at Satkhira, Khulna and Patuakhali and the other in the non-saline area at Ishurdi. A unit plot size was 5.0 m × 4.0 m. Seeds were sown at 5-7 cm distances within rows of 20 cm apart on 06, 10 and 14 December at Satkhira, Khulna and Patuakhali, respectively and on 22 November 2013 at Ishurdi. Application of recommended doses of fertilizers and other intercultural operations were followed as and when necessitated. Soil salinity records were gathered during sowing, vegetative and flowering stages from surface soil and 15 cm depth (Table 16).

Table 16. Salinity records of the experimental plots at different locations on different dates

Location and date	Depth	Salinity (dS m^{-1})
Satkhira		
17 January 2014	Surface soil	2.80
	15 (cm)	1.36
20 February 2014	Surface soil	1.02
	15 (cm)	1.30
Khulna		
17 January 2014	Surface soil	3.37
	15 (cm)	0.97
27 March 2014	Surface soil	3.94
	15	1.35
11 May 2014	Surface soil	1.90
	15 (cm)	0.75
Patuakhali		
15 December 2013	Surface soil	0.38
	15 (cm)	0.41
19 January 2014	Surface soil	0.82
	15 (cm)	0.44
4 March 2014	Surface soil	1.46
	15 (cm)	0.51
4 April 2014	Surface soil	1.77
	15 (cm)	0.49

Data on plant height, number of effective tillers, spike length, number of grains spike^{-1} and grain yield plot^{-1} were recorded at harvest. Grain yield plot^{-1} was converted into t ha^{-1}. Finally, all the collected data were subjected to proper statistical analyses and are presented in Table 17.

Table 17. Comparison of yield and some yield attributes of L-880-43 salt tolerant wheat line with BARI Gom-25 at the saline and normal areas

Lines/check	Plant height (cm)	Effective tillers $hill^{-1}$ (no.)	Spike length (cm)	Grains $spike^{-1}$ (no.)	1000-grain weight (g)	Grain yield ($t\ ha^{-1}$)
Ishurdi						
L-880-43	104	7.50	9.53	52.77	35.90	3.96
BARI Gom-25	99	7.50	10.57	42.50	51.43	3.78
$LSD_{(0.05)}$	3.85	NS	0.38	2.86	10.76	0.14
Satkhira						
L-880-43	89	7.53	10.07	49.83	38.13	3.37
BARI Gom-25	79	6.33	10.67	41.73	52.33	2.92
$LSD_{(0.05)}$	2.74	0.66	0.49	2.62	5.73	0.19
Khulna						
L-880-43	93	4.30	8.50	48.89	36.46	2.99
BARI Gom-25	94	4.13	10.30	44.23	51.40	3.27
$LSD_{(0.05)}$	NS	0.52	1.29	0.13	2.14	0.27
Patuakhali						
L-880-43	67	3.47	6.87	30.40	35.7	2.20
BARI Gom-25	66	2.97	8.73	29.43	48.4	1.98
$LSD_{(0.05)}$	NS	0.49	2.17	0.14	6.72	0.16
Location means						
Ishurdi	101.83	7.50	10.05	47.63	43.67	3.87
Satkhira	83.75	6.93	10.37	45.78	45.23	3.14
Khulna	93.12	4.22	9.40	46.56	43.93	3.13
Patuakhali	66.75	3.22	7.80	29.92	42.05	2.09
$LSD_{(0.05)}$ for location	1.31	0.52	NS	0.64	2.14	0.07
$LSD_{(0.05)}$ for variety over location	1.85	0.74	0.77	0.90	3.03	0.09

NS = not significant

The recorded salinities in all the locations in the saline areas were too low to affect growth and yield of wheat (Table 16) as becAuse from the previous experiment we observed wheat is sensitive to soil salinity ≥6 dS m^{-1} when exposed before sowing. However, it is evident from Table 17 that plant height and grain yield ha^{-1} of both L-880-43 and the check variety reduced significantly in saline areas (Satkhira, Khulna and Patuakhali) than non-saline area, Ishurdi. Additionally, effective tillers number of BARI Gom-25 and grain number of L-880-43 decreased significantly at all the locations in saline than non saline area. In contrast, 1000-grain weight of L-880-43 and BARI Gom-25 did not reduce significantly but increased to some extent without showing significant difference with each other at Ishurdi. Effective tillers number and spike length of L-880-43 reduced significantly at Khulna and Patuakhali locations while that of BARI Gom-25 reduced significantly only at Patuakhali.

These reductions in yield and yield attributes in saline area to that of non-saline area may be due to late transplanting. However, the line L-880-43 produced significantly higher grain yield than the salt tolerant check variety, BARI Gom-25 at all locations in both saline and non-saline areas except Khulna (Table 17). Therefore, this mutant will be put into variety evaluation trial in the coming wheat growing season over saline and non-saline areas for release it as a salt tolerant wheat variety.

RAPESEED-MUSTARD

On-station trial with F_8 rapeseed lines

Four F_8 rapeseed lines (Tori-7 × and Binasharisha-4) were evaluated through the on-station trial. The trial was conducted at the experimental farms of BINA Headquarters, Mymensingh and BINA sub-stations at Ishurdi, Rangpur and Magura. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown on mid November 2014 at BINA Headquarters and last week of October 2013 at Ishurdi, Rangpur and Magura. Unit plot size was 20 m^2 (5 m × 4 m) with 25 cm line to line spacing and 6-8cm from plant to plant within line. Recommended production packages i.e., application of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development. Data on plant height, branches $plant^{-1}$, siliquae $plant^{-1}$, seeds $siliqua^{-1}$ and 1000-seed weight were taken from 10 randomly selected plants from each plot. Maturity period was counted when 90% siliquae were matured. Seed yield of each plot was recorded after harvest and converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

Results obtained from the trail of individual location and combined over four locations for all the characters are presented in Table 18. Significant variations were observed among the mutants and the check varieties for all of the characters in both of individual location and combined over locations. On an average, maturity period varied from 81 days in RC-9 to 92 days Binasarisha-4 while Tori-7 required 83 days. Binasarisha-4 had the highest plant height (103 cm) having significant difference with the other four F_8 lines and Tori-7. RC-10 produced the shorter plant height (97 cm). RC-9 produced higher number of siliquae $plant^{-1}$ with higher seed yield 1477 kg ha^{-1}. The number of seeds $siliqua^{-1}$ ranges from 15.3 in Tori-7 to 25 in Binasarisha-4. RC-8 produced the lowest amount of seed 1185 kg ha^{-1}. Among the four locations, better performance was observed at Mymensingh.

On-farm trial with F_8 rapeseed lines

Four F_8 lines of rapeseed (Tori-7 × Binasharisha-4) were evaluated through this trial. The trial was conducted in the farmers' fields at Magura, Natore, Rangpur, Manikgonj and Tangail. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown on last week of October 2013 at Ishurdi, Rangpur and Magura and mid November at Manikgonj and Tangail. Unit plot size was 20 m^2 (5 m × 4 m) with 25 cm line to line spacing and 6-8 cm from plant to plant within line.

Recommended production packages i.e., application of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development. Data on plant height, branches $plant^{-1}$, siliquae $plant^{-1}$ seeds $siliqua^{-1}$ and 1000-seed weight were taken from 10 randomly selected plants from each plot. Maturity period was counted when 90% siliquae were matured. Seed yield of each plot was recoded after harvest and converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

Table 18. Mean of F_8 rapeseed mutants and check varieties for different characters

Locations	Mutants/ varieties	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliquae^{-1} (no.)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Ishurdi	Binasarisha-10	101ab	4.3ab	129ab	15.1b	3.28b	82.0b	1333ab
	RC-8	93bc	4.3ab	83c	13.8b	3.07bc	81.0b	1150c
	RC-9	97abc	5.7a	161a	14.5b	3.24b	80.7b	1467a
	RC-10	92c	4.9ab	125b	14.8b	2.95cd	81.0b	1250bc
	BINA-4	106a	2.3c	69c	30.8a	3.52a	92.0a	1467a
	Tori-7	97abc	3.7bc	76c	14.1b	2.94d	81.0b	1233bc
Rangpur	Binasarisha-10	99b	4.0a	121a	14.7b	3.35a	91.0b	1394a
	RC-8	102ab	4.3a	103b	15.6b	2.97c	91.7b	1039c
	RC-9	102ab	3.7ab	135a	16.3b	3.25b	91.3b	1385a
	RC-10	99b	3.9a	98bc	14.6b	2.89d	91.0b	1126bc
	BINA-4	104ab	2.4b	87c	23.0a	3.40a	99.0a	1199b
	Tori-7	105a	3.8ab	89bc	13.5b	2.94cd	91.0b	1098bc
Mymensingh	Binasarisha-10	92ab	3.6a	57bcd	13.9b	3.34b	75.0c	1508ab
	RC-8	95a	3.7a	56cd	15.7b	3.01c	74.0c	1408b
	RC-9	90ab	3.9a	86a	15.0b	3.29b	76.0c	1650a
	RC-10	86b	3.3ab	60bc	13.7b	2.94d	78.7b	1417b
	BINA-4	98a	2.1b	44b	23.7a	3.41a	90.0a	1667a
	Tori-7	92ab	3.3ab	70b	15.0b	2.93d	80.0b	1377b
Magura	Binasarisha-10	109a	4.4a	111a	22.0a	3.34b	78.0b	1395ab
	RC-8	108a	5.1a	84b	17.0bc	3.14bc	79.0b	1145c
	RC-9	109a	4.3a	110a	16.3c	3.50a	75.0c	1405ab
	RC-10	110a	5.1a	103a	18.7b	2.95c	76.0c	1250bc
	BINA-4	105a	2.5b	66c	22.3a	3.56a	85.0a	1540a
	Tori-7	105a	4.3a	76bc	18.7b	2.92c	79.0b	1247bc
Combined means	Binasarisha-10	100ab	4.1ab	105b	16.4b	3.33b	81.5c	1408a
	RC-8	100bc	4.4a	82c	15.5b	3.05c	81.4c	1185b
	RC-9	100bc	4.4a	123a	15.5b	3.32b	80.8c	1477a
	RC-10	97bc	4.3ab	97b	15.4b	2.93d	81.7c	1261b
	BINA-4	103a	2.3c	67d	25.0a	3.47a	91.5a	1468a
	Tori-7	100bc	3.8b	78c	15.3b	2.93d	82.8b	1239b
Location means	Ishurdi	98c	4.2a	107a	17.2b	3.17b	82.9b	1317b
	Rangpur	102b	3.7b	106a	16.3c	3.13c	92.5a	1207c
	Mymensingh	92d	3.3c	62b	16.2c	3.15bc	78.9c	1504a
	Magura	108a	4.3a	92a	19.2a	3.24a	78.7c	1330b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Table 19. Mean of F_8 rapeseed lines and check varieties for different characters at farmers' field during 2013-14

Locations	Mutants/varieties	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliqua^{-1} (no)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Magura	Binasarisha-10	98bc	3.9a	92b	17.0c	3.52ab	83d	1407ab
	RC-8	103ab	4.5a	76c	16.7c	3.26b	83d	1183c
	RC-9	101abc	3.7ab	100	18.0b	3.55ab	85bc	1398ab
	RC-10	92d	4.3a	98ab	17.0c	3.01c	86b	1285bc
	Binasarisha-4	104a	2.4b	64d	27.3a	3.62a	88a	1465a
	Tori-7	97cd	3.8ab	74c	18.0b	2.98c	84cd	1262c
Natore	Binasarisha-10	109a	4.1bc	94ab	17.7b	3.35^{NS}	83d	1433b
	RC-8	102b	2.8d	83ab	16.7b	3.17	88b	1200c
	RC-9	106ab	3.5c	80ab	17.7b	3.24	85c	1505b
	RC-10	105ab	5.1a	96a	18 .1b	2.97	88b	1283c
	Binasarisha-4	107ab	2.4d	62c	26.7a	3.56	92a	1717a
	Tori-7	108a	4.4ab	77bc	18.0b	2.92	84cd	1250c
Rangpur	Binasarisha-10	109c	5.1a	124abc	14.0d	3.39 ^{NS}	87c	1337b
	RC-8	115ab	5.7a	118bc	18.0b	3.19	88bc	1140b
	RC-9	114ab	5.2a	139ab	16.7c	3.29	89b	1280b
	RC-10	110bc	5.2a	135ab	16.0c	2.99	88bc	1107b
	Binasarisha-4	119a	3.3b	98c	31.0a	3.58	91a	1642a
	Tori-7	117a	5.5a	150a	13.7d	2.93	88bc	1150b
Manikgonj	Binasarisha-10	106a	4.3ab	103a	16.0b	3.38 ^{NS}	83c	1450bc
	RC-8	100c	3.7b	79b	15.7b	3.09	81c	1250c
	RC-9	100bc	4.9a	111a	15.3b	3.23	87b	1550b
	RC-10	105ab	4.9a	101a	16.0b	2.96	88b	1400bc
	Binasarisha-4	105ab	2.2c	56c	29.0a	3.52	91a	1817a
	Tori-7	103abc	3.5b	69bc	14.8b	2.90	87b	1267c
Tangail	Binasarisha-10	99ab	3.1b	92ab	18.3b	3.34 ^{NS}	83b	1464b
	RC-8	96b	4.4a	69c	18.7b	3.11	81c	1261bc
	RC-9	101a	3.9a	100a	17.7b	3.25	80c	1411bc
	RC-10	99ab	4.0a	86b	15.3c	2.95	81c	1222c
	Binasarisha-4	101a	2.1c	76c	28.3a	3.54	88a	1791a
	Tori-7	88c	4.0a	68c	13.4d	2.93	83b	1210c
Combined means	Binasarisha-10	104b	4.1b	101a	16.6b	3.40 ^{NS}	84d	1418b
	RC-8	103bc	4.2b	85b	17.1b	3.22	85c	1207c
	RC-9	104b	4.3b	106a	17.1b	3.33	85c	1429b
	RC-10	102c	4.7a	103a	16.5b	3.05	86b	1259c
	Binasarisha-4	107a	2.5c	71c	28.5a	3.61	90a	1686a
	Tori-7	102bc	4.2b	88b	15.5c	2.92	85c	1228c
Location means	Magura	99d	3.8b	84b	19a	3.32 ^{NS}	85c	1333bc
	Natore	106d	3.7b	82b	19a	3.20	87b	1398ab
	Rangpur	114a	5.1a	127a	18b	3.23	89a	1276c
	Manikgonj	103c	3.9b	86b	17c	3.18	87b	1456a
	Tangail	97d	3.6b	82b	19a	3.19	83d	1393ab

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Results obtained from the trial of individual location and combined over three locations for all the characters are presented in Table 19. Significant variations were observed among the mutants and check varieties for all of the characters in both of individual location and combined over locations. On an average, maturity period varied from 84 in Binasarisha10 to 90 days in Binasharisha-4. The highest number (106) of siliqua plant^{-1} was produced in RC-9 while the lowest number of siliquae plant^{-1} (71) found in Binasarisha-4. Average number of seeds siliqua^{-1} ranged from 28.5 in Binasarisha-4 to 15.5 in Tori-7. Among the four mutants, RC-9 produced the highest seed yield (1429 kg ha^{-1}).

On-station yield trials with M_8 advanced rapeseed (*B. napus*) mutants

Three M_8 rapeseed mutants along with mother variety Binasarisha-4 and check Tori-7 were evaluated through the trial. The trial was conducted at the farms of BINA sub-stations at Magura, Ishurdi and Rangpur. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown within 1st week of November 2013. The unit plot size was 20 m^2 (5 m × 4 m) with 25 cm line to line spacing and 6-8cm from plant to plant within lines. Recommended production packages i.e., application of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development. Data on plant height, branches plant^{-1}, siliquae plant^{-1}, seeds siliqua^{-1} and 1000-seed weight were taken from 10 randomly selected plants from each plot. Maturity period was counted when 70% siliquae were matured. Seed yield of each plot was recorded after harvest and appropriate statistical analyses were performed for comparison of means of each character.

The results of individual location and combined over four locations for all the characters are presented in Table 20. Most of the characters showed significant differences among the mutants and check for both individual location and combined over locations. On an average, Binasarisha-4 produced the highest plant height (107 cm) and the check produced 104 cm plant height. Binasarisha-9 produced higher number of siliqua plant^{-1} (106) with higher seed yield 1972 kg ha^{-1} followed by MM-64 produced 101 number of siliqua plant^{-1} with seed yield 1904 kg ha^{-1}. Number of seeds siliquae^{-1} ranges from 25.2 in Binasarisha-4 to 16.0 in Tori-7. Binasarisha-9 and MM-64 required 92 days for their maturity while Binasarisha-4 required 95 days. Among the three locations, yield performance was better at Magura.

Table 20. Mean of M_8 rapeseed mutants and check variety of mustard for different characters

Locations	Mutants/variety	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliqua^{-1} (no)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Magura	Binasarisha -9	107bc	2.5a	103a	27.7a	3.40	89b	2017a
	MM-63	109b	2.6a	88b	25.0b	2.97	88b	1705b
	MM-64	112a	2.5a	94b	25.7b	3.32	88b	1947ab
	Binasarisha-4	107bc	2.6a	91b	25.0b	3.56	93a	1860ab
	Tori-7	105c	2.9a	88b	15.7c	2.93	84c	1864ab

Table 20 Contd.

Locations	Mutants/variety	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliqua^{-1} (no)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Ishurdi	Binasarisha -9	95b	2.5b	105a	24.7a	3.39	92 a	1900a
	MM-63	96b	2.5b	104a	24.3a	2.95	90b	1725 ab
	MM-64	95b	3.0b	103a	23.7a	3.32	90b	1953a
	Binasarisha-4	105a	2.3b	102a	26.0a	3.55	93a	1950a
	Tori-7	97b	4.2a	83b	14.0b	2.92	81c	1475b
Rangpur	Binasarisha -9	109ab	4.5a	110a	21.3b	3.42	95bc	2000a
	MM-63	107b	3.1b	86d	20.7bc	2.98	96b	1425d
	MM-64	104c	3.6ab	105b	26.0a	3.34	99a	1813b
	Binasarisha-4	109ab	2.9b	97c	24.7a	3.54	99a	1667c
	Tori-7	111a	3.7ab	83d	18.3c	2.92	93c	1317d
Combined means	Binasarisha -9	104b	3.2b	106a	24.6a	3.40	92b	1972a
	MM-63	104b	2.8b	93d	23.4b	2.97	91c	1618b
	MM-64	104b	3.0b	101b	25.1a	3.33	92b	1904a
	Binasarisha-4	107a	2.6b	97c	25.2a	3.55	95a	1825a
	Tori-7	104b	3.6a	85c	16.0c	2.92	86d	1552b
Location means	Magura	108a	2.6b	93c	23.8a	3.24^{NS}	88b	1879a
	Ishurdi	97b	2.9b	100a	22.5ab	3.23	89b	1801a
	Rangpur	108a	3.6a	96b	22.2b	3.24	96a	1644b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

On-farm yield trials with advanced (*B. napus*) rapeseed M_8 mutants

Three M_8 rapeseed mutants along with the mother variety Binasarisha-4 and check Tori-7 were evaluated. The trial was conducted at the farmers' field at Magura, Natore and Rangpur. The experiment was laid out in a randomized complete block design with three replications. Seeds were sown on 1st week of November 2013. The unit plot size was 20 m^2 (5 m × 4 m) with 25cm line to line spacing and 6-8 cm from plant to plant within lines. Recommended production packages like application of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development in each plot. Data on plant height, branches plant^{-1}, siliquae plant^{-1} and seeds siliqua^{-1} were taken from 10 randomly selected plants from each plot. Maturity period was counted when 70% siliquae were matured. Seed yield of each plot was recorded and appropriate statistical analyses were performed for comparison of means of each character.

The results of individual location and combined over three locations for all the characters are presented in Table 21. Significant variations were observed among the mutants and check varieties for most of the characters in both of individual location and combined over locations. On an average, maturity period of the M_8 Mutant lines varied from 87 in MM-63 to 91 days MM-64. Among the mutants, MM-64 produced the highest seed yield (1818 kg ha^{-1}) with the maturity period of 89 days having 102 number of siliquae plant^{-1} with 26 seeds siliquae^{-1}. Binasarisha-9 produced 1804 kg ha-1 seed yield with the maturity period of 90 days which had 102 number of siliquae plant^{-1} with 26.4 seeds siliqua^{-1}. Among the four locations, best performance was found at Natore than the other locations, where seed yield was 1913 kg ha^{-1}.

Zonal yield trial with advanced (*B. napus*) M_8 mutant

Four rapeseed mutants along with check variety, Binasarisha-5 were evaluated to assess overall performance of the mutants for earliness, yield attributes and seed yield as compared to the check. The experiment was conducted at the farms of BINA Headquarters, Mymensingh and BINA sub-stations at Magura, Ishurdi and Jamalpur. The trial was laid out in a randomized complete block design with three replications. The unit plot size was 12 m^2 (4 m × 3 m) keeping 25-30 cm spacing between two lines and 6-8 cm among the plants in a row. Seeds were sown on 1st week of November 2013. Recommended production packages like application of recommended fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development. Data were taken for plant height, branches $plant^{-1}$, siliquae $plant^{-1}$, seeds $siliqua^{-1}$, maturity period, 1000-seed weight and seed yield. Maturity period was counted when 70% siliquae were matured and

Table 21. Mean of M_8 rapeseed mutants and check varieties of rapeseed for different characters at farmer's field

Locations	Mutants/variety	Plant height (cm)	Branches $plant^{-1}$ (no.)	Siliquae $plant^{-1}$ (no.)	Seeds $siliquae^{-1}$ (no)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Magura	Binasarisha-9	100c	2.5^{NS}	104.0a	28.3a	3.39	88b	1877a
	MM-63	100bc	2.7	96.7b	24.7b	2.96	88b	1595b
	MM-64	102ab	2.4	103.0a	27.3ab	3.29	88b	1858a
	Binasarisha-4	103a	2.6	101.0a	26.3ab	3.57	94a	2004a
	Tori-7	102abc	2.7	88.0c	15.0c	2.94	85c	1448b
Natore	Binasarisha-9	104a	2.7^{NS}	102.6ab	24.3a	3.38	89b	1838b
	MM-63	105a	3.1	106.7a	24.7a	2.99	87c	1975b
	MM-64	105a	2.9	97.7bc	24.3a	3.30	88bc	1725b
	Binasarisha-4	106a	2.5	109.0a	25.7a	3.54	95a	2250a
	Tori-7	105a	2.9	91.3c	17.3b	2.93	84d	1775b
Rangpur	Binasarisha-9	109b	2.9b	99.7a	26.7ab	3.39	92ab	1697b
	MM-63	103d	2.8bcb	93.7b	25.3b	2.98	90bc	1774ab
	MM-64	107c	2.8b	104.3a	27.7ab	3.32	91b	1870a
	Binasarisha-4	108bc	2.5cb	104.0a	29.0a	3.56	94a	1715b
	Tori-7	112a	4.3a	91.0b	16.0c	2.94	88c	1323c
Combined means	Binasarisha-9	104c	2.7b	102.1ab	26.4a	3.40	90b	1804b
	MM-63	103d	2.8b	99.0b	25.0b	2.98	88c	1782b
	MM-64	105b	2.7b	101.7ab	26.4a	3.29	89bc	1818b
	Binasarisha-4	106a	2.5b	104.7a	27.0a	3.56	94a	1990a
	Tori-7	106a	3.3a	90.1c	16.0c	2.92	86d	1516c
Location means	Magura	102c	2.6b	98b	24.3^{NS}	3.23^{NS}	89b	1757b
	Natore	105b	2.8ab	101a	23.3	3.23	89b	1913a
	Rangpur	108a	3.1a	98b	24.4	3.24	91a	1676b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

most of the plants turned into brownish in colour in each plot. Seed yield of each plot was recorded after harvest and appropriate statistical analyses were performed for comparison of means of each character which are presented in Table 22.

Results showed significant variations among the mutants and check for most of the characters in individual locations and combined over locations. On an average, it was observed that plant height ranged from 94 cm in MM-210 to 99 cm in MM-37. MM-10 produced the highest number of 69 siliquae plant^{-1} and MM-211 produced the lowest number of 56. Number of seeds siliqua^{-1} ranged from 24.6 to 26.0. Mutant MM-10 produced the higher seed yield 1389 kg ha^{-1} followed by MM-211 (1345 kg ha^{-1}) and Binasarisha-4 (1322 kg ha^{-1}). Among four locations, Ishurdi performed better in seed yield (1877 kg ha^{-1}). Seed yield was higher at Ishurdi (1877 kg ha^{-1}).

Table 22. Mean performance of rapeseed mutants and check for different character

Locations	Mutants/variety	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliqua^{-1} (no)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Magura	MM-10	113b	2.3^{NS}	84a	27.0a	3.56^{NS}	93c	1500a
	MM-210	106c	2.1	51e	25.7a	3.40	95b	1333a
	MM-37	125a	2.5	71b	22.3b	3.51	97ab	1291a
	MM-211	118ab	2.1	62c	26.7a	3.92	98a	1455a
	Binasarisha-4	115b	2.3	56d	24.7ab	3.54	93c	1430a
Ishurdi	MM-10	104a	2.4^{NS}	59a	27.7a	3.57^{NS}	90c	1972a
	MM-210	100b	2.3	53ab	26.7ab	3.42	96b	1750a
	MM-37	104a	2.3	53ab	25.0b	3.52	99a	1868a
	MM-211	101b	2.9	59a	26.0ab	3.95	98a	2022a
	Binasarisha-4	100b	2.1	45b	27.0ab	4.01	95b	1772a
Jamalpur	MM-10	85^{NS}	2.0^{NS}	66b	20.0b	3.57^{NS}	96b	1063a
	MM-210	85	2.0	57c	23.7a	3.45	94c	919b
	MM-37	84	2.0	57c	25.7a	3.52	98a	1039ab
	MM-211	84	2.0	48d	20.7b	3.98	98a	931b
	Binasarisha-4	86	2.0	77a	21.0b	3.59	94c	1069a
Mymensingh	MM-10	87^{NS}	2.5a	65b	26.0ab	3.55^{NS}	96b	1020b
	MM-210	86	2.3ab	73a	28.0ab	3.38	97ab	1148a
	MM-37	85	1.7c	55c	25.3b	3.51	98a	978b
	MM-211	87	2.0bc	53c	25.3b	3.95	96b	972b
	Binasarisha-4	87	2.2ab	57c	28.7a	3.56	92c	1016b
Combined means	MM-10	97a	2.3a	69a	25.2ab	3.56bc	94c	1389a
	MM-210	94b	2.2ab	59b	26.0a	3.42c	96b	1288a
	MM-37	99a	2.1b	59b	24.6b	3.52bc	98a	1294a
	MM-211	96a	2.3ab	56c	24.7b	3.95a	98a	1345a
	Binasarisha-4	97a	2.1b	59b	25.3ab	3.82ab	94c	1322a
Location means	Magura	116a	2.3ab	65a	25.3b	3.59^{NS}	95b	1402b
	Ishurdi	102b	2.4a	54c	26.5a	3.81	96a	1877a
	Jamalpur	85c	2.0c	61b	22.2c	3.62	96a	1004c
	Mymensingh	86c	2.2bc	61b	26.7a	3.59	96a	1027c

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Advanced yield trial with M_8 mustard (*B. juncea*) mutants

Five M_8 mutants along with check variety BARI Sarisha-11 were assessed to see their overall performance at Magura and Ishurdi. The trial was conducted in a randomized complete block design with three replications. Sowing was done within second week of November 2013. The unit plot size was 4 m × 3 m keeping 25-30 cm line to line spacing and 6-8cm from plant to plant within the lines. Data were taken for plant height, number of branches plant^{-1}, siliquae plant^{-1}, seeds siliqua^{-1} and 1000 seed weight from randomly selected 10 plants of each plot. Recommended management practices, fertilizer doses, intercultural operation etc. was followed carefully throughout the experiment. Maturity period was considered when 80% siliquae and plants turned into brownish in colour in each plot. Seed yield of each plot was recorded and appropriate statistical analyses were performed for comparison of means of all entries and check.

Mean performance showed significant variations among the mutants and check for most of the characters in individual location and combined over two locations (Table 23). On an average, the mutant MM-35 produced the highest number of 121 siliquae plant^{-1} closely followed by MM-37 with 119 siliquae plant^{-1}. Number of seeds siliqua^{-1} ranged from 12.5 BARI Sarisha-11 to 20.5 in MM-36. In combined over location, MM-37 produced the highest seed yield (1715 kg ha^{-1}) followed by MM-35 (1708 kg ha^{-1}). Among the mutants and check, MM-36 required the shortest maturity period (98 days) while BARI Sarisha-11 required the longest (105 days). Between two locations, Ishurdi performed better in respect of seed yield (1727 kg ha^{-1}). Seed yield performance was better at Ishurdi (1727 kg ha^{-1}).

Table 23. Mean performance of mustard mutants and check for different character at Magura and Ishurdi

Locations	Mutants/check variety	Plant height (cm)	Branches plant^{-1} (no.)	Siliquae plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	1000-seed weight (g)	Days to maturity	Seed yield (kg ha^{-1})
Magura	MM-31	108a	2.6c	96c	17.7b	2.77a	100b	1330c
	MM-35	107a	3.3a	110a	16.3c	3.01a	102ab	1527a
	MM-36	106a	2.9abc	106ab	21.7a	2.85a	98b	1411b
	MM-37	110a	3.1ab	102b	14.7d	3.24a	104a	1402b
	MM-39	109a	2.7bc	96c	13.3e	2.62a	104a	1150d
	BARI Sarisha-11	108a	2.5c	93c	13.7de	3.26a	103ab	1289c
Ishurdi	MM-31	102b	2.5b	100d	17.7b	2.78a	99b	1667b
	MM-35	107a	3.4a	132ab	16.0c	3.11a	100b	1889ab
	MM-36	104bc	3.3a	126b	19.3a	2.84a	98b	1695b
	MM-37	105ab	3.4a	136a	12.7d	3.27a	99b	2028a
	MM-39	104ab	3.0a	115c	12.0de	2.64a	100b	1322c
	BARI Sarisha-11	107a	2.3b	84e	11.3e	3.31a	105a	1761ab
Combined means	MM-31	105^{NS}	2.6cd	98c	17.7b	2.78a	100c	1499b
	MM-35	107	3.3a	121a	16.2c	3.06a	101b	1708a
	MM-36	105	3.1ab	116a	20.5a	2.84a	98d	1553b
	MM-37	108	3.3ab	119a	13.7d	3.26a	102b	1715a
	MM-39	107	2.8bc	105b	12.7de	2.63a	102b	1236c
	BARI Sarisha-11	108	2.4d	89d	12.5e	3.28a	104a	1525b
Location means	Magura	108a	2.8b	101b	16.2a	2.96b	102a	1352b
	Ishurdi	105b	3.0a	115a	14.8b	2.99a	100b	1727a

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Growing of M_4 population

M_4 mutant variants, developed from Tori-7 were grown in plant-progeny-rows for selecting desirable mutants at BINA Headquarters farm, Mymensingh. From them a total of five mutant lines were selected for further selection in M_5 generation.

Growing of M_2 population

A large number of M_2 variants, developed from Binasarisha-4, Tori-7 and accession MRH were grown in plant-progeny-rows for selecting desirable mutants at BINA Headquarters farm, Mymensingh. From them a total of 13 mutant variants were selected primarily for further selection in M_3 generation.

Growing of F_4 population

F_4 population from the cross between Binasarisha-4 and Tori-7 were grown at BINA Headquarters farm, Mymensingh. From them a total of 20 lines were selected primarily for further selection in F_5 generation.

Growing of F_2 population

F_2 population from the cross between Binasarisha-4 and Tori-7 were grown at BINA Headquarters farm, Mymensingh. From them, five lines were selected primarily for further selection in F_3 generation.

Crossing of Binasarisha-4 and Binasarisha-9 with Tori-7, BARI Sarisha-14 and BARI Sarisha-15

Binasarisha-4 and Binasarisha-9 were crossed with Tori-7, BARI Sarisha-14 and BARI Sarisha-15 and F_1 seeds were harvested to grow F_1 generations.

Maintenance of germplasm (mutants, local and exotic collection)

Forty germplasm were grown in the farms of BINA Headquarters farm, Mymensingh. After harvest, seeds of all these germplasm were collected and have been preserved as breeding materials.

GROUNDNUT

On-farm and on-station trials with some advanced M_9 mutants and F_{10} lines

This experiment was performed to assess the performance of two of each M_9 mutants and F_{10} lines of groundnut over saline and non-saline areas of Bangladesh. The popular variety, Dacca-1 and Zhingabadam were also included in this experiment. Seeds were sown in non-saline area on 18 and 24 December 2013 in BINA sub-station farms at Rangpur and Ishurdi, respectively, and in farmers' field at Jhenaidah, Lalmonirhat and Natore on 8 and February 13, and 2 March 2014, respectively. While in saline areas seeds were sown on 29 December 2013 and 11 January 2014, respectively at Patuakhali, Bhola and Noakhali, respectively. The experiment was carried out following RCB design with three replications and a unit plot size was 5.0 m × 4.0 m. Recommended doses of fertilizers were applied together with recommended cultural and intercultural practices. Soil salinity records from the experiments at Noakhali, Patuakhali and Bhola were gathered during sowing, vegetative and flowering stages from surface soil and 15 cm depth (Table 24). Data on plant height, matured pods plant^{-1} and shelling percentage were recorded after harvest from randomly selected five competitive plants while pod weight $plant^{-1}$ and 100-pod weight were recorded after proper sun drying. Pod yield was recorded from the plot area of 20 m^2 which was later converted to t ha^{-1}. Finally, the recorded data were subjected to proper statistical analyses and are presented in Table 25.

Table 24. Salinity records of the experimental plots at different locations on different dates

Date	Depth (cm)	Salinity (dS m^{-1})
Patuakhali		
01 December 2014	Surface soil	0.38
	15	0.41
19 January 2014	Surface soil	0.82
	15	0.44
04 March 2014	Surface soil	1.24
	15	0.46
04 April 2014	Surface soil	1.77
	15	0.49
04 May 2014	Surface Top soil	0.46
	15	0.51
04 June 2014	Surface soil	2.38
	15	0.51
Bhola		
29 December 2014	Surface soil	1.08
	15	0.78
05 March 2014	Surface soil	1.96
	15	0.78
05 April 2014	Surface soil	6.43
	15	0.89
03 May 2014	Surface soil	7.16
	15	0.70
30 May 2014	Surface soil	1.78
	15	1.50
Noakhali		
19 January 2014	Surface soil	0.53
	15	0.52
04 March 2014	Surface soil	7.7
	15	2.3
05 June 2014	Surface soil	0.60
	15	0.55

Among saline locations, performance at Subarnachar, Noakhali was better than that of Patuakhali and Bhola for most of the traits because of lower salinity during the growing period (Table 24). It appears that yield and related attributes had significantly lower scores in the saline area than that of non-saline area (Table 25). In contrast, of the two non-saline locations, performance at Ishurdi was the best of all for most of the traits including pod yield ha^{-1} (Table 25).

The mutants/lines/varieties showed significant differences for all the traits at all locations (Table 25). The two mutants and the two F_{10} lines mostly had significantly dwarf height than both the check varieties at all locations. Between two check varieties, Zhingabadam mostly had significantly taller height than Dacca-1 at all locations.

The mutant D_1/20/17-1 had significantly higher number of pods at Lalmonirhat, Natore and Bhola. In contrast, the other mutant RS/25/3-1 had significantly higher number of pods at Ishurdi and Patuakhali. Of the two F_{10} lines, the line GC(1)-24-1-1-2 showed significantly higher number of pod at Jhenaidah and Patuakhali. Pod yield/plant was mostly higher in GC (1)-32-3-1-1 except Lalmonirhat, Jhenaidah and Bhola (Table 25). At Lamonirhat, RS/25/3-1 at Jhenaidah Zhingabadam and at Bhola D_1/20/17-1 had higher pod yield plant^{-1}.

Pod size, expressed here as 100-pod weight, was significantly lower in D_1/20/17-1, RS/25/3-1 and GC(1)24-1-1-2 than Zhingabadam together with higher shelling percentages (Table 25). In contrast, the F_{10} line, GC(1)-32-3-1-1 had bigger pods, kernels but mostly lower shelling percentage. Finally, D_1/20/17-1 had significantly higher pod yield ha^{-1} than Dacca-1 at Rangpur, Lalmonirhat, Patuakhali and Bhola, RS/25/3-1 at Rangpur, Lalmonirhat, Ishurdi, Jhenaidah, Noakhali and Bhola, and GC(1)-24-1-1-2 at Lalmonirhat, Jhenaidah, Noakhali and Bhola. Therefore, application will be submitted to the National Seed Board of Bangladesh for registration of these mutants/lines for release as varieties.

Table 25. Pod yield and some related attributes of two M_9 mutant lines and F_{10} lines of groundnut at non-saline area

Mutant/lines/varieties	Plant height (cm)	Pods plant^{-1} (no.)	Pod weight (g)	100-pod weight (g)	100-kernel weight (g)	Pod yield (t ha^{-1})	Shelling (%)
Non-saline area							
Rangpur							
D1/20/17-1	32.20	30.10	20.23	69.3	30.37	3.69	60.20
RS/25/3-1	34.60	35.90	18.80	77.67	32.77	4.14	76.17
GC(1)32-3-1-1	32.53	35.90	35.03	78.1	38.60	2.89	54.53
GC(1)24-1-1-2	28.33	29.27	15.80	67.33	27.50	3.47	70.30
Dhaka-1	40.53	31.30	16.53	71.13	30.67	3.60	73.07
Zhinga badam	40.20	43.37	17.20	82.8	24.60	3.77	57.37
$LSD_{(0.05)}$	0.99	0.60	0.52	1.04	0.65	0.06	0.77
Lalmonirhat							
D1/20/17-1	59.67	25.93	14.93	62.20	27.73	3.32	79.47
RS/25/3-1	56.83	21.17	15.57	74.60	33.70	3.34	76.43
GC(1)32-3-1-1	47.30	21.47	12.87	122.10	45.77	3.13	66.73
GC(1)24-1-1-2	56.10	17.73	13.30	75.70	31.60	3.00	74.33
Dhaka-1	64.83	18.03	11.77	70.43	32.60	2.59	77.10
Zhinga badam	79.63	19.00	11.13	98.90	34.23	2.45	68.73
$LSD_{(0.05)}$	0.62	0.55	0.83	1.60	0.97	0.07	0.69
Ishurdi							
D1/20/17-1	42.97	28.53	13.90	53.60	22.20	3.06	74.07
RS/25/3-1	39.40	38.10	21.50	60.90	28.30	4.73	71.53
GC(1)32-3-1-1	35.47	23.37	23.00	110.67	40.47	5.13	65.05
GC(1)24-1-1-2	32.00	23.53	17.00	59.07	24.77	3.76	64.37
Dhaka-1	47.10	29.37	17.17	54.77	23.93	3.71	72.70
Zhinga badam	50.47	20.70	19.03	90.07	28.80	4.19	63.00
$LSD_{(0.05)}$	0.62	0.68	0.48	0.43	0.46	0.13	1.02

Table 25 Contd.

Mutant/lines/varieties	Plant height (cm)	Pods plant^{-1} (no.)	Pod weight (g)	100-pod weight (g)	100-kernel weight (g)	Pod yield (t ha^{-1})	Shelling (%)
Natore							
D1/20/17-1	40.27	20.90	8.63	58.77	26.30	2.69	78.17
RS/25/3-1	32.33	20.73	13.80	69.30	31.53	2.84	73.30
GC(1)32-3-1-1	35.90	15.50	15.83	107.80	41.60	3.43	68.77
GC(1)24-1-1-2	32.93	14.33	9.33	67.27	26.57	2.31	72.60
Dhaka-1	45.63	18.60	12.93	73.53	33.93	2.88	73.90
Zhinga badam	51.27	14.00	15.03	109.93	32.73	2.92	69.77
$LSD_{(0.05)}$	0.99	0.68	0.98	1.60	0.88	0.11	0.38
Jhenaidah							
D1/20/17-1	49.90	27.67	17.27	73.87	26.6	3.23	77.17
RS/25/3-1	42.53	27.27	19.67	74.4	33.17	4.08	76.93
GC(1)32-3-1-1	31.53	22.7	25.03	126.4	41.33	4.54	61
GC(1)24-1-1-2	38.57	28.87	20.73	69.8	28.53	3.59	74.8
Dhaka-1	50.23	22.6	15.87	70.43	29.90	3.18	75.87
Zhinga badam	48.43	25.733	26.00	108.18	30.43	3.90	68.63
$LSD_{(0.05)}$	1.06	0.86	0.49	2.66	0.69	0.15	0.92
Saline area							
Noakhali							
D1/20/17-1	33.47	17.80	10.30	54.50	28.10	2.31	71.2
RS/25/3-1	41.40	18.43	11.23	71.57	32.63	2.48	69.03
GC(1)32-3-1-1	50.90	15.07	12.83	93.17	37.13	2.34	59.17
GC(1)24-1-1-2	32.50	19.07	12.93	66.33	25.80	2.85	61.23
Dhaka-1	48.13	18.47	11.07	70.77	32.33	2.51	66.53
Zhinga badam	61.27	17.43	11.00	78.00	22.73	2.40	46.43
$LSD_{(0.05)}$	0.99	0.73	0.75	0.62	0.60	0.05	0.69
Patuakhali							
D1/20/17-1	16.93	21.5	9.23	49.03	22.87	1.66	66.07
RS/25/3-1	19.80	20.87	9.83	56.93	25.87	2.05	62.13
GC(1)32-3-1-1	19.77	19.83	13.17	80.97	31.33	2.62	53.03
GC(1)24-1-1-2	16.50	15.57	7.70	46.33	21.63	1.37	52.20
Dhaka-1	22.93	16.03	6.03	43.30	19.60	1.49	65.53
Zhingabadam	31.33	19.80	9.30	64.67	19.47	1.67	36.33
$LSD_{(0.05)}$	1.87	1.14	0.50	1.26	0.65	0.11	1.08
Bhola							
D1/20/17-1	15.73	18.37	7.20	47.77	21.57	1.28	66.63
RS/25/3-1	12.87	12.9	5.97	49.8	21.63	1.2	59.03
GC(1)32-3-1-1	11.60	8.8	4.05	71.7	28.3	0.91	45.9
GC(1)24-1-1-2	10.40	14.3	6.30	46.2	23.7	1.24	60.37
Dhaka-1	12.87	14.83	4.70	39.3	21.87	0.99	54.03
Zhinga badam	12.57	9.33	3.00	45.17	22	0.58	49.37
$LSD_{(0.05)}$	0.66	0.66	0.71	1.80	0.34	0.14	0.74
$LSD_{(0.05)}$ for mutant/variety × location interaction	0.93	0.72	0.67	6.50	1.08	0.16	0.74

Growing of M_2 generation of groundnut

With the objectives of selecting high yielding mutants with early maturity, resistance to drought, salinity, high/low temperatures, major diseases and insect-pests having medium size pod, M_2 populations derived from irradiating the seeds of Dacca-1, PK-1 and BARI Chinabadam-8 with 150, 200, 250 and 300 Gy doses of gamma rays. The seeds of the M_2 populations were sown at 15 cm distances within rows of 20 cm apart following plant progeny rows on 02 December, 2013 at BINA Headquarters farm, Mymensingh. There were 52, 62, 53 and 42 progenies of Dacca-1, 70, 66, 28 and 35 progenies of PK-1 and 65,106, 61 and 34 progenies of BARI Chinabadam-8. These progenies were derived from 150, 200, 250 and 300 Gy doses of gamma ray irradiations. Recommended doses of fertilizers were applied together with recommended cultural and intercultural practices. Data on plant height and pod number were recorded from randomly selected five competitive plants after harvest. The M_2 population having 25 or more number of pods was selected from the populations derived from Dacca-1 while that with 20 or more from PK-1 and BARI Chinabadam-8. Eighteen, six, eight and eleven progenies were selected from 150 Gy, 200 Gy, 250 Gy and 300 Gy dose irradiated populations of Dacca-1, respectively, (Table 26). In contrast, 15, 12, 01 and 02 progenies, respectively, from PK-1 (Table 27).

Table 26. Plant height and pod number of the selected populations from different doses of gamma ray irradiated populations of Dacca-1

M_2 populations	Plant height (cm)	Pods plant^{-1} (no.)
150 Gy		
D1/15/7	41.0	34.2
D1/15/9	36.6	33.7
D1/15/10	38.8	38.33
D1/15/12	54.6	36.7
D1/15/13	39.0	38.0
D1/15/15	34.4	37.3
D1/15/16	39.4	25.0
D1/15/17	43.0	25.0
D1/15/18	42.8	25.0
D1/15/26	34.8	29.4
D1/15/27	34.4	23.8
D1/15/28	34.0	28.0
D1/15/31	38.4	26.2
D1/15/34	44.8	25.4
D1/15/36	35.4	27.4
D1/15/40	46.4	26.4
D1/15/51	44.6	27.2
D1/15/52	47.2	26.0
200 Gy		
D1/20/40	51.4	26.6
D1/20/57	46.2	28.6
D1/20/60	51.0	31.2
Mean ± SE	-	-

M_2 populations	Plant height (cm)	Pods plant^{-1} (no.)
200 Gy		
D1/20/61	39.2	25.8
D1/20/68	38.6	30.4
D1/20/79	51.5	27.4
250 Gy		
D1/25/1	37.6	30.2
D1/25/22	48.6	28.8
D1/25/28	42.8	29.4
D1/25/33	38.8	25.4
D1/25/50	45.6	26.8
D1/25/52	45.4	26.8
D1/25/53	43.8	25.4
D1/25/54	42.0	26.4
D1/25/55	38.0	34.4
300 Gy		
D1/30/1	40.0	35.4
D1/30/3	36.0	27.2
D1/30/4	42.6	27.8
D1/30/5	41.0	26.0
D1/30/6	43.8	29.0
Dacca-1	34.6	12.6
Mean ± SE	41.75 ±0.85	28.58 ±0.77

But from BARI Chinabadam-8 only 02, 02 and 05 progenies were selected from 150, 200 and 250 Gy doses irradiated populations, respectively, (Table 28). These selected progenies will be further evaluated in M_3, in next year.

Table 27. Plant height and pod number of the selected populations from different doses of gamma ray irradiated populations of PK-1

M_2 populations	Plant height (cm)	Pods plant^{-1} (no.)
150 Gy		
PK1/15/15	27.8	21.8
PK1/15/16	28.0	20.2
PK1/15/17	29.4	21.2
PK1/15/29	32.2	20
PK1/15/34	30.0	24.2
PK1/15/37	31.4	22.4
PK1/15/40	31.4	20
PK1/15/44	23.6	20.2
PK1/15/48	36.2	24
PK1/15/50	31.4	21.4
PK1/15/55	29.4	21.8
200 Gy		
PK1/20/29	321.8	20.6
PK1/20/67	31.2	20.4
PK1/20/68	26.4	22.6
PK1/20/70	30.2	20.6
PK1/20/71	29.0	25.8
PK1/20/73	24.4	20.25
Mean ± SE		

M_2 populations	Plant height (cm)	Pods plant^{-1} (no.)
150 Gy		
PK1/15/65	24.4	20
PK1/15/69	28.6	21.4
PK1/15/73	33.2	22
PK1/15/86	33.8	20
200 Gy		
PK1/20/1	20.0	20.75
PK1/20/5	25.7	20.6
PK1/20/18	22.6	20
PK1/20/19	29.6	26
PK1/20/27	19.6	21.6
PK1/20/28	33.0	20.8
250 Gy		
PK1/25/20	26.4	20
300 Gy		
PK-1/30/31	39.4	23
PK-1/30/43	29.6	25.2
PK-1	38.6	14.8
Mean ± SE	38.7 ± 9.5	21.4 ± 0.39

Table 28. Plant height and pod number of the selected populations from different doses of gamma ray irradiated populations of BARI Chinabadam-8

M_2 populations	Plant height (cm)	Pod plant^{-1} (no.)
150 Gy		
B8/15/14	55.0	23.8
B8/15/31	30.6	20.25
200 Gy		
B8/20/20	19.4	20
B8/20/91	30.4	21.2
Mean ± SE	-	-

M_2 populations	Plant height (cm)	Pod plant^{-1} (no.)
250 Gy		
B8/25/11	28.8	21.2
B8/25/14	31.2	21.4
B8/25/15	29.8	21.6
B8/25/26	22.6	20
B8/25/64	41.8	20.6
BARI Chinabadam-8	28.6	12.4
Mean ± SE	31.8 ± 3.2	20.3 ± 0.94

SESAME

On-station yield trial with advanced sesame mutants

The trial was conducted in the farms of BINA sub-stations at Ishurdi, Magura and Rampur during Kharif-I 2014. There were four advanced mutant lines and two check varieties (Binatil-1and BARI Til-2). The mutants and check varieties were laid out in a randomized complete block design with three replications. Unit plot size was 20 m^2 (4 m × 5 m) keeping 25 cm spacing between two rows and 6-8 cm among the plants in rows. Seeds were sown within March 06-12, 2014. Recommended production packages like application of recommended doses of fertilizers, weeding, thinning, irrigation, application of pesticide etc. were followed to ensure normal plant growth and development. Data were taken for plant height, number of branches $plant^{-1}$, capsules $plant^{-1}$ and seeds $capsule^{-1}$ from 10 randomly selected plants from each plot. Maturity period was counted when 80% capsules were matured and most of the plants turned into straw or yellowish color in each plot. Seed yield of each plot was recorded after harvest and converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

The results of each location and combined over locations are presented in Table 29. The results showed significant variations for most of the characters among the mutants and check varieties in all locations and combined over locations. On an average, days to maturity ranged from 86 in mutants SM-8 and SM-9 to 94 in mutant SM-076. Among the mutants, SM-067 was the tallest (127 cm), but it was shorter than the check variety Binatil-1 (134 cm). Among the mutants, number of branches $plant^{-1}$ ranged from 4.8 in SM-067 to 5.1 in SM-058 while it was 4.8 in BARI Til-2 and 1.0 Binatil-1 (uniculm variety). Mutants SM-8 and SM-9 produced the significantly higher or similar number of capsules $plant^{-1}$ as compared to the check Binatil-1. The mutant line SM-058 had the higher number seeds $capsule^{-1}$ at Ishurdi, and the check variety Binatil-1 had higher number in other locations. The other mutant lines had significantly higher of seeds $capsule^{-1}$ as compared to the check variety BARI Til-2. The significantly higher of capsules as well as higher number of seeds $capsule^{-1}$ in SM-8, SM-9 and SM-058 resulted in significantly higher seed yield in all locations. In general, all mutants had significantly higher yield (combined over locations) as compared with check varieties.

Table 29. Mean performance of sesame lines along with check varieties for different quantitative characters

Genotype	Days to maturity	Plant height (cm)	Branches $plant^{-1}$ (no.)	Capsules $plant^{-1}$ (no.)	Seeds $capsule^{-1}$ (no.)	Seed yield (kg ha^{-1})
BINA sub-station farm, Ishurdi						
SM-8	91bc	107c	5.6a	55ab	66b	1545a
SM-9	92bc	108bc	5.6a	52ab	65b	1544a
SM-058	94b	110bc	6.5a	48bc	77a	1515a
SM-067	96a	119a	5.6a	48bc	68b	1458ab
Binatil-1	88c	111b	1.0b	59a	68b	1365b
BARI Til-2	93bc	116a	5.4a	43c	68b	1382b

Table 29 Contd.

Genotype	Days to maturity	Plant height (cm)	Branches plant-1 (no.)	Capsules plant-1 (no.)	Seeds capsule-1 (no.)	Seed yield (kg ha-1)
BINA sub-station farm, Magura						
SM-8	89b	129b	4.8a	55b	65cd	1575b
SM-9	89b	132b	4.5a	53b	75b	1768a
SM-058	86c	130b	4.4a	51b	68c	1626b
SM-067	94a	133b	4.4a	42c	67cd	1444c
Binatil-1	87c	151a	1.0b	62a	80a	1326d
BARI Til-2	89b	133b	4.5a	48bc	62d	1408cd
BINA sub-station farm, Rangpur						
SM-8	86d	132b	4.7a	65a	66d	1552ab
SM-9	87c	130b	4.5a	62b	72b	1591a
SM-058	89b	132b	4.3a	53c	66d	1500abc
SM-067	94a	131b	4.6a	59b	63e	1465bcd
Binatil-1	86d	142a	1.0b	39d	81a	1383d
BARI Til-2	89b	129b	4.5a	54c	71c	1398cd
Combined means over three locations						
SM-8	89c	122d	5.0a	58a	66d	1557b
SM-9	89c	123cd	4.9a	55a	71b	1634a
SM-058	90bc	124cd	5.1a	50b	71b	1547b
SM-067	94a	127b	4.8a	50b	66cd	1455c
Binatil-1	90b	134a	1.0b	55a	76a	1358d
BARI Til-2	90b	125bc	4.8a	48b	68c	1396d

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Growing of M_3 population of sesame

A large number of M_3 population from Binatil-1 were grown in plant progeny rows for selecting desirable mutants at BINA sub-station farm, Magura. From them primarily a total of 43 mutant variants have been selected for further selection in subsequent generations.

Maintenance of germplasm (mutants, local and exotic collections)

Thirty seven germplasm were grown at BINA sub-station farm Magura. After harvest, seeds of all these germplasm were collected and preserved as breeding materials for future research programme.

SOYBEAN

Multi-location yield trial of advanced soybean mutants

Four promising mutants along with two check varieties (Binasoybean-1 and BARI Soybean-5) of soybean were evaluated through this trial. The experiment was conducted at the experimental field of BINA Headquarters farm, Mymensingh and BINA sub-station farms at Magura and Comilla; farmers' field at Chandpur and Noakhali during January to April 2014. The experiments were laid out in randomized complete block design with three replications. Sowing was done within first week of January 2014. Spacing between rows was 30 cm and 7-10 cm between plants in a row. Unit plot size was 12 m^2 (4 m × 3 m). Recommended managements were followed to ensure proper growth and development of plants. Data on various characters such as plant height, number of branches $plant^{-1}$, pods $plant^{-1}$ and seeds pod^{-1} were taken from 10 randomly selected plants of each plot. Maturity period was counted when the plant and pods of each plot turned into yellowish brown color and almost all the leaves shed. Seed yield of each plot was recorded and converted into kg ha^{-1}. Data recorded from the experiment were analyzed following appropriate statistical design.

Location-wise mean values and means combined over three locations for different characters of the mutants and check varieties are presented in Table 30. Significant variations were observed for most of the characters in all locations and combined over locations. On an average, days to maturity ranged from 113 in Binasoybean-1 to 117 in the mutant SBM-9. The mutant line SMB-22 had the tallest (58 cm) plant height whereas, Binasoybean-1 SMB-9 was the shortest (48 cm) among the all genotypes. Number of branches $plant^{-1}$ ranged from 2.62 in Binasoybean-1 to 3.0 in SBM-9. On an average, all the mutants had the significantly higher or similar number of pods $plant^{-1}$ than the check varieties. All the mutants had significantly higher seed yield than the check varieties and particularly, SMB-22 produced the highest seed yield (2784 kg ha^{-1}). Number of seeds pod^{-1} ranged from 1.8 in SMB-9 to 1.92 in SMB-22; and hundred seed weight in the mutants ranged from 13.89 to 14.38 g.

Table 30. Mean performance of soybean lines along with check varieties for different quantitative characters

Mutants/varieties	Days to maturity	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (kg ha^{-1})
BINA Headquarters farm, Mymensingh							
SBM-9	118bc	71c	2.73a	56bc	1.81	13.87d	3151a
SBM-15	120a	77abc	2.50ab	70a	1.79	14.02c	2986b
SBM-18	119ab	74bc	2.33ab	50cd	1.90	14.41b	3160a
SBM-22	118b	80ab	2.46ab	59bc	1.82	13.90d	3155a
Binasoybean-1	115d	82a	2.00b	44d	1.83	12.38e	2792b
BARI Soybean-5	117c	74bc	2.33ab	61ab	1.82	14.61a	2782b
BINA sub-station farm, Magura							
SBM-9	128c	49bc	2.36ab	68ab	1.70	13.85d	2242a
SBM-15	126d	53ab	2.46ab	67ab	1.73	14.03c	2293a
SBM-18	128c	51ab	2.5ab	72a	1.83	14.36b	2320a
SBM-22	132b	55a	1.93b	72a	1.86	13.87d	2396a
Binasoybean-1	133ab	47c	2.26ab	61b	1.80	12.41e	1882b
BARI Soybean-5	132b	55a	2.63a	74a	1.80	14.58a	2023b

Table 30 Contd.

Mutants/varieties	Days to maturity	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield (kg ha^{-1})
BINA sub-station farm, Comilla							
SBM-9	102bc	35b	3.33ab	57a	1.86c	13.80e	2879a
SBM-15	104a	47a	3.06bc	51a	1.99b	14.00c	2912a
SBM-18	104a	37b	3.43ab	54a	2.17a	14.39b	2980a
SBM-22	100d	49a	3.6a	51a	1.99b	13.91d	3007a
Binasoybean-1	103b	37b	2.83c	43b	1.92bc	12.39f	2624b
BARI Soybean-5	101cd	49a	3.00bc	41b	2.01b	14.57a	2570b
Farmer's field, Chandpur							
SBM-9	118a	35b	2.63a	44a	1.77b	13.85e	2345a
SBM-15	106b	37b	2.37ab	43a	1.93b	14.01c	2308a
SBM-18	101e	38b	2.43ab	38b	1.83b	14.36b	2180b
SBM-22	102d	44a	2.03b	37b	1.87b	13.91d	2345a
Binasoybean-1	101e	37b	2.37ab	39ab	2.10a	12.54f	1841c
BARI Soybean-5	103c	37b	2.40ab	42ab	1.90b	14.56a	2133b
Farmer's field, Noakhali							
SBM-9	121a	50d	3.93a	50a	1.87	13.84d	2895abc
SBM-15	116bc	53bc	3.60bc	48ab	1.80	14.02c	2939ab
SBM-18	117b	51cd	3.50bc	53a	1.83	14.39b	3056a
SBM-22	116bc	61a	3.30c	53a	2.10	13.86d	3014a
Binasoybean-1	115c	49d	3.63b	41b	1.83	12.39e	2704bc
BARI Soybean-5	116bc	54b	3.57bc	46ab	1.83	14.57a	2687c
Combined means over five locations							
SBM-9	117a	48d	3.00a	55a	1.80b	13.84e	2660c
SBM-15	115b	53b	2.80ab	56a	1.85ab	14.02c	2682bc
SBM-18	114bc	51c	2.84ab	54a	1.91a	14.38b	2739ab
SBM-22	114bc	58a	2.66b	55a	1.92a	13.89d	2784a
Binasoybean-1	113d	50c	2.62b	46b	1.90a	12.42f	2369e
BARI Soybean-5	114bc	54b	2.78ab	53a	1.88ab	14.58a	2480d

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Growing of M_2 population

A large number of M_2 population from BARI Soybean-5 were grown in plant progeny rows for selecting desirable mutants at BINA Headquarters farm, Mymensingh but no selection was practiced.

Growing of M_1 population

To create genetic variability, seeds of two popular soybean varieties, Binasoybean-1 and BARI Soybean-5 were irradiated with 200, 250 and 300 Gy of gamma rays. M_2 seeds from five pods of each plant were collected to grow first segregating M_2 population.

MUNGBEAN

On-farm trial of one promising mutants of mungbean

On-farm trials were carried out with one mutant along with two check varieties (Binamoog-8 and BARI Mung-6) at Magura and Ishurdi during Kharif-1 season of 2014. Seeds were sown in RCB design with three replications. Unit plot size was 10 m × 8 m. Row to row and plant to plant distances were 40 and 10-15 cm, respectively. Data on days to maturity, plant height, pods plant^{-1}, pod length, seeds pod^{-1} and seed yield plot^{-1} were recorded from five randomly selected plants from each plot. Plot seed yield was converted to kg ha^{-1}. Mean values were used for statistical analyses (Table 31).

The results of mean over locations, the mutant MBM-07-3y-1 was taller than Binamoog-8 and BARI Mung-6. The mutant gave the almost similar number of pods plant^{-1} like check variety Binamoog-8. In respect of average seed yield, Binamoog-8 produced the highest seed yield of 1754 kg ha^{-1} followed by MBM-07-3y-1 (1658 kg ha^{-1}). Though this mutant MBM-07-3y-1 produced little lower yield than check variety, Binamoog-8 but its seed coat colour is yellowish and has consumers' preference. Hence, application will be made to the National Seed Board for release as variety.

Table 31. Performance of one elite mungbean mutant along with two check varieties grown at two locations during 2014

Mutants/varieties	Days to maturity	Plant height (cm)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Seed yield (kg ha^{-1})
Ishurdi						
MBM-07-3y-1	77a	42.6a	17.9a	7.7ab	10.6a	1668c
Binamoog-8 (check)	67c	38.9b	17.1a	7.7ab	10.0a	1843a
BARI Mung-6 (check)	70b	35.9c	13.3b	8.7a	9.3ab	1705b
Magura						
MBM-07-3y-1	78a	41.6a	18.4a	7.8ab	10.7ns	1622a
Binamoog-8 (check)	64c	39.9ab	18.4a	8.6a	10.7	1665a
BARI Mung-6 (check)	70b	40.5ab	16.6b	8.5a	10.2	1550b
Combined						
MBM-07-3y-1	77a	42.1a	18.2a	7.7ab	10.7a	1658b
Binamoog-8 (check)	65c	39.4ab	17.8a	8.2ab	10.4a	1754a
BARI Mung- 6 (check)	70b	38.3b	15.1b	8.6a	9.8ab	1628b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Zonal yield trial of some promising mungbean mutants

Four selected mungbean mutants along with two check varieties were put into zonal yield trial at Magura and Ishurdi during Kharif-1 season of 2014. The design of experiment was RCB with three replications. Unit plot size was 5 m × 4 m. Row to row and plant to plant distance were 40 cm and 10-15 cm, respectively. Recommended cultural practices including fertilizer doses were applied as and when necessary. Data on various characters, such as plant height, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, days to maturity and seed yield plot^{-1} were taken from five randomly selected plants of each plot. Plot seed yield was converted to kg ha^{-1}. Mean values were used for statistical analyses (Table 32).

From the result, mean over locations, it was observed that significant differences were observed for all the studied characters among the entries. The shortest plant height and highest number of pods plant^{-1} were observed in MBM-656-51(2) than other mutants and the check varieties. The number of seeds pod^{-1} for all the mutants were almost similar. The mutant MBM-477-60 matured 65 days which is 4 days earlier than the other mutants and the checks. Two mutants MBM-477-60 and MBM-07-y-2 produced higher seed yield than both check varieties. These two selected mutants will be further evaluated in on-farm yield trial in different mungbean growing locations of Bangladesh.

Table 32. Mean performance of four mutants along with two check varieties grown at Magura and Ishurdi during 2014

Mutants/varieties	Days to maturity	Plant height (cm)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	Seed yield (kg ha^{-1})
Ishurdi						
MBM-07(g)-2	69a	40.7b	13.8d	7.4ab	11.5a	1573c
MBM-656-51(2)	67ab	36.0c	19.4a	7.2ab	10.2b	1592c
MBM-07-y-2	66ab	38.4b	15.4c	7.4ab	11.0ab	1680b
MBM-477-60	67ab	39.7b	17.4b	7.6ab	11.0ab	1767a
Binamoog-8	68a	40.3b	16.2bc	8.6a	12.0a	1647b
BARI Mung-6	70a	45.4a	17.0b	8.2a	11.0ab	1560c
Magura						
MBM-07(g)-2	67ab	39.1b	17.5b	7.7ab	11.0ab	1430c
MBM-656-51(2)	66ab	34.7c	18.6a	7.6ab	13.4a	1490c
MBM-07-y-2	68a	37.6bc	17.8b	7.4ab	9.9b	1550b
MBM-477-60	63b	40.2b	17.2b	7.6ab	10.8ab	1683a
Binamoog-8	65ab	39.6b	17.0b	8.4a	11.5ab	1525b
BARI Mung-6	69a	44.4a	14.2c	8.1a	11.0ab	1475c
Combined						
MBM-07(g)-2	68a	40.0b	15.7b	7.5ab	11.3a	1502c
MBM-656-51(2)	66ab	35.2c	19.0a	7.4ab	11.8a	1541bc
MBM-07-y-2	67ab	38.1bc	16.6ab	7.5ab	10.3b	1615b
MBM-477-60	65b	39.8bc	17.3ab	7.6ab	10.7ab	1725a
Binamoog-8	66ab	39.9bc	16.6ab	8.5a	11.6a	1586bc
BARI Mung-6	69a	44.9a	15.6b	8.2a	10.9bab	1518c

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Advanced yield trial of some promising mutants of mungbean

Advanced yield trials were carried out with four mutants and one local variety along with two check varieties (Binamoog-8 and BARI Mung-6) at Magura and Ishurdi during Kharif-1 season of 2014 to develop varieties with early maturity, higher seed yield and disease tolerance. Seeds were sown in RCB design with three replications. Unit plot size was 4 m × 5 m. Row to row and plant to plant distances were 40 cm and 10-15 cm, respectively. Recommended fertilizer doses were applied. Usual cultural and inter-cultural practices were followed as and when necessary. Data on days to maturity, plant height, number of branches plant^{-1}, pods plant^{-1}, pod length, seeds pod^{-1} and seed yield plot^{-1} were recorded from five randomly selected plants of each plot. Plot seed yield was converted to kg ha^{-1}. Mean values were subjected to statistical analyses.

The results of means over locations for all the characters are presented in Table 33. Results showed significant variation in all studied parameters among all the mutants and check varieties. Mutant MBM-527-114 and MB-80 (local) produced the higher number of pods plant^{-1} than both check varieties. The mutant MBM-427-87-3 was found early maturing (64 days) followed by MBM-527-114 and Binamoog-8 than other mutants and check variety, BARI Mung-6.

Table 33. Mean performance of four mutants and one local variety along with the check varieties grown at Magura and Ishurdi during 2014

Mutants/varieties	Days to maturity	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Pods length (cm)	Seeds pod^{-1} (no.)	Seed yield (kg ha^{-1})
Ishurdi							
MBM-347-13	68bc	46.7ab	0.5ab	14.8bc	8.6ab	10.5a	1548b
MBM-527-114	67bc	46.0ab	0.3b	17.5b	8.5ab	9.5ab	1640a
MBM-390-94(y)	68bc	37.0c	0.7ab	13.3c	8.3ab	9.4ab	1508b
MBM-427-87-3	64c	49.4a	0.3b	15.2bc	7.0b	10.2a	1656a
MBM-80 (Local)	74a	48.8a	1.1a	23.9a	7.1b	10.2a	1145c
Binamoog-8	66bc	44.0b	0.1b	16.7b	9.4a	10.7a	1651a
BARI Mung-6	70b	44.4b	1.1a	15.3bc	8.9b	10.8a	1553b
Magura							
MBM-347-13	66ab	40.3b	0.3b	17.6b	8.0ab	9.4ab	1567b
MBM-527-114	65b	40.9b	0.5ab	13.3d	8.0ab	9.6ab	1630a
MBM-390-94(y)	67ab	37.2c	0.5ab	17.4b	6.9b	10.1a	1538b
MBM-427-87-3	65b	39.2bc	0.8ab	16.0bc	8.4ab	9.8ab	1619a
MBM-80 (Local)	70a	52.4a	1.5a	23.8a	8.8a	9.9ab	1043c
Binamoog-8	65b	40.8b	0.1b	15.1c	9.1a	10.3a	1552b
BARI Mung-6	68ab	38.4bc	0.7ab	14.5c	9.0a	10.2a	1525b
Combined							
MBM-347-13	67b	43.5bc	0.4c	15.6bc	8.6ab	10.1a	1557b
MBM-527-114	66bc	43.5bc	0.5c	17.5bc	8.3ab	9.5ab	1635a
MBM-390-94(y)	67b	37.4c	0.6b	13.3c	8.2ab	9.5ab	1523b
MBM-427-87-3	64bc	44.3b	0.6b	19.5b	6.9c	9.9ab	1637a
MBM-80 (Local)	72a	50.6a	1.3a	23.8a	7.8b	10.2a	1094c
Binamoog-8	66bc	42.3bc	0.1c	16.4bc	9.1a	10.0a	1601a
BARI mung-6	69a	41.4bc	0.9ab	15.2bc	9.0a	10.3a	1539b

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

In respect of seed yield, MBM-427-87-3 produced the highest seed yield (1637 kg ha^{-1}) followed by MBM-527-114 (1635 kg ha^{-1}) and Binamoog-8 (1601 kg ha^{-1}). Four mutants will be further evaluated for zonal yield trial in next growing season at different locations of Bangladesh.

Maintenance of AVRDC germplasm of mungbean

Fifteen AVRDC germplasm were grown at BINA sub-station farm, Ishurdi during Kharif-1, 2014. Cultural practices were done as and when necessary. Data on plant height, days to maturity, number of branches plant^{-1}, pod length, number of pods plant^{-1}, number of seeds pod^{-1}, 100-seed weight and seed yield plant^{-1} were recorded from each genotypes (Table 34). At harvest, seeds of all these germplasm were collected and have been preserved as breeding materials for future research programme.

Table 34. Agronomic performances of 15 AVRDC mungbean germplasm

Mutants/varieties	Days to maturity	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	100-seed weight (g)	Seed yield $plant^{-1}$ (g)
AVRDC 0001(y)	70	36.2	-	22	9.2	10	5.5	6.5
AVRDC 0001(g)	69	47.0	1.0	20	8.1	12	3.2	7.9
AVRDC 1001(y)	72	35.6	0.8	22	7.3	11	4.5	7.0
AVRDC 1001(g)	70	32.8	1.0	19	7.5	10	6.7	12.0
AVRDC 0002	69	41.2	-	17	9.2	11	5.0	6.3
AVRDC 1002	68	36.2	1.0	18	8.3	10	7.6	13.4
AVRDC 1003	73	33.2	1.0	15	7.9	11	6.6	11.5
AVRDC 1004	70	34.3	1.0	17	7.6	11	4.8	9.8
AVRDC 1005	74	34.1	2.0	15	7.4	10	6.2	8.2
AVRDC 1006(y)	70	41.2	0.8	18	8.2	12	4.9	7.9
AVRDC 1006(g)	65	40.2	-	19	9.2	10	7.3	12.1
AVRDC 1007	72	37.4	0.6	15	8.2	12	7.3	12.6
AVRDC 0201(y)	70	36.0	0.1	17	7.7	11	6.0	6.7
AVRDC 0201(g)	73	38.2	0.3	18	8.3	10	5.0	9.2
AVRDC 0401	71	42.1	1.0	20	8.0	12	7.6	11.7
AVRDC 0801(y)	69	39.8	1.0	19	8.1	10	4.0	5.4
AVRDC 0801(g)	69	39.5	0.7	18	7.4	10	7.0	11.1
AVRDC 8501	70	37.2	0.8	13	7.9	11	6.4	10.2
AVRDC 9701	68	36.0	0.6	20	8.4	10	4.9	7.0
AVRDC 0101	73	38.0	0.4	19	9.0	10	5.3	8.0

CHICKPEA

Preliminary yield trial of some selected chickpea mutants

Four chickpea mutants along with two check varieties (BARI Sola-7 and Binasola-7) were grown at Ishurdi, Rajshahi and Magura during 2013-2014. The main objective of this trial is to develop variety having large seed size and higher seed yield. The experiment was conducted in randomized complete block design with three replications. Unit plot size was 4 m × 2.5 m. Row to row and plant to plant distances were 40 and 10-15 cm, respectively. Data on plant height, days to maturity, number of primary branches, number of pods $plant^{-1}$, and number of seeds pod^{-1}, 100-seed weight and seed yield $plot^{-1}$ were recorded. Data were analyzed statistically (Table 35).

From the result, it is observed that mutant CPM-8-200 produced the highest yield at all the location. From combined analysis, CPM-8-200 and CPM (Kab) mutants were found promising for higher seed yield (1693 kg and 1559 kg ha-1). The check variety BARI Sola-7 and mutant CPM-4-300 produced the highest number of pods $plant^{-1}$. The 100-seed weight of CPM-200 was the highest, 23.5 (g) followed by Binasola-7, 21.7 (g) and CPM (Kab), 21.1 (g). Three mutants were selected for further trial in next growing season.

Table 35. Performance of four chickpea mutants along with two check varieties for different characters during 2013-14

Variety/mutants	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	100-seed weight. (g)	Seed yield (kg ha^{-1})
Rajshahi							
CPM (Kab)	119ns	49.2c	4.4a	37.8d	1.1^{NS}	21.3b	1598b
CPM -4-300	120	54.6b	3.6b	58.4a	1.2	13.4c	1327d
CPM-7-400	119	49.5c	3.6b	46.0b	1.2	13.1c	1416c
CPM-8-200	120	60.4a	4.0ab	37.1d	1.2	25.2a	1765a
BARI Sola-7 (Check)	121	55.4b	3.6b	59.4a	1.2	14.2c	1344d
Binasola-7 (Check)	121	61.2a	3.8ab	39.5c	1.2	24.3a	1510b
Magura							
CPM (Kab)	115ab	55.0c	5.4a	41.5b	1.3bc	21.3ab	1514b
CPM -4-300	112b	74.5a	5.1ab	43.0b	2.7a	13.2b	1203d
CPM-7-400	113b	69.5b	4.6b	44.7b	2.8a	13.9b	1660a
CPM-8-200	112b	68.0b	4.5b	55.4a	2.6a	24.8a	1680a
BARI Sola-7 (Check)	115ab	67.1b	5.1ab	48.8ab	1.6b	14.4b	1319c
Binasola-7 (Check)	117a	62.0bc	4.8b	36.3c	1.4bc	23.1a	1576b
Ishurdi (Pabna)							
CPM (Kab)	113c	75.5ab	3.8^{ns}	43.2ab	1.5b	20.8ab	1564ab
CPM -4-300	117b	82.6a	3.6	48.3a	1.8a	13.2c	1497b
CPM-7-400	117b	80.4a	3.9	44.2ab	1.7a	13.2c	1580ab
CPM-8-200	116b	75.3ab	3.8	43.7ab	1.7a	20.6ab	1634a
BARI Sola-7 (Check)	122a	81.4a	3.8	40.2b	1.6ab	22.3a	1486b
Binasola-7 (Check)	115bc	72.3b	3.4	33.8c	1.6ab	17.8b	1546ab
Combined							
CPM (Kab)	116ab	60b	4.5^{NS}	41.0bc	1.3b	21.1a	1559b
CPM -4-300	116ab	71a	4.1	50.0a	1.9a	13.3c	1342c
CPM-7-400	116ab	66ab	4.0	45.0b	1.9a	13.4c	1552b
CPM-8-200	116ab	68a	4.1	45.0b	1.8a	23.5a	1693a
BARI Sola-7 (Check)	119a	68a	4.2	49.0a	1.5ab	17.0b	1383c
Binasola-7 (Check)	118a	65ab	4.0	37.0c	1.4b	21.7a	1544b

NS = not significant
In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Advanced yield trial of some promising mutants of chickpea

Four mutants along with two check varieties were put into advanced yield trial at Rajshahi, Magura and Ishurdi. The experiment was carried out in a randomized complete block design with three replications. Unit plot size was 5 m × 4 m. Distances between rows and plants were 40 and 10-15 cm, respectively. Data on days to maturity, plant height, number of branches plant^{-1}, pods plant^{-1}, seeds pod^{-1}, 100-seed weight and seed yield plot^{-1} were recorded from randomly selected five plants of each plot. Plot yield was converted to kg ha^{-1}. The collected data were analyzed statistically and presented in Table 36.

Table 36. Advanced yield trial some selected mutants of chickpea during 2013-2014

Variety/mutants	Days to maturity	Plant height (cm)	Primary branches plant^{-1} (no)	Pods plant^{-1} (no)	Seeds pods^{-1} (no)	100-seed weight (g)	Seed yield (kg ha^{-1})
Rajshahi							
CPM -4-400	120ns	45.2b	3.7b	55.8b	1.0ns	13.1c	1491b
CPM-7-300	121	50.4ab	4.4a	83.2a	1.0	23.8ab	1461b
CPM-8-300	121	50.3ab	3.5b	34.9c	1.1	26.5a	1687a
CPM-8-400	121	57.8a	4.1ab	50.7b	1.2	28.6a	1745a
BARI Sola-7 (Check)	120	37.7c	3.4b	36.3c	1.0	19.3b	1375bc
Binasola-7 (Check)	120	52.4ab	4.0ab	58.1b	1.1	24.1ab	1484b
Magura							
CPM -4-400	118a	71.5a	4.2ab	41.1c	1.5b	13.2b	1421b
CPM-7-300	114b	67.4ab	4.8a	42.9c	1.8ab	14.2b	1502ab
CPM-8-300	116ab	67.7ab	4.6a	60.2b	1.6ab	24.5a	1690a
CPM-8-400	115ab	67.1ab	4.8a	33.7d	1.6ab	24.4a	1629a
BARI Sola-7 (Check)	120a	65.8b	4.4ab	27.2e	1.4b	13.4b	1475b
Binasola-7 (Check)	118a	58.9c	4.8a	66.7a	2.0a	25.4a	1557ab
Ishurdi (Pabna)							
CPM -4-400	122a	82.7a	2.9b	33.3d	1.7a	13.1c	1429c
CPM-7-300	121a	71.8b	3.3ab	53.8b	1.8a	17.5bc	1322d
CPM-8-300	105bc	71.2b	3.6a	47.7c	1.8a	26.5a	1520b
CPM-8-400	107bc	74.2b	3.6a	65.0a	1.6ab	14.8c	1820a
BARI Sola-7 (Check)	106bc	70.5b	3.2ab	45.1c	1.5ab	19.0b	1255d
Binasola-7 (Check)	110b	67.9bc	3.6a	39.4d	1.7a	20.7b	1491b
Combined							
CPM -4-400	120a	66.5a	3.6b	43.4bc	1.4ab	13.2c	1447d
CPM-7-300	119a	63.2ab	4.2a	60.0a	1.5a	18.5b	1428d
CPM-8-300	114b	63.1ab	3.9ab	47.6b	1.5a	25.9a	1632b
CPM-8-400	114b	66.4a	4.2a	49.9b	1.5a	22.6ab	1731a
BARI Sola-7 (Check)	115ab	58.0b	3.7b	36.2c	1.3ab	17.3b	1368d
Binasola-7 (Check)	116ab	59.8b	4.1a	54.8ab	1.6a	23.4ab	1511c

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

It was observed from the result that plant height of the entries ranged from 37.7-82.7cm. The days to maturity ranged from 105-122 days. The mutant CPM-8-300 matured earlier than both the check varieties. The mutant CPM-8-400 produced higher number of pods plant^{-1} than the other mutants and checks. The mutant CPM-8-400 produced significantly highest seed yield than other mutants and checks varieties at all locations due to production of higher number of pods plant^{-1} and bolder seed size. Out of four mutants, two showed promising in respect of number of pods plant^{-1} and seed yield kg ha^{-1}. These two mutants (CPM-8-300 and CPM-8-400) will be grown in the next year to assess their yield potential at different locations of Bangladesh.

LENTIL

On station yield trial of four selected mutants of lentil

Four mutants along with a check variety, BARI Masur-5 were put into on-station yield trial at BINA sub-station farms, Maugra and Ishurdi. The experiment was carried out in a randomized complete block design with three replications. Unit plot was 5 m × 4 m. Distances between rows and plants were 30 and 5-6 cm, respectively. Plant height, number of primary branches plant^{-1}, days to maturity and number of pods plant^{-1} were recorded from randomly selected 10 plants from each plot. Plot yield of each plot was recorded and converted into kg ha^{-1}.

Results showed that significant variations were present in all the characters except number of primary branches plant^{-1}(Table 37). It was observed from results that plant height ranged from 34.6 to 38.9 cm. The days to maturity ranged from 95 to 112 days for mutants while BARI Masur-5 matured in 112 days. The mutant LM-75-4 matured earlier mutants and the check. The mutant LM-75-4 produced the highest number of pods plant^{-1}. At Magura, mutant LM-75-4 produced significantly the highest seed yield followed by LM-132-7 and LM-185-2. At Ishurdi, mutant LM-75-4 produced the highest seed yield. But, the mutant LM-75-4 produced higher in seed yield and number of pods plant^{-1} among the mutants and the check variety. The selected mutant lines LM-75-4 and LM-132-7 will be grown in the next year to assess their yield potential at different locations of Bangladesh.

Table 37. Mean of yield and yield contributing characters of the selected promising mutants grown at Magura and Ishurdi during 2013-14

Mutant/variety	Plant height (cm)	Branches plant^{-1} (no.)	Days to maturity	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})		Mean
					Magura	Ishurdi	
LM-6-11(2)	36.11ab	2.8^{NS}	96c	158b	1890c	1845b	1868c
LM-185-2	37.8a	2.7	108a	169b	2025b	1998b	2012b
LM-75-4	34.6b	2.9	95c	216a	2641a	2598a	2619a
LM-132-7	38.9a	2.8	101b	198ab	2452a	2390ab	2421a
BARI Masur-5	37.4a	2.6	112a	162b	2055b	1903b	1979c

NS = not significant
In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Zonal yield trial for the selected mutants of lentil

Five mutants along with check variety, BARI Masur-5 were put into on-station yield trial at BINA sub-station farm, Maugra and Ishurdi. The experiment was carried out in a randomized complete block design with three replications. Unit plot was 5 m × 4 m. Distances between rows and plants were 30 and 5-6 cm, respectively. Plant height, number of primary branches plant^{-1}, days to maturity and number of pods plant^{-1} were recorded from randomly selected 10 plants of each plot. Plot yield of each plot was recorded and converted to kg ha^{-1}.

Results showed that significant variations were present in all the characters except number of primary branches plant^{-1} (Table 38). It was observed from the results that plant height ranged from 36.4 to 40.8 cm. The mutants matured earlier (99-104 days) than the check variety, BARI Masur-5 (113 days). The mutants, LM-156-1, LM-6-7(2) and LM-123-7 produced higher number of pods plant^{-1}. At Magura, LM-132-7 produced significantly the highest seed yield of 2576 kg ha^{-1} followed by LM-156-1 and LM-6-7(2). At Ishurdi, mutant LM-123-7 produced the highest seed yield among the mutants and check. On an average, mutant LM-123-7 produced the highest seed yield due to higher number of pods plant$^{-1.}$ The selected mutants LM-123-7, LM-156-1 and LM-6-7(2) will be grown in the next year to assess their yield potential at different locations of Bangladesh.

Table 38. Mean of yield and yield contributing characters of the selected promising mutants grown at Magura and Ishurdi during 2013-14

Mutant/variety	Plant height (cm)	Branches plant^{-1} (no.)	Days to maturity	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})		Mean
					Magura	Ishurdi	
LM-156-1	40.8a	2.7 ^{NS}	101c	198a	2379ab	2298b	2339ab
LM-13-1	36.4c	2.9	105b	164c	1868bc	1824c	1846c
LM-28-2	39.2a	2.8	104b	172bc	1987b	1890c	1939c
LM-6-7(2)	36.6bc	2.7	103b	195a	2295b	2219b	2257b
LM-123-7	38.5ab	2.9	99c	206a	2576a	2492a	2534a
BARI Masur-5	37.4b	2.5	113a	186b	2050bc	1984bc	2017bc

NS = not significant
In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

Advanced yield trial of some selected mutants of lentil

Seven mutants along with the check variety, BARI Masur-5 were put into an advanced yield trial at Magura and Ishurdi. The experiment was carried out in a randomized complete block design with three replications. Unit plot was 4 m × 3 m. Distances between rows and plants were 30 and 5-6 cm, respectively. Plant height, number of primary branches plant^{-1}, days to maturity and number of pods plant^{-1} were recorded from randomly selected 10 plants of each plot. Plot yield of each plot was recorded and converted into kg ha^{-1}. Recorded data were subjected to proper statistical analyses.

Results showed that significant variations were present in all the characters except number of primary branches plant^{-1} (Table 39). It was observed from the results that plant height ranged from 37.4 to 41.0 cm. The days to maturity ranged from 99 to 113 days for mutants while it was 113 days for mother variety, BARI Masur-5. The mutant LM-48-1 matured earliest among the mutants and check variety BARI Masur-5. At Magura, mutant LM-48-1 produced significantly the highest seed yield of 2296 kg ha^{-1} followed by LM-24-3 among the mutants and the check variety. At Ishurdi, the mutant LM-48-1 produced the highest seed yield at all the locations due to production of higher number of pods plant^{-1}. Out of seven mutants, two showed promising in respect of number of pods plant^{-1} and seed yield. The selected mutant lines, LM-48-1 and LM-24-3 will be grown in the next year to assess their yield potential at different locations of Bangladesh.

Table 39. Mean of yield and yield contributing characters of the selected promising mutants grown at Magura and Ishurdi during 2013-14

Mutant/variety	Plant height (cm)	Branches plant^{-1} (no.)	Days to maturity	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})		Mean
					Magura	Ishurdi	
LM-93-3	38.1b	2.8 ^{ns}	107ab	171b	1990b	1920ab	1955ab
LM-21-6	41.0a	2.8	110a	152c	1786c	1735c	1761c
LM-20-3	40.1ab	2.5	109a	145d	1654bd	1630c	1642c
LM-48-1	39.1ab	2.4	99c	201a	2296a	2205a	2250a
LM-24-3	40.4a	2.4	101b	190a	2179ab	2089a	2134a
LM-14-2	37.5c	2.2	108ab	162bc	1852bc	1909ab	1881b
LM-99-4	38.1b	2.6	102b	189a	2150ab	2012ab	2081ab
BARI Masur-5	37.4c	2.5	113a	150c	1781c	1660c	1721c

NS= not significant; In a column, values with same letter(s) do not differ significantly at 5% level by DMRT.

Preliminary yield trial of some promising mutants of lentil

Twelve mutants along with one check variety, BARI Masur-5 were put into preliminary yield trial at Ishurdi. The experiment was carried out in a RCB design with three replications. Unit plot was 3 m × 2 m. Distance between rows and plants were 30 and 5-6 cm, respectively. Plant height, branches plant^{-1}, days to maturity, pods plant^{-1} and number of pods plant^{-1} were recorded from randomly selected 10 plants of each plot. Plot seed yield of each plot was recorded and converted into kg ha^{-1}. Recorded data were subjected to proper statistical analyses.

Results showed significant variations in all the characters (Table 40). It was observed from results that plant height ranged from 34.7 to 38.8 cm. The days to maturity ranged from 96 to 114 days for mutants while it was 114 days for mother variety BARI Masur-5. The mutants LM-5(4)-4, LM-6(2)-5 and LM-6(3)-28 produced higher number of pods plant^{-1}.

Table 40. Mean of yield and yield contributing characters of the selected promising mutants grown at Ishurdi during 2013-14

Mutant/variety	Plant height (cm)	Branches plant^{-1} (no.)	Days to maturity	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})
LM-5(3)-24	38.2a	2.9ab	111a	126c	1633c
LM-5(3)-29	36.4b	2.7ab	112a	172b	2016bc
LM-B6-2(2)	37.7b	3.2a	110a	173b	2150b
LM-B6-11(2)	36.8b	3.1a	105c	197ab	2416ab
LM-B6-7(2)	39.2a	2.9ab	110a	175b	2083bc
LM-5(4)-4	38.8a	3.1a	96c	210a	2750a
LM-5(3)-11	34.7d	3.3a	108ab	188ab	2300b
LM-5(3)-22	35.1cd	3.2a	107ab	131d	1766c
LM-6(2)-5	36.8b	2.9a	98c	205a	2550a
LM-6(2)-10	36.7b	2.8ab	109ab	179b	2233b
LM-6(3)-28	37.9b	3.0a	99c	200ab	2426ab
LM-6(4)-14	34.4d	2.4b	112a	148c	1783c
BARI Masur.-5	35.6c	2.8ab	114a	154c	1800c

In a column, values with same letter(s) for individual location/combined means do not differ significantly at 5% level by DMRT.

The mutants LM-5(4)-4 and LM-6(2)-5 produced higher seed yield at Ishurdi. Moreover, these two mutants had higher number of pods plant^{-1} and matured 15 and 18 days earlier than the parent, BARI Masur.-5. These two mutants will be assessed over different locations for confirmation in the next year.

On-farm yield trial of three promising of lentil

Trials on two promising lentil mutants along with a check variety were conducted at Natore, Magura and Jessore during 2013-14 in order to assess the performance of these mutants at farmers' field. The mutants were LM-75-4 and LM-132-7, and BARI Masur-5 was used as check. Each trial was conducted in non-replicated field with individual plot size of 100 m^2 (10 m × 10 m). Data on days to maturity and yield kg ha^{-1} were recorded from each trial and are summarized in Tables 41a and 41b.

The duration and yield of lentil mutants/variety ranged from 95-114 days and 2085-2690 kg ha^{-1}, respectively. At Magura, the mutant LM-75-4 produced the highest seed yield at all locations with matured earliest (97 days). Yield ranged from 2565-2685 kg ha^{-1}, 2380-2490 kg ha^{-1}, and 2085-2196 kg ha^{-1}, respectively in the mutants LM-75-4, LM-132-7 and BARI Masur-5 with mean yield over all locations 2647, 2418 and 2125 kg ha^{-1}.

Table 41a. Mean of days to maturity of three mutants and a check variety of lentil at three locations during 2013-14 (average of three locations)

Mutants/lines	Natore	Magura	Jessore	Average
LM-75-4	101b	95b	96b	97b
LM-132-7	102b	99b	100b	100b
BARI Masur-5	114a	110a	112a	112a

In a column, values with same letter(s) do not differ significantly at 5% level by DMRT.

Table 41b. Mean of seed yield (kg ha^{-1}) of three mutants and a check variety of lentil at three locations during 2013-'14 (average of three locations)

Mutants/lines	Natore	Magura	Jessore	Mean seed yield (kg ha^{-1})
LM-75-4	2565a	2690a	2685a	2647a
LM-132-7	2385ab	2380ab	2490ab	2418ab
BAR Masur-5	2085b	2196b	2094b	2125b

In a column, values with same letter(s) do not differ significantly at 5% level by DMRT.

Preliminary yield trial with some promising mutants of lentil

The trials were carried out with 13 lentil mutants and a check variety, BARI Masur-6 at two locations, BINA sub-stations, Ishurdi and Magura during 2013-14. The experiments were laid out in a randomized complete block design with three replications. Unit plot size was 1.8 m^2 with row to row and plant to plant distances of 30 and 5-6 cm, respectively. Recommended cultural practices were followed for normal plant growth and development. At harvest, days to maturity, plant height, number of primary branches plant^{-1}, number of pods plant^{-1} were recorded from 10 randomly selected plants of each plot. Maturity period was counted when 90% plants were matured and most of the plants turned straw or yellowish color in each plot. Seed yield of each plot was recoded after harvest and converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

Table 42. Mean of different quantitative characters of 13 selected mutants of lentil and a check variety, BARI Masur-6 at two locations, Ishurdi and Magura during 2013-14

Mutants/variety	Days to maturity	Plant height (cm)	Primary branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})		
					Ishurdi	Magura	Average
LM-201-1	105h	37.0ab	3.1^{NS}	101a-d	859de	1240c	1050e
LM-138-1	107def	36.8ab	3.0	81ef	895de	1055de	957f
LM-206-5	108a-d	35.3b	3.7	106ab	1387b	1407b	1397b
LM-118-1	109abc	37.6ab	3.0	78f	1522a	1255c	1388b
LM-118-5	107def	35.3b	3.4	98a-e	918de	1073de	996ef
LM-206-4	106fg	35.6b	2.9	92b-f	733f	1027de	880g
LM-118-8	109ab	39.5a	3.5	110a	1495a	1537a	1516a
LM-138-2	108cde	39.9a	3.3	95a-f	795f	1194c	972f
LM-206-2	106gh	35.7b	3.4	94a-f	731f	1009e	870g
LM-612-3	103i	35.5b	3.1	62g	942d	1055de	999ef
LM-512-1	106fg	35.1b	3.4	84def	844e	898f	870g
LM-138-3	108a-d	36.9ab	3.2	109ab	1538a	1240c	1389b
LM-118-9	108a-d	38.0ab	3.1	103abc	1397b	1092d	1244d
BARI Masur-6	109a	38.2ab	3.3	86c-f	1275c	1357b	1316c

NS = not significant; In a column, values with same letter(s) do not differ significantly at 5% level by DMRT.

Significant variations were observed for all the characters amongst the tested mutants and the check variety except for number of primary branches plant^{-1} (Table 42). The mutant line LM-612-3 matured earlier than the check and the other mutants. The average plant height ranged from 35.1 - 39.9 cm and the mutants LM-138-2 and LM-118-9 were found the tallest. Regarding number of pods plant^{-1}, the highest number of pods plant^{-1} was recorded in LM-118-8 followed by LM-138-3 and LM-206-5. The mutant line, LM-118-8 produced the highest seed yield both at Ishurdi and Magura followed by LM 206-5. The promising three mutants, LM-118-8, LM-206-5 and LM-138-3 will be evaluated further for their performance in different locations of the country.

On-station yield trial with two advanced lines of lentil

The trial was conducted with two advanced lentil lines and one check variety, BARI Masur-5 at BINA sub-stations, Ishurdi and Magura during 2013-14. The experiment was laid out in a randomized complete block design with three replications. Unit plot size was 12 m^2 with 30 and 5-6 cm row to row and plant to plant distances, respectively. Recommended production packages, such as application of fertilizers, weeding, thinning, etc. were followed as and when necessitated to ensure normal plant growth and development. Data were recoded for days to maturity, plant height, number of primary branches plant^{-1}, number of pods plant^{-1} from 10 randomly selected plants from each plot. Maturity period was counted when 90% plants were matured and most of the plants turned into yellowish to straw colour in each plot. Seed yield of each plot was recorded after harvest and proper drying, and converted into kg ha^{-1}. Appropriate statistical analyses were performed for comparison of means of each character.

Table 43. Mean of different quantitative characters of two advanced lines and a check variety, BARI Masur-5 at Ishurdi during 2013-14

Strains/variety	Days to maturity	Plant height (cm)	Primary branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})
LG-206	113a	45.3 ns	3.7 ns	95c	1750b
LG-208	109b	41.2	4.2	158a	1950a
BARI Masur-5	111ab	46.2	3.7	122b	1800ab

NS = not significant

The results are presented in Table 43 and showed significant variations for all the characters except plant height and number of primary branches plant^{-1}. The mutant line LG-208 matured earlier than the check and the other line. The highest number of pods plant^{-1} was recorded in LG-208 followed by the check BARI Masur-5 and the line LG-208 produced the highest seed yield. The lines will be further evaluated in different locations of the country.

Evaluation of ICARDA lines of lentil

Seeds of 6 genotypes along with one check variety, BARI Masur-4 were put into yield trial at Magura and Ishurdi. The experiment was carried out in a randomized complete block design with three replications. Unit plot was 3 m × 2 m. Distances between rows and plants were 30 and 5-6 cm, respectively. Plant height, number of primary branches plant^{-1}, days to maturity, number of pods plant^{-1} and number of pods plant^{-1} were recorded from randomly selected 10 plants of each plot. Plot yield of each plot was recorded and converted into kg ha^{-1}. Recorded data were subjected to proper statistical analyses.

Table 44. Mean of yield and yield contributing characters of ICARDA lines of lentil grown at Magura and Ishurdi during 2013-14

Lines/variety	Plant height (cm)	Primary branches plant^{-1} (no.)	Days to maturity	Pods plant^{-1} (no.)	Seed yield (kg ha^{-1})		Mean seed yield (kg ha^{-1})
					Magura	Ishurdi	
ICA-23118	40.2a	2.8^{NS}	108ab	178ab	1968a	1902a	1944ab
ICA-23126	39.3a	2.7	107ab	176ab	1878ab	1803ab	18401b
ICA-23136	37.3ab	2.9	106b	177ab	1909ab	1893a	1901ab
ICA-23121	38.2ab	2.7	109ab	178ab	1921ab	1875a	1898b
ICA-23129	36.5b	2.8	108ab	159bc	1692c	1551c	1622c
ICA-23105	35.2b	2.7	107ab	188a	2012a	1943a	1978a
BARI Masur-4	37.4ab	2.6	112a	145c	1603c	1590c	1597c

NS = not significant; In a column, values with same letter(s) do not differ significantly at 5% level by DMRT.

Results showed significant variations in all the characters except plant height and number of primary branches plant^{-1} (Table 44). Plant height ranged from 35.2 to 40.2 cm. The days to maturity ranged from 106 to 112 days for genotypes while it was 112 days for check variety BARI Masur-4.

The genotype ICA-23105 produced significantly the highest number of pods plant^{-1}. The genotype ICA-23105 produced the highest at Magura with significant difference from the remaining genotypes. At Ishurdi, ICA-23105 produced the highest seed yield followed by ICA-23118, ICA-23136 and ICA-23121. In average over two locations, the genotype ICA-23105 had the highest seed yield followed by ICA-23128. Out of six genotypes, two showed promising in respect of number of pods plant^{-1} and seed yield. The selected lines ICA-23105 and ICA-23118 will be grown in the next year to assess their yield potential at different locations of Bangladesh.

ONION

Zonal yield trial with M_7 mutant lines for bulb yield potential in Kharif-II season at Rangpur and Ishurdi

The experiment was carried out to assess bulb yield potentials of four summer onion mutants in Kharif-II season. Seeds were sown on 20 July 2013 at BINA Headquarters farm, Mymensingh. BARI Piaz-3 was included as a check variety. Seedlings were transplanted on 28 August 2013 at Rangpur and 27 August at Ishurdi sub-station farms, following RCB design with three replications. A unit plot size was 2.0 m × 1.65 m. Plants were spaced at 15 cm within rows of 20 cm apart. Fertilizers were applied at the rate of Urea 200, TSP-175, MoP-150, Gypsum-110, ZnO-3.0 kg ha^{-1} apart from 5.0 t ha^{-1} of farm yard manure. The whole amount of TSP, MOP, Gypsum and ZnO were applied during final land preparation while urea was applied at three equal installments during final land preparation, 25 and 50 days after transplanting. Farm yard manure was applied two weeks before final land preparation. Data on number of leaves at vegetative stage and bulb diameter were recorded from randomly selected ten competitive plants. Fresh bulb weight was recorded from whole plot at harvest. Dry bulb weight was recorded after 1.5-2.0 months of harvest and finally converted to yield ha^{-1}. Finally, the collected data were subjected to proper statistical analyses and are presented in Table 45.

It appears that irrespective of mutants and check variety, leaf number, individual bulb weight and diameter, fresh and dry bulb weights and yield were significantly higher at Ishurdi than Rangpur (Table 43). At Rangpur, only the mutant BP_2/100/1 had significantly higher number of leaves plant^{-1} than the check variety BARI Piaz-3. In contrast, at Ishurdi three mutants, BP_2/75/2, BP_2/100/2 and BP_2/100/12 had significantly higher number of leaves than the check variety with BP_2/100/12 being the highest followed by BP_2/75/2. At Rangpur, all the mutants had significantly larger bulb diameter than check variety with BP_2/75/2 being the largest while at Ishurdi BP_2/75/2 and BP_2/100/12 being the largest. Individual bulb weight was significantly higher in BP_2/72/2 and BP_2/100/2 than the check variety at Rangpur while at Ishurdi three mutants had significantly higher individual bulb weight including the two that had significantly higher bulb weight at Rangpur. The mutants BP_2/75/2, BP_2/100/2 and BP_2/100/12 had significantly higher fresh and dry bulb weights at both locations than the check variety (Table 45). Finally, bulb yield ha^{-1}, the ultimate goal of any plant breeding program, was significantly higher in only BP_2/75/2 at Rangpur while all the mutants had significantly higher bulb yield at Ishurdi than the check variety. All these mutants will be further tested in the next season to confirm these results.

Zonal yield trial with M_7 mutant lines for bulb yield potentials in Kharif-II season at Magura

The experiment was carried out to assess bulb yield potentials of three summer onion mutants in Kharif-II season. BARI Piaz-3 was included as a check variety. Sets were transplanted on 30 July 2013 at Magura sub-station farm, BINA following RCB design with 3 replications. A unit plot size was 2.0 m × 1.65 m. Plants were spaced at 15 cm within rows of 20 cm apart.

Fertilizers were applied at the rate of Urea 200, TSP-175, MOP-150, Gypsum-110, ZnO-3.0 kg ha^{-1} apart from 5.0 t ha^{-1} of farm yard manure. The whole amount of TSP, MOP, Gypsum and ZnO were applied during final land preparation while urea was applied at three equal installments during final land preparation, 25 and 50 days after transplanting. Farm yard manure was applied two weeks before final land preparation. Data on number of leaves at vegetative stage and bulb diameter were recorded from randomly selected ten competitive plants. Fresh bulb weight was recorded from whole plot at harvest. Dry bulb weight was recorded after 1.5-2 months of harvest and finally converted to yield ha^{-1}. Finally, the collected data were subjected to proper statistical analyses and are presented in Table 46.

Table 45. Bulb yield and some related traits of some promising summer onion mutants during Kharif II season, 2013 at Rangpur and Ishurdi

Mutants/variety	Leaves plant^{-1} (no.)	Bulb diameter (cm)	Individual bulb weight (g)	Fresh bulb weight plot^{-1} (g)	Dry bulb weight plot^{-1} (g)	Bulb yield (t ha^{-1})
Rangpur						
BP_2/75/2	8.13	5.66	18.90	843	605	7.55
BP_2/100/1	8.73	4.92	11.97	408	267	4.78
BP_2/100/2	8.27	5.42	16.97	1142	842	6.80
BP_2/100/12	8.13	5.17	11.67	677	487	4.29
BARI Piaz-3	8.27	4.79	15.60	423	280	6.68
$LSD_{0.05}$	0.26	0.08	0.24	18.47	25.60	0.85
Ishurdi						
BP_2/75/2	11.20	5.30	61.33	1540	1458	21.59
BP_2/100/1	9.33	4.93	47.67	607	592	18.68
BP_2/100/2	11.13	4.97	56.67	1502	1082	18.24
BP_2/100/12	11.67	5.30	57.67	1005	1010	21.95
BARI Piaz-3	7.97	4.63	46.67	682	645	16.11
$LSD_{(0.05)}$	0.27	0.23	0.98	29.00	29.83	0.52
$LSD_{(0.05)}$ var.× loc.	0.24	0.19	0.62	21.53	29.42	0.73

Table 46. Bulb yield and some related traits of some promising summer onion mutants during Kharif II season, 2013 at Magura

Mutant/variety	Leaves plant^{-1} (no.)	Bulb diameter (cm)	Individual bulb weight (g)	Fresh bulb weight plot^{-1} (g)	Dry bulb weight plot^{-1} (g)	Bulb yield (t ha^{-1})
BP_2/75/2	3.83	2.80	2.23	283	181	7.32
BP_2/100/1	3.03	2.57	4.63	640	436	15.42
BP_2/100/2	3.50	2.50	4.73	470	293	14.04
BARI Piaz-3	2.30	2.29	4.01	193	126	13.36
$LSD_{(0.05)}$	0.19	0.19	0.12	19.30	17.00	0.46

From the table it is clear that all the mutants had significantly higher number of leaves plant^{-1} than that of the check variety BARI Piaz-3 with BP_2/75/2 being the highest followed by BP_2/100/2 and BP_2/100/1. Similarly, all the mutants had larger bulb diameter than the check variety with BP_2/100/1 being the largest followed by BP_2/75/2 and BP_2/100/2. The mutants BP_2/100/1 and BP_2/100/2 had significantly larger individual bulb weight than the check variety BARI Piaz-3. In contrast, the other mutant BP_2/75/2 had the smallest individual bulb weight of all. All the mutants had significantly higher fresh and dry bulb weights than the check variety with BP_2/100/1 being the highest followed by BP_2/100/2 while the check variety had the lowest fresh and dry bulb weight. Bulb yield ha^{-1} was significantly the highest in the mutant BP_2/100/1 followed by BP_2/100/2. For confirmation, all the mutants will be further tested in next season.

Production of M_7 pure seed of summer onion mutants

As onion is a solely cross pollinated crops, to avoid contamination by other varieties, seeds of four mutants were grown at four different locations in non replicated plots. The mutant BP_2/75/2 was grown at BINA sub-station farm, Magura, BP_2/100/1 at Rangpur, BP_2/100/12 at Chapainawabgonj and BP_2/100/2 at Ishurdi. Seeds were sown on 13 October 2013 at BINA Headquarters farm. Seedlings were transplanted on 25 November, 2013 at Magura, Rangpur, Ishurdi and 30 November, 2013 at Chapainawabgonj. The mutant BP_2/75/2 was planted in 50m^2, BP_2/100/1 in 15 m^2, BP_2/100/2 in 35 m^2 and BP_2/100/12 in 30 m^2 areas. Plants were spaced at 15 cm within rows of 20 cm apart. Fertilizers were applied at the rate of Urea 270, TSP-280, MoP-170, Gypsum-110 and ZnO-15.0 kg ha^{-1} apart from 10 t ha^{-1} of farm yard manure. The whole amount of TSP, Gypsum and ZnO were applied during final land preparation while urea and MoP were applied at four equal installments during final land preparation, 25, 50 and 70 days after transplanting. Farm yard manure was applied two weeks before final land preparation. At maturity, only total seed yield plot^{-1} was recorded. BP_2/75/2, BP_2/100/1, BP_2/100/2 and BP_2/100/12 produced 40, 320, 71 and 300 kg ha^{-1} of seed yield, respectively.

BLACKGRAM

Growing of M_3 generation of blackgram

To create variability three varieties of blackgram, Binaash-1, BARI Mash-1 and BARI Mash-3, were irradiated with gamma rays and grown at BINA Headquarters farm, Mymensingh in 2011. Seeds from 192 M_1 plants were harvested separately and M_2 generation was grown at Magura in 2012 and a total of 27 plants were selected from M_2 generation and these 27 M_3 mutant variants were grown in plant-progeny rows. From 27 M_3 mutant variants, 12 mutants were selected and M_4 seeds will be sown in plant-progeny-rows in next season.

Growing of M_2 generation of blackgram

To create variability seeds of three black ram varieties, BARI Mash-1, BARI Mash-2, and BARI Mash-3, were irradiated with 200, 300, 400 and 500 Gy of gamma rays and grown M_1 generation during 2012. M_2 seeds were collected from every M_1 plant. A large number of M_2 plants were grown during 2013 and primarily 34 mutant variants were selected to grow them in M_3 generation during 2014 for desirable characters.

GRASSPEA

Growing of M_2 generation of grasspea

To create variability seeds of three of grasspea varieties, Binakheshari-1, BARI Kheshari-1, and BARI Kheshari-2, were irradiated with 250, 300 and 350 Gy of gamma rays and grown at BINA Headquarters farm, Mymensingh during 2012-13. M_2 seeds from 450 M_1 plants were harvested separately and grown them during 2013-14 and M_3 seeds from 47 mutant variants were collected. M_3 generation will be grown during 2013-14.

Breeder seed production and distribution

During 2011-12, 2012-13 and 2013-14 Plant Breeding Division produced 18199, 23535 and 25657 kg and distributed 16356, 19605 and 21538 kg breeder seeds, respectively (Table 47, 48 and 49, respectively) different crop varieties developed by Plant Breeding Division. The breeder seeds were distributed mainly to BADC, NGOs, Private seed companies etc.

Table 47. Production and distribution of breeder seed of different crop varieties developed by Plant Breeding Division during 2011-12

Crops		Production (kg)	Distribution (kg)		
			BADC	NGOs and others	Total distribution
Rice	T. aman	4600	2300	1030	3330
	Boro	480	220	120	340
	Total	5080	2520	1150	3670
Oilseeds	Rapeseed-mustard	600	250	191	441
	Groundnut	4579	1650	2929	4579
	Sesame	200	48	119	167
	Soybean	500	200	145	345
	Total	5879	2148	3384	5532
Pulses	Mungbean	4200	2200	1950	4150
	Lentil	1200	600	600	1200
	Chickpea	1470	400	1050	1450
	Blackgram	15	-	10	10
	Grasspea	350	210	100	310
	Total	7235	3410	3710	7120
Vegetables	Tomato	5	-	4	4
Grand total (kg)		18199	8078	8248	16326

Table 48. Production and distribution of breeder seed of different crop varieties developed by Plant Breeding Division during 2012-13

Crops		Production (kg)	Distribution (kg)		
			BADC	NGOs and others	Total distribution
Rice	T. aman	7150	3130	800	3930
	Boro	800	-	-	-
	Total	7950	3130	800	3930
Oilseeds	Rapeseed-mustard	705	150	105	255
	Groundnut	5904	2400	3504	5904
	Sesame	255	80	146	226
	Soybean	550	238	167	405
	Total	7414	2868	3922	6,790
Pulses	Mungbean	4600	2070	2520	4590
	Lentil	1200	600	600	1200
	Chickpea	1890	380	1490	1870
	Blackgram	25	-	20	20
	Grasspea	450	220	180	400
	Total	8165	3270	4810	8,080
Vegetables	Tomato	6	-	5	5
Grand total (kg)		23535	9268	9537	18805

Table 49. Production and distribution of breeder seed of different crop varieties developed by Plant Breeding Division during 2013-14

Crops		Production (kg)	Distribution (kg)		
			BADC	NGOs and others	Total distribution
Rice	T. aman	7000	2120	2580	4700
	Boro	2150	90	500	590
	Total	9150	2210	3080	5290
Oilseeds	Rapeseed-mustard	621	45	521	566
	Groundnut	7968	2134	5834	7968
	Sesame	320	135	157	292
	Soybean	600	200	310	510
	Total	9509	2514	6822	9336
Pulses	Mungbean	4800	2000	2780	4780
	Lentil	1432	600	832	1432
	Chickpea	280	140	110	250
	Blackgram	30	-	25	25
	Grasspea	450	100	320	420
	Total	6992	2840	4067	6907
Vegetables	Tomato	6	-	5	5
Grand total (kg)		25657	7564	13974	21530

CROP PHYSIOLOGY DIVISION

RESEARCH HIGHLIGHTS

Five aromatic rice mutant/varieties *viz*., Binadhan-13, Kalizira, BRRI dhan34, Ukunimadhu and RM-100-16 were evaluated under water stress (30% FC) and control (100% FC) during grain growth period. Photosynthesis, chlorophyll content in flag leaves and grain weight decreased under water stress in all the mutant/varieties. The rice mutant/varieties achieved physiological maturity at 24 days after fertilization. Among the mutant/varieties, Binadhan-13 performed the best under water stress condition.

Four rice varieties *viz*., Binadhan-8, Binadhan-10, NERICA-1 and NERICA-10 were evaluated with four levels of salinity *viz*., 0, 6, 9 and 12 dS/m. Grain yield decreased with increasing salinity levels in all the varieties and the decrement was the lowest in NERICA-10.

Two *Aman* rice varieties *viz*., Binadhan-13, Kalizira and a mutant RM-100-16 were evaluated at farmers' fields of Rangpur, Rajshahi and Satkhira districts. The highest grain yield was found in Binadhan-13 followed by the mutant RM-100-16. Four *Boro* rice varieties namely Binadhan-6, Binadhan-8, Binadhan-10 and Irratom-24 were also evaluated at farmers' fields at Rangpur, Rajshahi and Satkhira districts. Binadhan-6 performed the best in respect of yield and yield attributes.

Thirty one lentil mutants were evaluated at BINA sub-stations at Ishurdi and Magura. Four mutants *viz.*, N_1I-123, N_2I-206, E_3I-803 and E_4I-723 were found promising for seed yield. In another experiment, three mutants *viz*., N_4M-540, E_3I-316 and E_4M-819 were also found promising for seed yield.

Four mungbean mutants (MB-1, MB-2, MB-13 and MB-17) were evaluated at sub-stations, Ishurdi and Magura and no mutant was found promising.

Foliar application of the growth regulator chitosan was sprayed @ 0, 25, 50, 75 and 100 ppm on Binatomato-6 and Binatomato-7 during flowering stage. The application of chitosan at any concentration had no significant influence on growth and yield of tomato. However, foliar application of chitosan @ 0, 25, 50, 75 and 100 ppm on Binamoog-7 and Binamoog-8 increased seed yield and application of chitosan @75 ppm was found suitable for increasing seed yield in mungbean.

Photosynthesis, grain growth and chlorophyll stability of aromatic rice mutant/varieties under water stress

A pot experiment was carried out with five aromatic rice mutant/varieties to assess photosynthesis, grain growth and chlorophyll stability under water stress during grain growth period. Control (100% FC) and water stress (30% FC) were imposed on Binadhan-13, Kalizira, BRRI Dhan34, Ukunimadhu and a mutant RM-100-16 at flowering stage and continued until maturity. The experiment was laid out in a Complete Randomized Design with three replications. Thirty day old seedlings were transplanted in plastic pots containing 8 kg soils pot^{-1} on 16 August 2013. Recommended doses of fertilizers were applied and cultural practices were done whenever required. Grain dry weights of 10 grains of selected panicles, chlorophyll content (SPAD reading) and photosynthetic rate of flag leaf were measured at 3 days interval from fertilization to maturity.

Results showed that grain dry weight, photosynthetic rate and chlorophyll content of flag leaf decreased significantly (Table 1). The highest grain dry weight, chlorophyll content and photosynthetic rate was found in Binadhan-13. Kalizira had medium grain dry weight and photosynthetic rate. BRRI dhan34 showed better grain dry weight with lower photosynthetic rate. The lowest grain dry weight was found in Ukunimadhu. The mutant RM-100-16 had lower grain dry weight and photosynthetic rate. Chlorophyll contents of all the mutant/varieties were statistically identical unlike Binadhan-13. Grain dry weight increased with age till 24 days after anthesis followed by a Plateau wheras SPAD reading and photosynthesis rate decreased with grain age until physiological maturity.

Table 1. Effect of water stress on grain dry matter accumulation, chlorophyll content and photosynthesis of flag leaves of aromatic rice genotypes during grain filling period

Treatment	Dry weight grain^{-1} (mg)	SPAD reading (Chlorophyll)	Photosynthetic rate (μmolCO$_2$ m^{-2}S^{-1})
Water stress			
Control (100% FC)	7.50 a	37.99 a	20.83 a
Water stress (30% FC)	6.83 b	37.30 b	13.60 b
Variety			
Binadhan-13	8.71 a	39.51 a	19.18 a
Kalizira	6.70 c	37.59 b	17.04 b
BRRIdhan 34	7.65 b	36.02 b	16.44 d
Ukunimadhu	6.28 e	37.44 b	16.90 c
RM-100-16	6.49 d	37.65 b	16.48 d
Harvest (days)			
0	1.42 g	39.48 a	21.38 a
4	2.17 f	39.21 a	19.49 b
8	5.18 e	38.19 ab	18.66 c
12	7.87 d	37.88 ab	17.58 d
16	8.98 c	37.37 ab	16.85 e
20	9.82 b	36.68 b	15.13 f
24	10.95 a	36.47 b	14.54 g
28	10.94 a	35.86 b	14.04 h

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Effect of salinity on physiological attributes and yield of four rice varieties

A pot experiment was carried out at BINA pot yard with four rice varieties *viz*., Binadhan-8, Binadhan-10, NERICA-1 and NERICA-10 in *Boro* season 2014 to evaluate the effect of salinity on physiological attributes and yield. The experiment was conducted following CRD with four replicates. To establish the experiment perforated pots were filled up with 9 kg well mixed soil with cow dung and fertilizer @ 50 N, 25 P and 25 K mg kg^{-1} of soil. A polythene shade was established above the experiment area to avoid the rain water. Eight filled pots were set in each glass fibre tray and filled the tray with water up to the neck of the pot. Three sprouted seeds were sown in each pot. Normal cultural practices were done as and when necessary. Four levels of salinity *viz*., 0, 6, 9 and 12 dSm^{-1} were imposed at maximum tillering stage and maintained until maturity. Data on chlorophyll content in leaves were recorded at 13, 24 and 34DAS and nitrate reductase (NR) activity at 20, 32 and 40 DAS. At harvest, yield and yield contributing characters, root and shoot dry weight were recorded.

Results revealed that Binadhan-8 and Binadhan-10 produced greater root and shoot dry weight and higher grain yield through showing better yield component characteristics than NERICA-1 and NERICA-10 (Table 2, Fig. 1). All the plant parameters decreased with increasing salinity levels and 12 dSm^{-1} showed the lowest except number of unfilled grains $panicle^{-1}$. In respect of chlorophyll content and nitrate reductase activity, NERICA-1 and NERICA-10 showed higher chlorophyll at any days after saline application (DASA) where only NERICA-1showed higher NR activity in all DASA (Table 3).

Table 2. Effect of salinity on yield and yield components of four rice varieties

Treatment	Plant height (cm)	Tillers $plant^{-1}$ (no)	Effective tillers $plant^{-1}$ (no)	Grains $panicle^{-1}$ (no)	Unfilled grains $panicle^{-1}$ (no)	Panicle length (cm)	Grain weight $panicle^{-1}$ (g)	Shoot weight $plant^{-1}$ (g)	Root weight $plant^{-1}$ (g)
Varieties									
Binadhan-8	76.06 b	12.69 a	7.688 b	67.85 a	41.92 a	23.31 b	14.97a	20.96 b	7.423 b
Binadhan-10	90.56 a	15.5 a	10.81 a	59.39 a	34.96ab	25.26 a	14.32 b	27.51 a	12.1 a
NERICA-1	59.63 d	7.563 b	3.313 c	31.35 b	27.5 b	16.31 c	5.169 b	11.97 c	6.648 c
NERICA-10	66.69 c	8.375 b	3.25 c	23.8 b	35.22 b	17.01 c	5.139 b	11.57 c	5.511d
Level of sig.	**	**	**	**	**	**	**	**	**
Salinity levels (dSm^{-1})									
0	85.81 a	13.25 a	11.81 a	95.76 a	37.09 b	25.35 a	26.53 a	23.8 a	12.83 a
6	80.38 b	11 ab	7.5 b	67.41 b	32.74ab	24.02 b	10.16 b	20.49 b	8.542 b
9	65.13 c	10.06 b	2.75 c	16.36 c	26.69 b	15.98 c	1.995 c	14.65 c	6.033 c
12	61.63 d	9.813 b	3 c	2.85 d	43.1 a	16.54 c	0.911c	13.08 d	4.27 d
Level of sig.	**	**	**	**	*	**	**	**	**
CV%	5.78	11.33	25.16	34.64	44.48	7.13	24.07	10.64	10.43

In a column, within treatment, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Table 3. Effect of salinity on chlorophyll and nitrate reductase activity of four rice varieties

Treatment	SPAD reading			Nitrate Reductase Activity (µmol NO^{-2} gfw^{-1} h^{-1})		
Varieties	13 DASA	24 DASA	34 DASA	20 DASA	32 DASA	40 DASA
Binadhan-8	40.69b	39.7b	44.39b	0.540b	13.32ab	8.59b
Binadhan-10	38.29c	40.56b	45.07b	0.395c	13.34ab	10.59a
NERICA-1	47.70a	47.64a	49.98a	1.069a	13.95a	9.83a
NERICA-10	46.52a	48.75a	50.64a	0.493b	12.92b	10.56a
Level of sig.	*	*	**	**	*	**
Salinity levels (dSm^{-1})						
0	41.72b	41.44c	46.61c	0.896a	11.9b	14.85a
6	43.76a	45.62a	46.47c	0.456c	12.26b	8.45b
9	44.38a	45.38ab	47.94b	0.489c	11.95b	9.01b
12	43.34ab	44.21b	49.05a	0.656b	17.42a	7.26c
Level of sig.	**	**	**	**	*	**

In a column, within treatment, means followed by same letter(s) do not differ significantly at 5% level by DMRT.
*, ** indicate significant at 5% and 1% levels of probability, respectively; DASA, days after saline application

The interaction effect of different levels of salinity and varieties showed significant variations where Binadhan-8 and Binadhan-10 produced better number of grains $panicle^{-1}$ and grain weight $hill^{-1}$ at 6 dSm^{-1} and Binadhan-8, Binadhan-10 and NERICA-1 produced almost same at 9 dSm^{-1} (Figs. 2a & 2b). Chlorophyll status of different dates of different varieties revealed that NERICA-1 and NERICA-10 showed higher than Binadhan-8 and Binadhan-10 in all salinity levels (Fig. 2c). Nitrate reductase (NR) activity of different dates revealed that NR activity decreased with increasing salinity level at 20 DASA (Fig. 2d). But at 32 DASA, Binadhan-8 and NERICA-1 had increased NR activity at 9 dSm^{-1} salinity level and NERICA-1 showed the highest NR activity at 12 dSm^{-1} and after 40 DASA all the varieties showed decreasing trend with increasing salinity level except Binadhan-10. Binadhan-10 produced the highest shoot and root dry weight $hill^{-1}$ at all salinity levels followed by Binadhan-8 (Figs. 2e & 2f).

For percent reduction in grain yield $hill^{-1}$ as compare to control, Binadhan-8 reduced 63% at 6 dSm^{-1}, 96% at 9 and 12 dSm^{-1}, Binadhan-10 reduced 62% at 6 dSm^{-1}, 77% at 9 dSm^{-1}, NERICA-1 reduced 77, 79 and 100 % at 6, 9 and 12 dSm^{-1}, respectively. NERICA-10 reduced 45 and 100% at 6, 9 and 12 dSm^{-1}, respectively (Fig. 1a). In respect of shoot and root dry weight $hill^{-1}$, Binadhan-8 and Binadhan-10 showed lower reduction at 9 and 12 dSm^{-1} salinity levels. From the above results, it revealed that Binadhan-8 and Binadhan-10 showed better performances than NERICA-1 and NERICA-10 against salinity where NERICA-1 and NERICA-10 had the capacity to produce higher chlorophyll up to 12 dSm^{-1}.

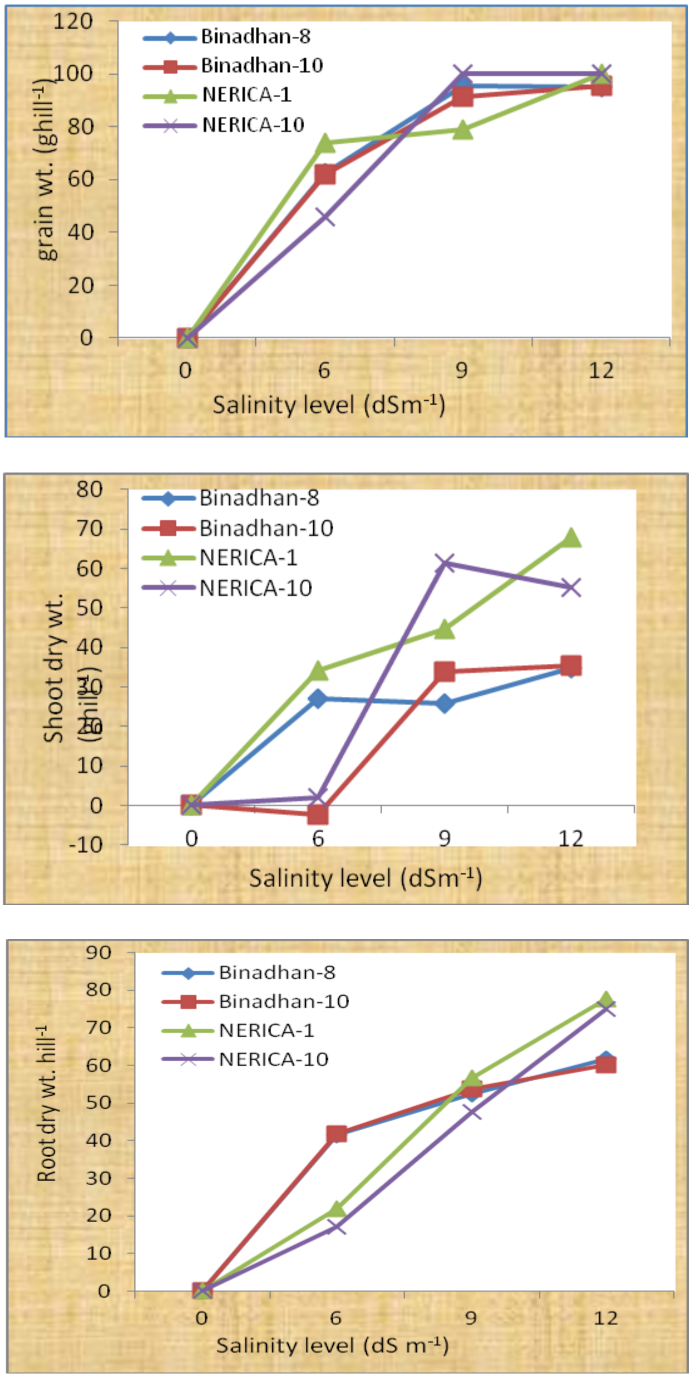


Fig. 1. Per cent reduction of (a) grain weight hill^{-1} (b) shoot dry weight hill^{-1} and (c) root dry weight hill^{-1} compare to control

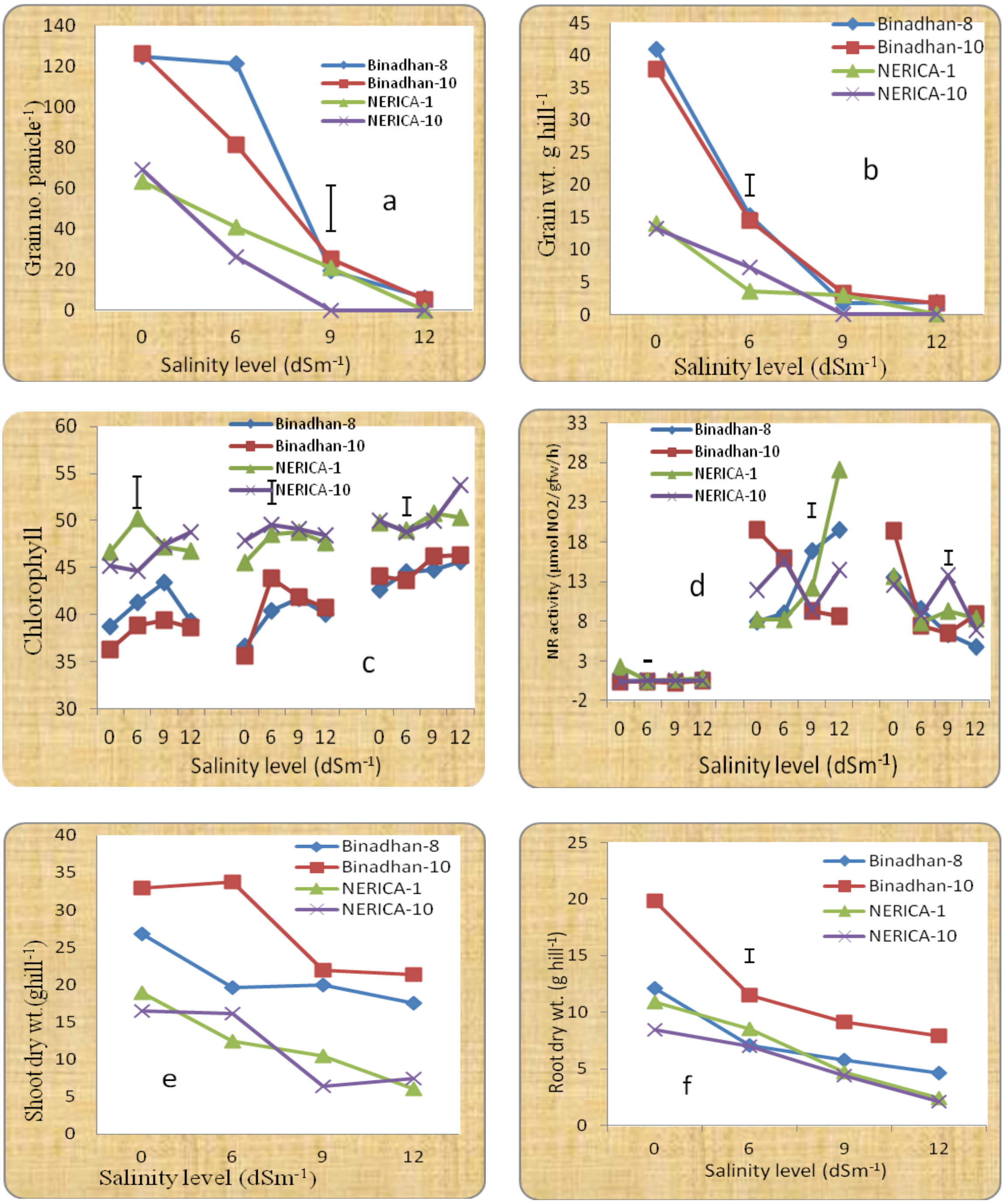


Fig. 2. Interaction effect of salinity and variety on (a) number of grains panicle^{-1}, (b) grain weight hill^{-1}, (c) chlorophyll content, (d) nitrate reductase activity, (e) shoot dry weight hill^{-1} and (f) root dry weight hill^{-1}

Field evaluation of selected temperature tolerant fine grain aromatic rice mutant/varieties at different locations

One aromatic rice mutant namely RM 100-16 and two varieties, Binadhan-13 and Kalizira were evaluated at farmers' field of three locations *viz*., Satkhira, Rajshahi and Rangpur districts during *Aman* season, 2013. Each trial was conducted in a three replicated plot of 5 m × 4 m size and spacing between hills and rows were 20 cm × 15 cm, respectively. Normal cultural practices like application of fertilizers, weeding and pesticides etc. were done as and when necessary. At harvest, 10 hills plot^{-1} was randomly selected for collecting necessary plant parameters. Grain yield plot^{-1} was finally converted into tons ha^{-1}.

Result showed that Binadhan-13 was shorter than RM-100-16 and Kalizira (Table 4). Binadhan-13 and RM-100-16 produced higher number of effective tillers hill^{-1} than the variety Kalizira. The highest filled grain was recorded in RM 100-16 and the lowest in Kalizira. The lowest unfilled grain was recorded in Binadhan-13 and the highest in Kalizira. The larger grain size was recorded in Binadhan-13 followed by Kalizira. The smallest grain was recorded in RM-100-16.

Table 4. Means of morphological and yield contributing characters of two aromatic rice varieties and a mutant conducted at three locations during *Aman* season of 2013

Varieties/mutant	Plant height (cm)	Effective tillers hill^{-1} (no)	Filled grains panicle^{-1} (no)	Unfilled grains panicle^{-1} (no)	1000-grain weight (g)
Binadhan-13	154.9 c	10.5 a	171.8 b	6.26 d	13.56 a
RM 100-16	175.9 a	10.5 a	186.3 a	19.2 c	11.23 c
Kalizira	173.9 a	8.22 b	133.6 c	46.0 a	12.16 b
CV (%)	4.44	11.88	9.54	13.30	3.66

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Results indicated that location had no much influence on yield performance of the varieties/mutant (Table 5). Considering the yield performance over locations, results further indicated that Binadhan-13 and RM-100-16 performed almost similar and higher grain yield than Kalizira. The lowest grain yield was recorded in Kalizira at all locations. The grain yield of Kalizira was lower due to fewer number of effective tillers hill^{-1} and lower number of grains panicle^{-1}. Crop duration was 4-10 days shorter in RM-100-16 than the Binadhan-13 and Kalizira.

Table 5. Mean grain yield and days required to maturity of two aromatic rice varieties and a mutant grown at three farmers' field during July-December 2013

Mutant/cultivars	Grain yield (t ha^{-1})				Crop duration (days)
	Satkhira	Rajshahi	Rangpur	Mean	
Binadhan-13	3.13 a	3.49 a	3.29 a	3.26 a	144 c
RM 100-16	3.27 a	3.16 ab	3.35 a	3.29 a	140 d
Kalizira	2.53 c	2.35 d	2.44 b	2.40 c	150 a
CV (%)	7.00	3.99	8.88	6.96	2.67

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Field evaluation of selected temperature tolerant boro rice varieties at different locations

Four rice varieties namely Binadhan-6, Binadhan-8, Binadhan-10 and Irratom-24 were evaluated for their morphological, yield and yield contributing characters at farmers' field at three locations *viz.*, Satkhira, Rajshahi and Rangpur during *Boro* season in 2013-14. The experiments were set up following randomized complete block design with three replicates. The unit plot size of each experiment was 5 m × 4 m. Normal cultural practices like application of fertilizers, weeding and pesticides etc. were done as and when necessary. At harvest, 10 hills plot^{-1} was randomly selected for collecting necessary plant parameters. Grain yield plot^{-1} was finally converted into tons ha^{-1}.

Results revealed that the variety Binadhan-6 was the tallest and the Irratom-24 was the shortest in height (Table 6). Significantly higher number of effective tillers hill^{-1} and filled grains panicle^{-1} was recorded in Binadhan-6 and Irratom-24 with being the highest in Irratom-24. The unfilled grain production was greater in Binadhan-8 and Binadhan-10 than Binadhan-6 and Irratom-24. The grain size was significantly larger in Binadhan-6 and Irratom-24 than in Binadhan-8 and Binadhan-10 with being the largest in Binadhan-6 although this difference was not significant. Similarly, significantly higher harvest index was observed in Binadhan-6 and Irratom-24 than Binadhan-8 and Binadhan-10. Considering unfilled grains production over locations, results indicated that unfilled grain number in all the varieties was lower at Satkhira than Rajshahi and Rangpur (Table 7). Similarly, Crop duration of all varieties was significantly shorter at Satkhira (132 days) than Rajshahi (140 days) and Rangpur (144 days) might be due to shorter winter duration in the southern part, Satkhira than the north-west part of Bangladesh, Rajshahi and Rangpur.

The grain yield of the varieties ranged from 6.0 to 7.92 t ha^{-1} (Table 8). Considering yield performance of each variety over locations, results indicated that there was not much variation in yield performance of the varieties among the locations. Location-wise results showed that Irratom-24 produced the highest grain yield at Satkhira, the southern part of Bangladesh followed by Binadhan-6 with same statistical rank. In contrast, Binadhan-6 performed the best at the north-west part of Bangladesh followed by Irratom-24. Lower grain yield was recorded in Binadhan-8 and Binadhan-10 at all locations. Crop duration of all varieties at different locations ranged 123-158 days.

Table 6. Means of morphological and yield contributing characters of four *Boro* rice varieties conducted at three locations during 2013-14

Variety	Plant height (cm)	Effective tillers hill^{-1} (no.)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)	Harvest index (%)
Binadhan-6	121.1 a	11.60 a	144.0 a	21.0 c	28.63 a	52.5 a
Binadhan-8	98.80 c	9.84 b	123.5 b	24.0 b	25.69 c	48.1 b
Binadhan-10	108.7 b	10.38 b	126.3 b	27.3 a	26.18 bc	47.5 b
Irratom-24	83.30 d	11.72 a	150.4 a	20.3 c	27.97 ab	54.2 a
CV (%)	3.85	10.39	7.67	8.32	2.92	8.17

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Table 7. Effect of locations on unfilled grains production and crop duration of four Boro rice varieties grown at three locations during 2013-14

Varieties	Number of unfilled grains panicle^{-1}			Days to maturity		
	Satkhira	Rajshahi	Rangpur	Satkhira	Rajshahi	Rangpur
Binadhan-6	13.1 c	25.0 b	26.0 bc	149 a	157 a	158 a
Binadhan-8	20.0 b	24.1 b	30.1 ab	125 b	130 c	133 c
Binadhan-10	25.0 a	32.3 a	32.7 a	123 b	128 c	130 c
Irratom-24	14.7 c	24.0 b	24.0 c	148 b	150 a	155 a
CV (%)	13.05	10.11	8.46	0.32	0.92	0.77

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Table 8. Grain yields and days required to maturity of four Boro rice varieties conducted at farmers' field of three locations during 2013-14

Varieties	Grain yield (t ha^{-1})				Crop duration (days)
	Satkhira	Rangpur	Rajshahi	Mean	
Binadhan-6	7.23 a	7.77 a	7.92 a	7.85 a	155 a
Binadhan-8	6.00 b	7.02 c	6.45 c	6.46 c	129 d
Binadhan-10	6.17 b	6.12 d	6.15 c	6.45 c	127 d
Irratom-24	7.77 a	7.05 b	6.94 b	7.40 ab	151 b
CV (%)	4.36	7.20	6.66	8.93	1.85

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Screening of lentil mutants in respect of morphological attributes and yield

The experiment was conducted during winter season of 2013-14 at two locations *viz.,* BINA farm, Magura and Ishurdi sub-stations with thirty one lentil mutants following randomized complete block design with three replications. The unit plot size was 1 m × 1.5 m. Row to row and plant to plant distances were 30 cm and 5-7 cm, respectively. Urea, triple superphosphate and muriate of potash were applied at the rate of 40, 120 and 80 kg ha^{-1}, respectively at the time of final land preparation. Proper cultural practices were followed as and when necessary. Data on plant height, branch number, yield and yield attributes were recorded at harvest from 10 randomly selected plants in each plot and seed yield was taken from the whole plot and converted into kg ha^{-1}.

Results showed that nine mutants were taller (range 36.0-37.8 cm) while three mutants were shorter (range 29.3-32.2 cm) (Table 9). However, high yielding mutants, in general, had higher number of branches plant^{-1} than the low yielding ones. Bold seeded mutants produced fewer pods plant^{-1} than the small and medium seeded ones with no significant difference in number of seeds pod^{-1}. Two mutants out of thirty one produced significantly higher seed yield plant^{-1} with being the highest in N_1I-123 (2.60 g) due to the production of higher number of pods plant^{-1}. In case of mean seed yield hectare^{-1} over locations, the highest seed yield was recorded in N_1I-123 (1560 kg ha^{-1}) followed by E_3I-803 (1313 kg ha^{-1}). However, no mutant had consistent higher seed yield over locations. Considering location effect, results indicated that most of the mutants performed better at Ishurdi in case of growth, yield attributes and yield than at Magura.

Table 9. Mean performance of thirty one lentil genotypes over locations on morphological, yield attributes and yield conducted during winter season of 2013-14

Treatment	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed wt. plant^{-1} (g)	Seed weight ha^{-1} (kg)		
							Magura	Ishurdi	Mean
Genotype									
N_1I-101	36.0	3.50	52.4	1.47	16.93	1.47	1122	642	882
N_1I-109	32.2	3.50	66.4	1.57	18.00	1.81	1302	876	1089
N_1I-123	34.7	3.85	91.7	1.63	17.55	2.60	2028	1092	1560
N_2I-206	33.7	3.08	71.1	1.57	18.98	2.14	1638	930	1284
N_2I-210	36.1	3.13	49.2	1.57	17.63	1.56	1326	552	939
N_2I-211	34.4	3.30	79.1	1.60	15.68	1.93	1266	1050	1158
E_5M-229	37.4	3.63	72.7	1.73	16.59	2.02	1224	1200	1212
N_2M-231	33.5	3.07	86.7	1.57	16.43	2.11	1506	1026	1266
N_3I-321	36.0	3.53	67.1	1.60	14.97	1.96	948	1404	1176
N_2M-338	34.2	2.87	71.9	1.53	16.00	1.38	990	660	825
N_4I-413	36.9	3.48	87.3	1.57	15.93	2.08	1044	1452	1248
N_4M-423	35.9	3.00	61.6	1.50	16.32	1.87	1326	918	1122
N_5I-504	29.3	2.73	56.4	1.57	18.45	1.72	840	1218	1029
N_5M-539	33.3	3.03	53.2	1.57	16.60	1.57	912	978	945
N_5M-555	33.2	3.17	54.7	1.57	17.25	1.54	822	1026	924
N_5M-568	35.5	3.70	61.5	1.53	16.18	1.69	942	1086	1014
E_1M-622	36.4	3.17	60.7	1.57	17.22	1.78	894	1248	1071
E_1M-626	33.1	3.65	59.6	1.57	16.43	1.79	876	1266	1071
E_2M-711	35.7	4.07	71.7	1.57	18.18	2.00	726	1674	1200
E_2I-714	36.9	3.90	72.7	1.50	15.58	1.66	840	1152	996
E_2M-719	33.6	2.68	78.5	1.53	16.47	1.85	870	1356	1113
E_2M-727	32.6	3.17	73.9	1.60	15.92	1.54	822	1032	927
E_2M-752	35.5	3.60	80.2	1.57	17.85	1.91	1068	1224	1146
E_3I-803	35.2	4.83	101.3	1.57	15.45	2.42	1092	1434	1313
E_2M-835	30.8	2.98	67.2	1.57	17.70	1.80	1056	1104	1080
E_4I-723	35.7	2.93	78.5	1.57	17.28	2.10	1044	1474	1259
E_4I-931	33.9	2.63	78.2	1.57	15.81	1.64	696	1272	984
E_5M-1020	34.3	3.20	54.6	1.53	15.85	1.37	738	960	849
E_5M-1027	37.8	2.63	52.0	1.53	15.92	0.99	570	624	597
IC-4414	33.1	2.95	54.3	1.57	17.37	1.66	996	996	996
IC-44202	37.3	3.70	76.2	1.57	15.88	1.99	1104	1290	1197
LSD $_{(0.05)}$	2.11	0.37	5.55	0.17	1.00	0.33	88.2	95.5	91.4
Range	29.3-37.8	2.63-4.83	49.2-101.3	1.47-1.73	14.97-18.98	0.99-2.60	570-2028	552-1684	597-1560
Location									
Magura	32.5	2.85	56.1	1.56	17.98	1.75	1022	---	---
Ishurdi	36.8	3.77	82.1	1.57	15.46	1.93	1101	---	---
LSD $_{(0.05)}$	1.87	0.30	5.01	0.13	0.87	0.28	71.7		

Morpho-physiological evaluation of selected lentil mutants

The experiment was conducted during winter season of 2013-14 at two locations *viz.,* BINA farm, Magura and Ishurdi sub-stations with sixteen lentil mutants along with one check variety following a randomized complete block design with three replications. The unit plot size was 1.5 m × 1.5 m. Row to row and plant to plant distances were 30 cm and 5-7 cm, respectively. Urea, triple superphosphate and muriate of potash were applied at the rate of 40, 120 and 80 kg ha^{-1}, respectively at the time of final land preparation. Proper cultural practices were followed as and when necessary. Data on plant height, branch number, yield and yield attributes were recorded at harvest from 10 randomly selected plants in each plot and seed yield was taken from the whole plot and converted into kg ha^{-1}.

Results indicated that there was no much variation in plant height among the sixteen mutants/ genotypes ranging from 36.9 cm to 43.4 cm (Table 10). High yielding genotypes, in general, had higher number of branches $plant^{-1}$ than the low yielding ones. Bold seeded genotypes produced fewer pods $plant^{-1}$ than the small and medium seeded ones with no significant difference in number of seeds pod^{-1}. The highest seed yield $plant^{-1}$ was recorded in N_4M-540 (3.49 g) followed by Binamasur-4 (2.88 g). In contrast, the lowest seed yield $plant^{-1}$ was observed in E_2M-728 (1.50 g) due to production of fewer pods $plant^{-1}$. In case of mean seed yield $hectare^{-1}$ over locations, the highest seed yield was also observed in N_4M-540 (2091 kg ha^{-1}). This mutant also performed consistent higher seed yield over locations. The second highest seed yield was recorded in Binamasur-4 (1728 kg ha^{-1}). Considering location effect, results indicated that most of the genotypes performed better at Ishurdi in case of growth, yield attributes and yield than at Magura.

Table 10. Mean performance of sixteen lentil mutants/variety over locations on morphological, yield attributes and yield conducted during winter season of 2013-14

Treatment	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Seed $spod^{-1}$ (no.)	1000-seed weight (g)	Seed weight $plant^{-1}$ (g)	Seed weight ha^{-1} (kg)		
							Magura	Ishurdi	Mean
Genotype									
N_4M-412	39.1 bc	3.67 b	90.6 b	1.53^{ns}	17.55 b	2.48 c	1360 e	1618 b	1489 cd
E_5M-501	40.3 b	3.58 b	83.8 c	1.53	18.25 a	2.29 d	1030 h	1712 a	1371 e
N_4M-540	40.8 b	4.43 a	92.5 b	1.47	17.47 c	3.49 a	2528 a	1654ab	2091 a
N_5M-546	38.4 c	2.88	68.7 d	1.53	16.76 d	1.83 e	786 i	1416 d	1101 f
N_5M-560	41.5ab	3.52 b	105.4 a	1.53	15.27 f	2.45 cd	1421 d	1510 cd	1466 cd
N_4I-925	43.4 a	3.27 c	71.6 d	1.57	17.37 c	2.37 cd	1450 d	1388 e	1419 d
E_3I-316	38.1 c	3.32 c	89.3 b	1.57	17.07 c	2.58 c	1560 c	1532 c	1546 c
E_4M-819	39.2 bc	3.57 b	92.0 b	1.63	17.82 b	2.50 c	1427 d	1572 bc	1500 c
E_5M-1026	40.9 b	3.12 d	85.7 c	1.53	16.10 e	2.32 d	1184 g	1596 bc	1390 e
E_2M-728	37.6 cd	2.88 d	53.3 e	1.63	16.60 d	1.50 f	1044 h	760 i	902 g
E_2M-720	36.5 d	3.35 c	72.7 d	1.60	16.60 d	1.87 e	1269 ef	972 h	1121 f
IC-44251	42.2 ab	3.33 c	91.2 b	1.57	17.63 b	2.33 d	1266 ef	1532 c	1399 e
N_3M-320	40.2 b	2.90 d	72.4 d	1.53	16.20 e	1.90 e	1020 h	1264 f	1142 f
N_4I-411	43.4 a	3.02 c	82.7 c	1.57	18.52 a	2.42 d	1331 e	1568 c	1450 cd
N_4I-404	40.3 b	3.12 c	85.3 c	1.47	17.15 c	2.41 d	1808 b	1082 g	1445 d
Binamasur-4	43.4 a	3.87 b	94.3 b	1.60	17.23 c	2.88 b	1830 b	1626 b	1728 b
Location									
Magura	35.5 b	2.68 b	73.8 b	1.54^{ns}	17.98 a	2.38 ^{ns}	1394	---	
Ishurdi	45.2 a	4.05 a	92.6 a	1.55	16.42 b	2.53	1455	---	
CV (%)	4.46	7.80	9.99	2.31	3.30	6.88	4.57	8.10	6.30

In a column, within treatment, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Morpho-physiological evaluation of selected summer mungbean mutants

The experiment was conducted during Kharif-I season of 2014 at two locations *viz.,* BINA sub-stations, Magura and Ishurdi with three mungbean mutants along with two check varieties following a randomized complete block design with three replications. The unit plot size was 3 m × 2.0 m. Row to row and plant to plant distances were 30 cm and 10 cm, respectively. Urea, triple superphosphate and muriate of potash were applied at the rate of 40, 120 and 80 kg ha^{-1}, respectively at the time of final land preparation. Proper cultural practices were followed as and when necessary. Data on plant height, branch number, seed yield and yield attributes were recorded at harvest from 10 randomly selected plants in each plot and seed yield was taken from the whole plot and converted into kg ha^{-1}.

Results indicated that Binamoog-7 was the tallest (50.3 cm) of all the mutants/varieties while the mutant MB 1 was the shortest (38.9 cm) of all (Table 11). Other three mutants had medium plant height (range 42.8-44.2 cm). The highest number of branches plant^{-1} was recorded in Binamoog-7 and the lowest was in MB 1. However, branch number had no relation with seed yield in mungbean. Bold seeded mutants produced significantly lower number of pods plant^{-1} than the small seeded ones. Results further indicated that the mutants did not out yield the two check varieties. Five mutants/varieties out of six produced higher seed yield plant^{-1} with being the highest in Binamoog-8 (6.59 g) due to the production of bolder seeds. In case of mean seed yield hectare^{-1} over locations, result showed that Binamung-8 produced the highest seed yield (1.67 t ha^{-1}) followed by Binamoog-7 (1.52 t ha^{-1}) with same statistical rank. The lowest seed yield was recorded in Binamoog-7 (1.14 t ha^{-1}).

Table 11. Mean performance of six mungbean mutants/varieties over locations on morphological, Yield attributes and yield conducted during Kharif-I, 2014

Genotype	Plant height (cm)	Branches plant^{-1} (no.)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no)	1000-seed weight (g)	Seed weight plant^{-1} (g)	Seed yield (kg ha^{-1})		
								Magura	Ishurdi	Mean
MB 1	38.9 c	1.20 c	17.7 c	8.55 a	10.1 b	42.42 a	5.77 b	1.56 ab	1.18 bc	1.37 b
MB 2	43.3 b	1.27 c	21.0 b	8.23ab	10.7 a	37.30 b	6.38 a	1.54 ab	1.23 bc	1.39 b
MB 13	44.2 b	1.40 b	21.9 b	8.31ab	11.1 a	39.25 b	6.33 a	1.49 b	1.26 bc	1.38 b
MB 17	42.8 bc	1.70 b	22.0 b	8.03 b	10.8 a	37.10 b	6.53 a	1.59 ab	1.25 bc	1.42 b
Binamoog-7	50.3 a	2.20 a	27.0 a	6.32 c	10.7 a	24.81 c	6.42 a	1.65 ab	1.38 b	1.52 ab
Binamoog-8	40.0 c	1.40 b	18.2 c	8.53 a	10.8 a	43.81 a	6.59 a	1.73 a	1.60 a	1.67 a
CV (%)	4.11	10.98	7.57	2.50	3.20	3.06	5.81	7.70	6.05	6.78

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.

Effect of foliar application of chitosan on yield of Binatomato-6 and Binatomato-7

The experiment was conducted at BINA sub-station Ishurdi durng the period from November 2013 to April 2014 to investigate the effect of different levels of chitosan on yield and yield contributing characters of two tomato varieties, Binatomato-6 and Binatomato-7. Five concentrations *viz.*, 0, 50, 75, and 100 ppm were sprayed at vegetative and reproductive stages. In control, water was sprayed as per treatment. The experiment was laid out in randomized complete block design with 3 replicates. The unit plot size was 4 m × 3 m and spacing was 50 cm × 50 cm. Recommended intercultural operations were done as when as required.

The foliar application of chitosan had significant effects on plant parameters except fruit size (Table 12). Significant variations was not found among the treatments in respect of fruit size and fruit yield whereas 100 ppm showed taller plant and 50 ppm showed higher branch and number of fruits. Average effect of treatments on Binatomato-7 showed better performance in most of the parameters. From the interaction effect of variety and chitosan, it was observed that Binatomato-7 produced the highest fruit yield (61.13 t ha^{-1}) when chitosan applied at the rate of 75 ppm followed Binatomato-6 at 25 ppm and Binatomato-7 at 50 ppm (Table 13). Therefore, 75 ppm chitosan may be applied to increase fruit yield of tomato.

Table 12. Effects of chitosan on morphological characters, yield attributes and fruit yield of Binatomato-6 and Binatomato-7

Treatment	Plant height (cm)	Branches $plant^{-1}$ (no.)	Fruits $plant^{-1}$ (no.)	Single fruit weight (g)	Yield (t ha^{-1})
Concentration (ppm)					
0	79.50 c	3.39 bc	24.00 ab	56.91	52.43
25	85.65 ab	3.01 c	22.03 b	58.26	52.82
50	82.70 bc	4.11 a	26.68 a	57.16	55.27
75	82.10 bc	3.32 bc	22.77 b	60.81	56.17
100	87.39 a	3.94 ab	20.61 b	57.94	48.73
Level of sig.	**	**	*	ns	ns
Variety					
Binatomato-6	57.44 b	4.11 a	22.92	55.81 b	50.91 b
Binatomato-7	109.49 a	3.01 b	23.51	60.63 a	55.25 a
Level of sig.	**	**	ns	**	*
CV%	3.89	15.03	12.50	8.62	11.56

In a column, within treatment, means followed by same letter(s) do not differ significantly at 5% level by DMRT.
*, ** indicate significant at 5% and 1% levels of probability, respectively.

Table 13. Interaction effect of foliar application of chitosan on Binatomato-6 and Binatomato-7

Interaction		Plant height (cm)	Branches $plant^{-1}$ (no.)	Fruits $plant^{-1}$ (no.)	Single fruit weight (g)	Yield (ton ha^{-1})
Variety	**Chitosan (ppm)**					
Binatomato-6	0	55.22 f	4.00 b	21.89 e	55.25 d	47.60 d
	25	60.78e	3.67 cd	24.17 c	57.62 bcd	58.57 ab
	50	54.67 f	4.45 a	28.78 a	51.93 e	52.00 c
	75	56.21 f	3.99 b	22.33 de	57.84 bcd	51.20 c
	100	60.33 e	4.44 a	17.45 g	56.40 cd	45.20 d
Binatomato-7	0	103.8 d	2.78 e	26.11 b	58.57 bc	57.27 b
	25	110.5 b	2.37 f	19.89 f	58.91 bc	47.07 d
	50	110.7 b	3.79 bc	24.58 bc	62.39 a	58.53 ab
	75	108.0 c	2.67 e	23.20 cde	63.78 a	61.13 a
	100	114.4 a	3.45 d	23.78 cd	59.48 b	52.27 c
Level of significance		*	*	**	*	*
CV (%)		3.89	15.03	12.50	8.62	11.56

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.
*, ** indicate significant at 5% and 1% levels of probability, respectively.

Effect of foliar application of chitosan on yield of mungbean

The experiment was conducted at Ishurdi, Bangladesh Institute of Nuclear Agriculture during March to May 2014 to investigate the response of mungbean to different concentrations of chitosan on yield and yield contributing characters. Five different concentrations of chitosan *viz.,* 0, 25, 50, 75 and 100, were sprayed at vegetative and reproductive stages of two mungbean varieties, Binamoog-7 and Binamoog-8. In control, water was sprayed as per treatment**.** The experiment was laid out in randomized complete block design with 3 replicates. The unit plot size was 2 m × 3 m and plant spacing was 30 cm × 10 cm. Recommended cultural practices were done as when as necessary. The grain yield was recorded on plot basis and converted to kg ha^{-1}.

The influence of foliar application of chitosan on plant height, number of branches $plant^{-1}$ and seeds pod^{-1}, 100-seed weight and seed weight $plant^{-1}$ as well as seed yield was significant but pod production and pod size was not significantly influenced by chitosan (Table 14). Results indicated that seed yield was greater in chitosan applied plants than control. The highest seed yield both per plant and per hectare was recorded in 75 ppm followed by 50 ppm chitosan due to production of higher pods $plant^{-1}$. Between the two varieties Binamoog-8 showed higher yield performance due to bolder seed size.

Table 14. Effect of foliar application of chitosan on morphological characters, yield and yield attributes of mungbean

Treatment	Plant height (cm)	Branchesplant^{-1} (no.)	Pods plant^{-1} (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed wt. plant^{-1} (g)	Yield (t ha^{-1})
Concentration (ppm)								
0	42.00 a	0.633	14.87	7.10	10.27 b	31.08 b	3.32 d	2.71 b
25	38.78 b	0.933	15.18	7.37	10.07bc	32.33ab	3.75 c	2.84 ab
50	42.70 a	1.783	15.07	7.37	10.40ab	30.13 c	3.90 b	2.88 ab
75	41.87 a	0.983	15.70	7.20	11.17 a	32.50 a	4.16 a	3.20 a
100	42.33 a	1.033	15.37	7.27	9.43 c	32.70 a	3.89 b	2.88 ab
Level of sig.	**	*	ns	ns	**	*	**	*
Variety								
Binamoog-7	46.69 a	1.85 a	18.09 a	6.35 b	9.73 b	25.69 b	3.75 b	2.74 b
Binamoog-8	36.38 b	0.86 b	13.26 b	8.17 a	10.4 a	38.81 a	4.05 a	3.09 a
Level of sig.	**	**	**	**	*	**	*	*

In a column, within treatment, means followed by same letter(s) do not differ significantly at 5% level by DMRT.
*, ** indicate significant at %% and 1% level of probability, respectively; ns, Not significant.

The interaction effect of different levels of chitosan and variety showed significant variations in respect of plant height, pod number $plant^{-1}$, seeds $pod^{-1}$and seed weight $plant^{-1}$ (Table 15). In both varieties, foliar application of chitosan @ 75 ppm produced higher seed weight $plant^{-1}$ consequently seed yield (t ha^{-1}) due to higher seeds pod^{-1} and pod number $plant^{-1}$. In crux, the seed yield of Binamoog-7 and Binamoog-8 accelerated by spraying chitosan @ 75 ppm.

Table 15. Interaction of variety and concentration of chitosan on yield and yield components of mungbean varieties

Variety	Conc. (ppm)	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Pod length (cm)	Seeds pod^{-1} (no)	1000-seed weight (g)	Seed wt. $plant^{-1}$ (g)	Yield (t ha^{-1})
Binamoog-7	0	46.20 bc	0.77	17.27 ab	6.07	9.80 b	26.37 f	2.89 g	2.65
	25	41.07 d	1.23	16.33 b	6.53	9.93 b	24.90 g	3.63 f	2.72
	50	45.80 c	1.13	16.47 b	6.53	10.33 ab	24.60 h	3.71 ef	2.76
	75	48.80 b	1.43	17.67 a	6.27	10.73 ab	26.40 e	4.25 ab	2.92
	100	51.60 a	1.67	17.73 a	6.33	7.87 c	26.17 f	3.75 ef	2.67
Binamoog-8	0	37.80 ef	0.50	12.67 d	8.13	10.73 ab	35.80 d	3.75 ef	2.98
	25	36.50 f	0.63	14.03 c	8.20	8.20 c	39.77 b	3.88 de	2.97
	50	39.60 de	2.43	13.67 cd	8.20	10.47 ab	37.67 c	4.08 c	3.00
	75	34.93 fg	0.33	12.93 d	8.13	11.60 a	41.60 a	4.51 a	3.43
	100	33.07 g	0.40	13.00 d	8.20	11.00 ab	39.23 b	4.04 bc	3.08
Level of sig.		**	ns	**	ns	**	ns	**	ns

In a column, means followed by same letter(s) do not differ significantly at 5% level by DMRT.
** indicates significant at 1% level of probability; ns, Not significant.

SOIL SCIENCE DIVISION

RESEARCH HIGHLIGHTS

Evaluation of soil characters showed site-specific variations and changes in practicle size distribution (sand, silt and clay), soil pH, organic carbon, total nitrogen, available phosphorus and exchangeable cation (Ca, K and Na) contents in the selected soils of North-West Bangladesh during the period between 1977 and 2012, which might be due to the differential management practices fallowed at the farm level.

Assessment of arsenic contents showed wide variations among the soil (3.62-17.83 mg kg^{-1}) and water (2.75-245 µg l^{-1}) samples and arsenic contaminated sites were found in Ganges River Floodplains of South-West Bangladesh.

From the experimental results of T.aman rice, the highest yield and nutrient uptake were observed in T_6 treatment where an increase of 25% NPK nutrients applied over STB (T_1) with few exceptions. The highest tuber yield (25.5 t ha^{-1}) of potato at Debigonj (Panchagar), wheat grain yield (3.63 t ha^{-1}) at Atgharia (Pabna) and garlic (8.93 t ha^{-1}) on zero tillage at Baraigram (Natore) were recorded in treatment T_6 (T_1 + 25% NPK) during Rabi season of 2013-14. Results of partial budget analysis of different cropping patterns demonstrated differential benefits from different locations. The changes in soil pH, organic matter and different plant nutrients due to the use of different doses of fertilizers in different cropping patterns showed little change at different locations within 2 (two) years.

Combination of organic manure and chemical fertilizer was found better for higher crop production. The treatment T_5 [Fertilizer for HYG + CD (5t ha^{-1}) based on IPNS] was found the best and produced the highest grain yield of Binadhan-8. It also noted that chemical fertilizer dose in treatment T_5 ($N_{160}P_{30}K_{60}S_{18}$) along with cowdung (5 t ha^{-1}) was the best treatment for the highest grain yield.

Economic doses of nutrients for four mutant lines of Boro rice were determined and $N_{150}P_{28}K_{70}S_{20}Zn_2B_1$ nutrients dose was found suitable for higher production of mutants lines at Mymensingh.

Economic nutrients doses for soybean mutants were determined and the dose $N_{40}P_{35}K_{56}S_{24}Zn_2B_1$ was found suitable for higher production of mutant lines at Magura. In case of Binatil-3, the dose $N_{90}P_{25}K_{48}S_{20}Zn_2B_1$ was found suitable for higher production of mutant lines at Magura.

There was ample scope for increasing the yield of tomato and cabbage through the use of organic fertilizers along with recommended inorganic fertilizers based on integrated nutrient management approaches. The uses of organic fertilizers are capable of reducing 15-30% of the recommended chemical fertilizers and can increase the yield up to 25% depending on location.

In saline area of Satkhira districts, rice straw could be used to reduce the effect of salinity as well as to increase organic matter for higher production.

In drought prone areas, application of nitrogen fertilizer was applied 180 kg ha^{-1} with three equal splits (during crown root initiation, flag leaf and anthesis stage) gave the highest grain and straw yield (5.17 and 8.37 tha^{-1}, respectively) of wheat.

In saline area, the highest rice yield was observed when the seedlings were transplanted in a single row sloping bed approaches under continues flooding condition. From July-October the soil salinity status of Noakhali (Subarnachar and Hazirhat) was found minimum (2-3 dSm^{-1}). After the month of October, it gradually increases and the maximum soil salinity (up to 9-10 dSm^{-1}) was observed during the month of April.

Application of additional Gypsum (175 $kgha^{-1}$) and Potassium (40 $kgha^{-1}$) along with the recommended doses of N, P, K, S & Zn, the highest rice yield was recorded in saline area under continuous flooding situation.

Lowland and very lowland are the efficient resourver for carbon sequestration in soil.

The level of *As* from few districts showed that 27.3% DTW water contain >200 ppb As, 47.7% contain >50 ppb *As* and 52.3% water contain *As* below risk limit (<50 ppb). 26.1% STW water contain >200 ppb *As*, 41.3% contain >50 ppb *As* and 32.6% water contain *As* below risk limit (<50 ppb). 28.0% HTW water contain >200 ppb *As*, 20.7% contain >50 ppb *As* and 51.2% water contain *As* below risk limit (<50 ppb). The highest DTW water *As* (474.4 ppb) was recorded from west aliabad, Faridpur sadar, Faridpur, the highest STW water *As* (619.5 ppb) was found in Vadulia, Ratail union, Kashiani upazilla, Gopalgonj district and the highest HTW water *As* (905.08 ppb) was found in Choto krisnopur, Bhangabazar union, Zajira upazilla, Shariatpur district.

FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$) was distributed into different soil depth with decreasing trend with the increasing soil depth. Soil eroded from summit and upper slope positions by 24.93 and 6.33 $tha^{-1}yr^{-1}$, respectively and deposited on middle slope position (10.21 t ha^{-1} yr^{-1}), lower slope position (38.34 t ha^{-1} yr^{-1}), and bottom position (51.26 t ha^{-1} yr^{-1}). The gross erosion rate was 5.2 t ha^{-1} yr^{-1}.

Application of chemical fertilizer with cowdung seems to be better for T. aman, cabbage and boro rice production as well as maintaining good soil health.

Application of micronutrients like Mg, Zn and B in soil produced 3.6-20.7 % higher grain yield at BINA substation farm, Rangpur as well as in farmer's field, Birgonj and Dinajpur. Increased micronutrient content in grain and straw of wheat was also recorded with the application of micronutrients.

In Binadhan-14, 17 - 21% grain yield was found to be increased by applying plant growth promoting rhizobacteria (PGPR) biofertilizer.

50% P from TSP + Phosphatic biofertilizer gave comparable seed yields of mustard to the 100% P from TSP alone.

Phosphatic biofertilizer with 50% P from TSP could be used for cultivation of summer mungbean as an alternative of 100% P from TSP.

A superior rhizobial strain for lentil inoculation has identified by field evaluation at Magura Sub-station, BINA.

Three new rhizobial species have identified in Bangladesh by molecular characterization of rhizobia from lentil root nodules.

SOIL MANAGEMENT AND BIOFERTILIZER

Evaluation of soil characters for assessment of land degradation situation in Bangladesh

A study was initiated to evaluate the changes in soil characters over time for the assessment of land degradation situation in Bangladesh. The study was based on those soils selected by Ali et al. (1977). Based on those previous sites, soil samples from the same sites/series were collected during June 2012. The sampled soils covered part of the Old Himalayan Piedmont Plain and Tista Meander Floodplain Soils and a brief description of the soils are presented in Table 1.

Table 1. Description of the soils in terms of morphology and land uses

Soil series	AEZ	Land type	Cropping pattern/Present land use
Atwari	Old Himalayan Piedmont Plain (AEZ 1)	Highland	Wheat/vegetables - T. aman
Baliadangi	,,	,,	Wheat/Boro - T. aman
Ruhea	,,	,,	Boro/vegetables - T. aman
Panchagar	,,	,,	Wheat/Groundnut - T. aman
Mithapukur	Tista Meander Floodplain (AEZ 3)	,,	Jute/ Boro- T.aman

The soil samples were collected from 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-75 cm depths from each location and taken to the laboratory for physical and chemical analysis. The soils were then dried at room temperature, processed and passed through 10 mm sieve and stored for analysis. The soil samples were analyzed following standard methods, viz.: particle size distribution by hydrometer method, soil pH by glass electrode pH meter, organic carbon by wet oxidation and total nitrogen by Micro-Kjeldahl method, available phosphorus was extracted from the soil by dilute acid solutions. Exchangeable calcium (Ca), potassium (K) and sodium (Na) were determined by ammonium acetate extraction method. In this method, soil sample was saturated with NH_4Oac solution and the supernatant clear solution was separated and collected. The NH_4OAC solution was added again to make the final volume up to 100 ml for each sample. For the exchangeable cation of Ca^{++}, K^+ and Na^+ the flame photometer was separately adjusted and different standard curves were prepared to find out the concentration of the cation but the extracting solution used for each sample was same. From each reading the concentration of each ion was obtained from their respective standard curves and was expressed as me %.

RESULTS AND DISCUSSION

Changes in particle size distribution

Table 2 shows the changes in particle size distribution (sand, silt and clay contents) of the studied soils during the period between 1977 and 2012 in AEZs 1 and 3. Changes in the particle size distribution showed a decline in the clay and silt contents in favour of the sand contents in all the surface soils except the silt contents of Atwari series. However, the highest decrease in clay content of 31.3% was observed in the Ruhea series soils and that of the lowest decrease of 14% was observed in the Mithapukur series soils (Table 2).

Table 2. Changes in sand, silt and clay content in different soils during the period between 1977 and 2012

Soil series	Depth	%sand			%silt			%clay		
	(cm)	1977	2012	% changes	1977	2012	%changes	1977	2012	%changes
Atwari	0-15	66	71	+7.5	16	14	-12.5	18	15	-16.7
	15-30		65			20			11	
	30-45		62			24			14	
Baliadangi	0-15	67	74	+10.5	18	13	-27.8	15	13	-13.3
	15-30		63			24			11	
	30-45		60			25			15	
Ruhea	0-15	65	72	+10.8	19	17	-10.5	16	11	-31.3
	15-30		78			12			10	
	30-45		69			21			10	
Panchagar	0-15	58	64	+10.3	22	20	-9.09	20	16	-20.0
	15-30		60			28			12	
	30-45		64			26			10	
Mithapukur	0-15	34	41	+20.6	39	36	-7.69	27	23	-14.0
	15-30		66			20			14	
	30-45		62			24			14	

Changes in soil pH, organic carbon and total N contents

The soil pH of Old Himalayan Piedmont Plain (AEZ-1) and Tista Meander Floodplain (AEZ-3) were acidic to slightly acidic in reaction. Table 3 shows the changes in pH values of different soils of AEZs 1 and 3 during the period between 1977 and 2012. Changes in pH values showed a decline in all of the sampled horizons of the soil profiles under study. However, the highest decrease in pH values of 21% was observed in the surface layer of Atwari series and that of the lowest decrease of 0.81% was observed in the Mithapukur series soils (Tables 3). The decline in pH values of different soils was mainly due to the differences of the farm management practices fallowed in the study areas.

Changes in organic carbon contents showed general decrease in the surface layers of all the sampled soil series but showed general trand in increase in the 15-30 cm layers of all the soils except Panchagar.

Table 3 showed the changes in the total N contents of the soils during the period between 1977 and 2012. Changes in total N contents showed an increase in the soils of Atwari, Baliadangi and Mithapukur. A decrease was also observed in the soils of Ruhea and Panchagar under study (Table 3).

Table 3. Changes in soil pH, organic C and total N in different soils during the period between 1977 and 2012

Soil series	Depth (cm)	pH			Organic C (%)			Total N (%)		
		1977	2012	% changes	1977	2012	% changes	1977	2012	% changes
Atwari	0-15	5.9	4.66	-21.0	1.29	1.45	-11.6	0.13	0.15	+15.4
	15-30		4.78		0.86	1.37	+5.81	0.09	0.13	+44.4
	30-45		5.02		0.54	1.06	-27.5	0.06	0.09	+50.0
Baliadangi	0-15	6.0	5.06	-15.7	1.05	1.22	-54.2	0.09	0.10	+11.1
	15-30		4.66		0.93	1.00	+7.53	0.06	0.09	+50.0
	30-45		4.87		0.59	0.78	-18.7	0.07	0.05	-28.6
Ruhea	0-15	5.9	4.90	-17.0	1.07	1.62	-57.0	0.13	0.12	-7.69
	15-30		4.60		0.83	1.24	+37.4	0.11	0.11	0.0
	30-45		4.78		0.55	0.84	-7.27	0.08	0.06	-25.0
Panchagar	0-15	6.1	5.10	-16.4	1.57	1.25	-20.4	0.20	0.12	-40.0
	15-30		4.88		1.25	0.95	+9.6	0.17	0.08	-52.9
	30-45		4.62		1.09	0.68	-18.4	0.12	0.08	-33.3
Mithapukur	0-15	6.2	6.15	-0.81	0.51	1.49	-13.7	0.06	0.12	+66.7
	15-30		5.89		0.41	0.98	+39.0	0.05	0.13	+60.0
	30-45		5.68		0.34	0.55	-20.6	0.04	0.09	+50.0

Changes in exchangeable cations (Ca, K and Na) content

Table 4 showed the changes in exchangeable cation (Ca, K and Na) contents of the soils in AEZs 1 and 3. Changes in the exchangeable Ca contents showed an increase in the soils of Atwari, Panchagar and Baliadangi soils but showed a decrease in the Ruhea and Mithapukur series soils during the period between 1977 and 2012. However, the highest increase in the exchangeable Ca contents of 116% was observed in the surface layer of Panchagar series soils and that of the lowest decrease of 2.61% was observed in the surface layer of Mithapukur series soil. Changes in the exchangeable K contents showed a general decrease in all the soils except the surface soils of Atwari (Table 4). Changes in the Mithapukur in place of Atwari exchangeable Na contents showed a general increase in all the soil series except a decrease in Atwari (Table 4).

Table 4. Changes in exchangeable Ca, K and Na content in different soils during the period between 1977 and 2012

Soil series	Depth (cm)	Exch. Ca (me%)			Exch. K (me%)			Exch. Na (me%)		
		1977	2012	%changes	1977	2012	%changes	1977	2012	% changes
Atwari	0-15	0.4	0.65	+62.5	0.25	0.23	-8.0	0.14	0.19	-35.7
	15-30	1.3	0.61	-53.1	0.28	0.25	-10.7	0.09	0.14	-55. 6
	30-45	0.4	1.16	+190	0.34	0.29	-14.7	0.45	0.18	-60.0
Baliadangi	0-15	0.5	0.63	+26.0	0.23	0.20	-13.0	0.11	0.22	+100
	15-30	0.6	0.58	-3.33	0.29	0.28	-3.45	0.11	0.16	+45.5
	30-45	1.3	2.02	+55.4	0.31	0.28	-9.68	0.10	0.11	+10.0
Ruhea	0-15	0.5	0.37	-26.0	0.27	0.20	-25.9	0.11	0.16	+45.5
	15-30	0.8	0.26	-67.5	0.37	0.27	-27.0	0.10	0.18	+80.0
	30-45	0.8	1.40	+75.0	0.38	0.32	-15.8	0.16	0.12	-25.0

Table 4 Contd.

Soil series	Depth (cm)	Exch. Ca (me %)			Exch. K (me %)			Exch. Na (me %)		
		1977	2012	%changes	1977	2012	%changes	1977	2012	% changes
Panchagar	0-15	0.5	1.08	+116	0.26	0.29	-11.5	0.12	0.16	+33.3
	15-30	0.6	0.70	+16.7	0.43	0.38	-11.6	0.16	0.24	+50.0
	30-45	0.9	1.24	+37.8	0.33	0.29	-12.1	0.14	0.18	+28.6
Mithapukur	0-15	2.3	2.24	-2.61	0.25	0.28	+12.0	0.27	0.33	+22.2
	15-30	3.0	2.29	-23.7	0.26	0.26	0.0	0.43	0.25	-41.9
	30-45	3.0	2.88	-4.0	0.21	024	-14.29	0.34	0.28	-17.7

Conclusion

The findings of this study revealed the location-specific increase or decrease in the particle size distribution (sand, silt and clay), soil pH, organic carbon, total N and exchangeable cation (Ca, K and Na) contents during the period between 1977 and 2012 in the North-West part in Bangladesh. This study suggests the importance of soil management for controlling the processes of land degradation for maintenance of soil fertility and productivity for sustainable crop production.

Assessment of arsenic contents in water and soil samples of some selected areas from Ganges River Floodplains in the South-West Bangladesh

Currently groundwater arsenic contamination is a severe problem in Bangladesh. Besides domestic use (drinking, cooking, etc.), a significant quantity of groundwater is utilized in agricultural sector, especially for irrigation. This toxic heavy metal may enter into the food chain and thus posing a significant threat to human health. Environmental degradation has become a major problem due to increase of population in Bangladesh. The situation is now more aggravating due to current ground water arsenic contamination in the country. However, no detailed information is available regarding the status of As content in soils. Therefore, present study, we try to assess the extent of arsenic contamination in water and soil samples of some selected areas from Ganges River Floodplains in the South-West Bangladesh and identify the factors regulating the As contamination in the water and soils of in Bangladesh.

The study was based on the selected sampling sites of South-Western Bangladesh. The water samples were collected from some selected shallow and deep tube wells. Only the surface soil samples were collected and analyzed for assessment arsenic contamination by groundwater. Air-dried soil samples were ground and passed through a 10 mm sieve and stored in a plastic bottle for laboratory analysis. Approximately 0.500g of air-dried soil samples were taken in a 100 ml digestion tube. Several concentrated acids are commonly utilized in acid digestion procedure. After several steps of extraction the total arsenic content was measured by hydride generation Atomic Absorption Spectrophotometer according to Loeppert (2002).

Results and Discussion

Arsenic contents of water samples in some selected areas of Ganges River Floodplains

The means and ranges of arsenic contents of water samples of five districts of South-Western Bangladesh are presented in Table 5. The means of arsenic content of water samples showed contamination at Alamdanga, Chuadanga and Kaligonj, Satkhira among the five sampled districts. However, the ranges arsenic values showed arsenic contamination in all five districts except Jhinaidah sadar. Many reports {Ali and Wakatsuki (2002), Karim et al. (1997), Ishiga et al. (2000), Nickson et al. (2000) and Asia Arsenic Network (AAN), 1999 and 2000} indicated the large variability of groundwater arsenic contamination. They observed little indication of increasing soil arsenic concentration on both local and regional scale over time because of irrigation. However, the present causes of arsenic contamination in groundwater are yet to be clearly established in Bangladesh.

Arsenic contents of water samples in some selected areas of Ganges River Floodplains

The means and ranges of arsenic contents of soil samples are presented in Table 5. The means and ranges of arsenic contents of soil samples showed contamination among the soils of five sampled districts from the South-West Bangladesh. However, Ali et al. (2003) also reported arsenic contamination in some selected soils from the Ganges River Floodplain areas. According to Vinogradov (1959) and Backer and Chesnin (1975), the natural content of arsenic in soils is 5 mg kg^{-1}, the same to Bowen (1979) with 6 mg kg^{-1}. Smith et al. (1998) reported a background arsenic level of 8 mg kg^{-1} for non-contaminated agricultural soils. However, Ali et al. (2003) proposed the background level of arsenic for the selected soil series, physiographic units and land types in Bangladesh.

Table 5. Mean and range of As in water and soils in the part of Ganges River Floodplain area

District	Number of samples	Water (μg l^{-1})		Soil (mg kg^{-1})	
		Mean	Range	Mean	Range
Sadar Meherpur	8	39.34	10.39-62.14	7.85	3.62-16.02
Alamdanga Chuadanga	10	71.79	31.92-150.45	11.08	5.06-15.73
Sharsha Jessore	9	20.33	2.75-51.35	7.99	4.58-13.60
Kaliganj Satkhira	11	53.42	7.06-244.99	8.78	4.26-17.83
Sadar Jhenaidah	9	6.72	1.86-18.06	5.79	4.09-7.45

Conclusion

This study showed arsenic contamination in both of the water and soil samples from Ganges River Floodplain of South-West Bangladesh might be due to irrigation with the arsenic contaminated groundwater in these areas.

Coordinated Project on Soil Fertility and Fertilizer Management for Crops and Cropping Patterns (SPGR funded)

Soil fertility is a dynamic property which varies with crops, cropping intensity and input use. Plant nutrients are depleting from soils due to intensive cropping with inadequate replenishment. Fertilizer use efficiency is becoming much more important in the market economy of agriculture products. Present level of fertilizer use in farmers' field shows under or over use of recommended fertilizer doses. BARC developed fertilizer recommendation guide needs to be updated every five years. Therefore, it is very important for verification of existing recommended doses of fertilizers for different crops based on soil test crop response studies by location-specific field experiments under AEZs. In the present study reported results of T. aman rice and Rabi crops experiments conducted during 2013-2014.

Field experiments were conducted at Birgonj, Dinajpur; Debigonj, Panchagarh; Kaligonj, Lalmonirhat; Pirgonj, Rangpur; Trisal, Mymensingh; Madhupur, Tangail; Atgharia, Pabna; Baraigram, Natore and Shamnagar, Satkhira districts. Randomized Complete Block Design (RCBD) was followed in the experiments with eight treatments and three replications. Applications of fertilizers were made as per treatments used. Urea was top dressed in three equal splits. Irrigation and inter cultural operations were done as and when necessary. Data on yields (grain and straw) and yield contributing characters were collected during harvesting of crops. The recorded data were statistically analyzed to find out the significance of variance and the mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Treatments

T_1 = 100% NPK (STB)	$T_5 = T_1$ + 25% PK
$T_2 = T_1$ + 25% N	$T_6 = T_1$ + 25% NPK
$T_3 = T_1$ + 25% NP	T_7 = 75% of T_1
$T_4 = T_1$ + 25% NK	T_8 = Control

Results and discussion

T. aman rice experiments during 2013

Results indicate that application of fertilizers at different proportion significantly affected both the grain and straw yields (Table 6a to Table 6b). From Table 6a, the highest grain yield was found in treatment T_6 (T_1 + 25% NPK) at Debigonj, Panchagar and Pirgonj, Rangpur and in T_3 (T_1 + 25% NP) at Birgonj, Dinajpur. Statistically identical yield was observed with treatments T_2, T_4, T_5 and T_6 at Birgonj, Dinajpur; T_2, T_3, T_4 and T_5 at Debigonj, Panchagar. The highest grain yield was observed in T_2 which was statistically identical with other treatments except T_7 and T_8 at Kaligonj, Lalmonirhat. In case of straw, the highest yield was found in treatment T_6 (T_1+25% NPK). Statistically identical yield was found in T_2, T_3, T_4 and T_5 at Birgonj, Dinajpur; T_1, T_2, T_3, T_4 and T_5 at Debigonj, Panchagar, T_4 at Pirgonj, Rangpur and in T_2 and T_4 at Kaligonj, Lalmonirhat. The lowest grain and straw yield was recorded in control treatment (T_8).

Table 6a. Effects of fertilizers on the yield (t ha^{-1}) of T. aman rice during 2013 at selected locations

Treatments	Birgonj, Dinajpur		Debigonj, Panchagarh		Pirgonj, Rangpur		Kaligonj, Lalmonirhat	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1 = 100% (STB)	4.75b	5.65bc	4.10b	4.55ab	4.56de	6.43bc	3.86ab	4.48bc
$T_2 = T_1$ + 25% N	5.10ab	6.20ab	4.27ab	4.64ab	4.70d	5.38d	4.12a	4.87ab
$T_3 = T_1$ + 25% NP	5.56a	7.06a	4.38ab	4.81ab	4.85c	6.35c	3.89ab	4.36c
$T_4 = T_1$ + 25% NK	5.15ab	6.67a	4.20ab	4.94ab	5.04b	6.88a	3.91a	4.92a
$T_5 = T_1$ + 25% PK	5.20ab	6.73a	4.18ab	4.78ab	4.42e	6.60b	3.99a	4.46bc
$T_6=T_1$+25% NPK	5.50a	7.15a	4.75a	5.24a	5.47a	7.01a	3.80ab	5.04a
T_7 = 75% of T_1	3.65c	5.00c	3.85b	4.58b	3.81f	4.99e	3.57b	3.93d
T_8 = Control	2.51d	3.71d	2.28c	3.44c	2.98g	3.35f	2.56c	2.69e
CV (%)	6.04	8.39	7.89	8.25	1.85	1.92	4.61	5.11

STB: Birgonj, Dinajpur = $N_{64}P_6K_{32}S_8$; Debigonj, Panchagarh = $N_{67}P_6K_{32}S_6$; Pirgonj, Rangpur = $N_{65}P_6K_{28}S_8$ and Kaligonj, Lalmonirhat = $N_{64}P_6K_{32}S_6$

Application of fertilizers using different combinations significantly affects the grain and straw yield of T. aman rice (Table 6b). The highest grain yield of T. aman rice was obtained from treatment T_6 (T_1 + 25% NPK) at Trisal, Mymensingh, Madhupur, Tangail and Shamnagar, Satkhira which was statistically identical with T_2 and T_3 treatments at Trisal, Mymensingh, in all other treatments except T_7 and T_8 at Madhupur, Tangail and Shamnagar, Satkhira. The straw yielded similarly as that of grain yields at these locations. However, the highest grain yield was found in treatment T_4 (T_1 + 25% NK) which differed statistically with other treatments at Atgharia, Panbna. In case of straw, the highest yield was found in treatment T_4 (T_1 + 25% NK) which also differed statistically with other treatments.

Table 6b. Effects of fertilizers on the yield (t ha^{-1}) of T. aman rice during 2013 at selected locations

Treatments	Trisal, Mymensingh		Madhupur, Tangail		Atgharia, Pabna		Shamnagar, Satkhira	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1= 100% (STB)	4.20c	5.10bc	5.0a	6.26a	4.18d	5.13d	4.33a	5.90a
$T_2 = T_1$ + 25% N	4.68ab	5.41abc	5.1a	6.57a	4.32cd	5.70b	4.17a	5.53ab
$T_3 = T_1$ + 25% NP	4.87a	5.54ab	5.5a	6.48a	4.66b	5.49c	4.43a	4.93b
$T_4 = T_1$ + 25% NK	4.50bc	4.98c	5.8a	6.93a	4.90a	5.91a	4.53a	5.80a
$T_5 = T_1$ + 25% PK	4.30c	4.48d	5.6a	6.10a	4.41c	5.78b	4.50a	5.86a
$T_6 = T_1$ + 25% NPK	5.02a	5.88a	5.8a	6.31a	4.43c	5.50c	4.57a	5.90a
T_7 = 75% of T_1	3.52d	4.15d	3.8b	4.50b	3.28e	4.87e	3.47b	4.80b
T_8 = Control	2.11e	3.10e	2.7c	3.16c	2.13f	2.59f	2.33c	3.27c
CV (%)	5.75	5.37	10.40	8.40	4.78	4.01	5.85	7.65

STB: Trisal, Mymensingh = $N_{64}P_{14}K_{28}S_6$; Madhupur, Tangail = $N_{68}P_{12}K_{32}S_8$; Atgharia, Pabna = $N_{64}P_8K_{24}S_6$ and Shamnagar, Satkhira = $N_{72}P_{16}K_{40}S_8$

Effects of fertilization on the Nutrient uptake and fertilizer use economy in different cropping patterns at the selected locations

(i) Potato - Boro - T. aman cropping pattern at Birgonj, Dinajpur; Debigonj, Panchagar and Pirgonj, Rangpur

Nutrient uptake

Nutrient uptake by Potato-Boro-T. aman cropping pattern at different locations was influenced due to different treatments (Table 7). In case of average nutrient uptake over two years, the highest N uptake was observed in treatment T_6 in all locations. Phosphorus uptake was the highest in T_6 at Birgonj, Dinajpur and Pirgonj, Rangpur and in T_3 at Debigonj, Panchagar. Potassium uptake was highest in T_6 at Birgonj, Dinajpur & Debigonj, Panchagar and T_5 at Pirgonj, Rangpur. Sulphur uptake was highest in T_3 at Birgonj, Dinajpur; in T_6 at Debigonj, Panchagar and Pirgonj, Rangpur.

Table 7. Effects of fertilizers on nutrient uptake (kg ha^{-1}) by crops in Potato-Boro-T. aman pattern (two years average) at Birgonj, Dinajpur; Debigonj, Panchagar and Pirgonj, Rangpur

Treatments	Birgonj, Dinajpur				Debigonj, Panchagarh				Pirgonj, Rangpur			
	N	P	K	S	N	P	K	S	N	P	K	S
T_1 = 100% (STB)	426	61	474	39	363	49	399	34	372	48	394	41
$T_2 = T_1$+25% N	439	67	591	44	405	53	413	34	410	53	413	47
$T_3 = T_1$+25% NP	436	78	517	49	414	64	400	41	417	51	423	42
$T_4 = T_1$+25% NK	492	71	521	50	378	56	452	40	393	53	446	43
$T_5 = T_1$+25% PK	482	78	533	51	383	58	421	37	405	55	447	44
$T_6 = T_1$+25% NPK	505	80	616	46	459	63	474	46	454	56	435	52
T_7 = 75% of T_1	304	46	386	32	319	42	343	29	329	39	321	33
T_8 = Control	226	31	258	21	146	21	193	13	159	19	138	16

Economics of fertilizers use

Average yield (t ha^{-1}) of crops and results of partial budget analysis of Potato-Boro-T. aman pattern are shown in Table 8a to Table 8c. Results of partial budget analysis demonstrated the highest net benefit of Tk ha^{-1} 4,42,632 in T_6 followed by Tk ha^{-1} 4,31,752 and Tkha^{-1} 4,24,717 in T_3 and T_5 treatments, respectively at Birgonj, Dinajpur (Table 8a). The highest net benefit of Tk ha^{-1} 3,79,267 was obtained in T_6 followed by Tk ha^{-1} 3,48,382 and Tk ha^{-1} 3,38,367 in T_5 and T_4 treatments at Debigonj, Panchagarh (Table 8b). At pirgong, Rangpur the highest net benefit of Tk ha^{-1} 4,40,747 was recorded in T_6 which was followed by Tk ha^{-1} 4,17,692 and Tk ha^{-1} 4,15,037 in T_5 and T_4, respectively (Table 8c). The highest MBCR (4.57, 4.75 & 6.73) was obtained in T_3 at Birgonj, Dinajpur and T_6 treatment at Debigonj, Panchagarh and Pirgonj, Rangpur. Based on the most profitable treatment, the following doses of fertilizers are recommended for Potato-Boro-T. aman cropping pattern: $N_{169}P_{31}K_{135}S_{12}Zn_2B_1$-$N_{175}P_{10}K_{75}S_{10}Zn_1B_{0.5}$-$N_{80}P_{7.5}K_{32}S_8$ at Birgonj, Dinajpur (AEZ 1), $N_{188}P_{23}K_{169}S_8Zn_2B_1$-$N_{188}P_{10}K_{94}S_8Zn_1B_{0.5}$-$N_{84}P_{7.5}K_{40}S_6$ at Debigonj, Panchagarh (AEZ 1) and $N_{181}P_{10}K_{148}S_{12}Zn_2B_1$-$N_{183}P_{10}K_{81}S_{10}Zn_1B_{0.5}$-$N_{81}P_{7.5}K_{35}S_8$ at Pirgong, Rangpur (AEZ 3).

Table 8a. Effects of fertilizers on the average yield (t ha^{-1}) of crops and fertilizer use economy in Potato-Boro-T. aman pattern at Birgonj, Dinajpur

Treatments	Average (2011-12 & 2012-13)					Gross return	Fert. cost	Net return	Marginal return	MBCR
	Potato	Boro		T. aman		Tk. ha^{-1}				
	Tuber	Grain	Straw	Grain	Straw					
T_1= 100% (STB)	26.26	5.44	6.09	4.77	5.89	4,27,730	35,563	3,92,167	147217	4.14
$T_2 = T_1$ + 25% N	28.5	5.84	7.63	4.93	5.98	4,62,160	39,388	4,22,772	177822	4.51
$T_3 = T_1$ + 25% NP	28.93	6.00	7.15	5.31	6.54	4,72,640	40,888	4,31,752	186802	4.57
$T_4 = T_1$ + 25% NK	28.68	5.71	8.18	4.94	6.88	4,61,610	42,438	4,19,172	174,222	4.11
$T_5 = T_1$ + 25% PK	29.13	6.05	7.43	4.65	5.60	4,64,830	40,113	4,24,717	179767	4.48
T_6=T_1+25% NPK	28.96	6.68	7.43	5.49	6.49	4,86,070	43,438	4,42,632	197,682	4.55
T_7 = 75% of T_1	22.39	5.08	6.89	3.64	4.11	3,65,700	27,238	3,38,462	93512	3.43
T_8 = Control	16.29	2.68	3.39	2.37	2.91	2,44,950	-	2,44,950	-	-

Grain = 15 Tk. kg^{-1}; Straw = 1 Tk. kg^{-1}; Potato=10 Tk. kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk. kg^{-1};
K = 50 Tk. kg^{-1}; S = 55 Tk. kg^{-1} and Zn = 102 Tk. kg^{-1}, MBCR = Marginal benefit cost ratio

Table 8b. Effects of fertilizers on the average yield (t ha^{-1}) of crops and fertilizer use economy in Potato-Boro-T. aman pattern at Debigonj, Panchagarh

Treatments	Average (2011-12 & 2012-13)					Gross return	Fert. cost	Net return	Marginal return	MBCR
	Potato	Boro		T. aman		Tk. ha^{-1}				
	Tuber	Grain	Straw	Grain	Straw					
T_1 = 100% (STB)	17.67	5.6	6.65	4.15	4.86	3,34,455	35,335	2,99,120	1,27,660	3.61
$T_2 = T_1$ + 25% N	19.8	6.09	7.71	4.21	5.09	3,65,305	39,473	3,25,970	1,54,510	3.91
$T_3 = T_1$ + 25% NP	19.99	6.64	7.89	4.29	5.11	3,76,845	40,673	3,36,172	1,64,712	4.05
$T_4 = T_1$ + 25% NK	21.38	6.05	7.53	4.19	5.96	3,80,890	42,523	3,38,367	1,66,907	3.93
$T_5 = T_1$ + 25% PK	22	6.17	7.23	4.19	5.34	3,87,965	39,583	3,48,382	1,76,922	4.47
$T_6 = T_1$ + 25% NPK	23.78	6.74	8.39	4.67	5.73	4,22,990	43,723	3,79,267	2,07,807	4.75
T_7 = 75% of T_1	14.99	4.58	5.25	4.00	4.83	2,88,678	26,993	2,61,685	90,225	3.34
T_8 = Control	9.48	2.28	3.46	2.38	3.38	1,71,460	-	1,71,460	-	-

Grain = 15 Tk. kg^{-1}; Straw = 1 Tk. kg^{-1}; Potato = 10 Tk. kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk. kg^{-1};
K = 50 Tk. kg^{-1}; S = 55 Tk. kg^{-1} and Zn = 102 Tk. kg^{-1}, MBCR = Marginal benefit cost ratio.

Table 8c. Effects of fertilizers on the average yield (t ha^{-1}) of crops and fertilizer use economy in Potato-Boro-T. aman pattern at Pirgonj, Rangpur

Treatments	Average (2011-12 & 2012-13)					Gross return	Fert. cost	Net return	Marginal return	MBCR
	Potato	Broo		T. aman						
	Tuber	Grain	Straw	Grain	Straw			Tk. ha^{-1}		
T_1 = 100% (STB)	17.17	5.27	6.62	4.55	5.80	4,17,270	32,228	3,85,042	1,86,512	5.79
$T_2 = T_1$ + 25% N	18.15	5.67	7.17	4.69	5.42	4,40,240	36,233	4,04,007	2,05,477	5.67
$T_3 = T_1$+25% NP	18.5	5.62	6.81	4.68	5.77	4,44,580	37,133	4,07,447	2,08,917	5.63
$T_4 = T_1$ + 25% NK	19.29	5.32	7.05	4.78	6.02	4,53,920	38,883	4,15,037	2,16,507	5.57
$T_5 = T_1$ + 25% PK	19.24	5.72	6.62	4.49	6.10	4,53,470	35,778	4,17,692	2,19,162	6.13
$T_6 = T_1$+25% NPK	20.23	5.53	6.62	5.15	6.48	4,76,750	36,003	4,40,747	2,42,217	6.73
T_7 = 75% of T_1	14.2	4.15	6.19	3.96	4.93	3,45,770	24,823	3,20,947	1,22,417	4.93
T_8 = Control	7.13	2.59	3.77	3.06	3.06	1,98,530	-	1,98,530	-	-

Grain = 15 Tk. kg^{-1}; Straw = 1 Tk. kg^{-1}; Potato=10 Tk. kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk. kg^{-1};
K = 50 Tk. kg^{-1}; S = 55 Tk. kg^{-1} and Zn = 102 Tk. kg^{-1}, MBCR = Marginal benefit cost ratio.

Changes in post harvest soil status at three locations

The changes in soil pH, organic matter and different nutrients due to the use of different doses of fertilizers in Potato-Boro-T. aman cropping pattern for two years are shown in Table 9a to Table 9c. There is a little change in soil pH at all three locations. It appears the decreasing tendency of soil organic matter content to some extent. The changes in soil N, P, K and S content do not follow any definite trend. In general, control treatment had tendency to decrease nutrient status of soil compared with initial value.

Table 9a. Changes in soil status at Birgonj, Dinajpur after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	5.6	1.55	0.070	27.74	0.085	11.98
$T_2 = T_1$ + 25% N	5.5	1.55	0.078	29.11	0.085	16.61
$T_3 = T_1$ + 25% NP	5.4	1.51	0.078	29.80	0.082	11.84
$T_4 = T_1$ + 25% NK	5.4	1.55	0.072	26.73	0.082	13.75
$T_5 = T_1$ + 25% PK	5.5	1.66	0.072	31.85	0.080	11.84
$T_6 = T_1$ + 25% NPK	5.2	1.69	0.078	31.85	0.082	16.61
T_7 = 75% of T_1	5.3	1.55	0.070	25.00	0.077	11.84
T_8 = Control	5.3	1.42	0.056	22.67	0.074	10.07
Initial soil	5.4	1.74	0.087	25.50	0.090	12.00

Table 9b. Changes in soil status at Debigonj, Panchagarh after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	5.9	1.16	0.056	14.26	0.076	19.07
$T_2 = T_1$ + 25% N	5.8	1.22	0.061	14.17	0.076	20.98
$T_3 = T_1$ + 25% NP	5.6	1.16	0.061	16.02	0.084	19.07
$T_4 = T_1$ + 25% NK	5.8	1.16	0.062	14.24	0.089	18.61
$T_5 = T_1$+ 25% PK	5.6	1.16	0.063	14.59	0.089	20.75
$T_6 = T_1$+25% NPK	5.6	1.16	0.068	15.68	0.092	19.59
T_7 = 75% of T_1	5.9	1.22	0.056	13.89	0.073	19.07
T_8 = Control	6.0	1.09	0.042	12.32	0.073	17.16
Initial soil	5.4	1.20	0.060	16.60	0.090	21.90

Table 9c. Changes in soil status at Pirgonj, Rangpur after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 =100% (STB)	5.1	1.30	0.078	19.93	0.147	11.71
$T_2 = T_1$ + 25% N	5.3	1.32	0.078	16.42	0.140	15.52
$T_3 = T_1$ + 25% NP	5.1	1.27	0.078	17.39	0.142	17.43
$T_4 = T_1$ + 25% NK	5.1	1.34	0.067	26.81	0.112	19.34
$T_5 = T_1$+ 25% PK	5.3	1.25	0.076	22.07	0.108	18.39
$T_6 = T_1$+25% NPK	5.4	1.34	0.069	20.35	0.158	10.76
T_7 = 75% of T_1	5.3	1.33	0.073	20.21	0.102	10.89
T_8 = Control	5.3	1.38	0.064	17.11	0.090	13.62
Initial soil	5.6	1.35	0.068	20.10	0.130	11.20

(ii) Potato-Groundnut-T. aman at Kaligonj, Lalmonirhat (AEZ 3)

Nutrient uptake

Nutrient uptake by Potato-Groundnut-T. aman at Kaligonj, Lalmonirhat was influenced due to different treatments (Table 10). In case of average nutrient uptake of two years, the highest N, P, K and S uptake of 474, 53, 377 and 37 kg ha^{-1}, respectively was observed in treatment T_6. The lowest nutrient uptake was found in control plot (T_8) in all cases.

Economics of fertilizers use

The results of partial budget analysis demonstrated that the highest net benefit of Tk ha^{-1} 3,02,229 was obtained from T_6 followed by Tk ha^{-1} 2,93,734 from T_4 treatment (Table 11). The highest MBCR (3.54) was also obtained by the T_6 treatment followed by T_2 (3.48) treatment. Based on the most profitable treatment, the recommended doses of fertilizers are $N_{169}P_{10}K_{163}S_{10}Zn_2B_1$-$N_{56}$ $P_{31}K_{88}S_{15}Zn_1$ $B_{0.5}$-$N_{80}P_{7.5}K_{40}S_6$ for Potato-Groudnut-T. aman cropping pattern at Kaligonj, Lalmonirhat.

Table 10. Effects of fertilizers on the nutrient uptake by crops in Potato-Groundnut-T. aman cropping pattern (two years average) at Kaligonj, Lalmonirhat

Treatments	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
T_1 = 100% (STB)	374	44	290	31
T_2 = T_1+25% N	400	45	337	34
T_3 = T_1+25% NP	424	49	337	31
T_4 = T_1+25% NK	439	46	360	31
T_5 = T_1+25% PK	416	48	345	33
T_6 = T_1+25% NPK	474	53	377	37
T_7 = 75% of T_1	357	37	270	25
T_8 = Control	185	19	138	14

Table 11. Average yield and fertizer use economy as affected by different nutrient combination at Kaligonj, Lalmonirhat

Treatments	Average (2011-12 & 2012-13)				Gross return	Fert. cost	Net return	Marginal return	MBCR
	Potato Tuber	Groundnut pod	T. aman						
			Grain	Straw	(Tkha^{-1})				
T_1 = 100% (STB)	19.13	2.37	4.01	5.06	3,03,835	30,741	2,73,094	1,04,619	3.40
T_2 = T_1+25%N	20.1	2.48	4.17	5.49	3,18,470	33,486	2,84,984	1,16,509	3.48
T_3 = T_1+25% NP	20.96	2.51	3.92	5.22	3,23,820	34,911	2,88,909	1,20,434	3.45
T_4 = T_1+25% NK	21.59	2.52	3.89	5.65	3,30,120	36,386	2,93,734	1,25,259	3.44
T_5 = T_1+25% PK	20.11	2.50	3.89	5.07	3,14,590	35,066	2,79,524	1,11,049	3.17
T_6 = T_1+25% NPK	22.42	2.53	3.97	5.79	3,40,040	37,811	3,02,229	1,33,754	3.54
T_7 = 75% of T_1	16.7	2.22	3.47	4.55	2,67,825	24,033	2,43,792	75,317	3.13
T_8 = Control	9.45	1.76	2.38	2.78	1,68,075	-	1,68,475	-	-

Grain = 15 Tk. kg^{-1}; Straw = 1 Tk. kg^{-1}; Potato=10 Tk. kg^{-1}; Groundnut= 20 Tk. kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk. kg^{-1}; K = 50 Tk. kg^{-1}; S = 55 Tk. kg^{-1} and Zn = 102 Tk. kg^{-1}, MBCR = Marginal benefit cost ratio.

Changes in post harvest soil status

The changes in soil pH, organic matter and different nutrients due to the use of different doses of fertilizers in Potato-Groundnut-T. aman cropping pattern for 2 (two) years are shown in Table 12. There is a little increase in soil pH at this location except T_7 treatment. Definite trend of increase or decrease are not found in case of organic matter, N and P but an increasing trend is observed for the case of K and S contents. In general, control treatment had tendency to decrease nutrient status of soil compared with initial value.

Table 12. Changes in soil status at Kaligonj, Lalmonirhat after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	5.5	1.71	0.110	29.70	0.130	21.94
$T_2 = T_1$ + 25% N	5.4	1.63	0.089	27.10	0.120	20.99
$T_3 = T_1$ + 25% NP	5.7	1.81	0.077	31.40	0.140	26.71
$T_4 = T_1$ + 25% NK	5.4	1.63	0.099	26.90	0.150	26.70
$T_5 = T_1$ + 25% PK	5.5	1.69	0.078	30.40	0.130	20.03
$T_6 = T_1$ + 25% NPK	5.4	1.65	0.095	28.30	0.140	26.71
T_7 = 75% of T_1	5.7	1.65	0.083	27.50	0.120	20.99
T_8 = Control	5.2	1.59	0.064	25.50	0.100	18.13
Initial soil	5.3	1.74	0.087	31.60	0.110	19.10

(iii) Boro-Fallow-T. aman cropping pattern at Trisal, Mymensingh (AEZ 9)

Nutrient uptake

The nutrient uptake by Boro-Fallow-T.aman rice at Trisal, Mymensingh is shown in Table 13. In case of average nutrient uptake of two years, the highest N, K and S uptake was in treatment T_3; P in T_3 and T_6. The lowest N, P, K & S uptake was found in the control plot (T_8).

Table 13. Effects of fertilizers on nutrient uptake (kg ha^{-1}) by Boro-Fallow-T. aman cropping pattern (two years average) at Trisal, Mymensingh

Treatments	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
T_1 = 100% (STB)	177	27	204	17
$T_2 = T_1$+25% N	200	26	216	20
$T_3 = T_1$+25% NP	212	33	233	21
$T_4 = T_1$+25% NK	198	27	198	19
$T_5 = T_1$+25% PK	195	27	203	19
$T_6 = T_1$+25% NPK	196	33	219	20
T_7 = 75% of T_1	156	23	170	16
T_8 = Control	79	12	103	8

Economics of fertilizers use

The results of partial budget analysis of Boro-Fallow-T. aman (Table 14) demonstrated that the highest net benefit of Tk ha^{-1} 1,50,831 in T_6 which was followed by T_3 (Tk ha^{-1} 1,47,371). Another attempt was also been made to find out the marginal benefit cost ratio (MBCR) against the treatments, which was found highest in T_2 (2.74) treatment followed by T_3 (2.73) treatment. Based on the most profitable treatment, the recommended doses of fertilizers are $N_{175}P_{31}K_{113}S_8Zn_1B_{0.5}$-$N_{80}P_{18}K_{35}S_6$ for Boro-Fallow-T. aman cropping pattern at Trisal, Mymensingh.

Table 14. Average yield (t ha^{-1}) and fertizer use economy as affected by different nutrient combinations at Trisal, Mymensingh

Treatments	Average (2011-12 & 2012-13)				Gross return	Fert. cost	Net return	Marginal return	MBCR
	Boro		T. aman						
	Grain	Straw	Grain	Straw	(Tk ha^{-1})				
T_1 = 100% (STB)	5.49	6.64	4.12	4.88	1,55,670	22,004	1,33,666	56,746	2.58
T_2 = T_1+25% N	5.87	6.99	4.51	5.18	1,67,870	24,299	1,43,571	66,651	2.74
T_3 = T_1+25% NP	5.92	7.48	4.77	5.34	1,73,170	25,799	1,47,371	70,451	2.73
T_4 = T_1+25% NK	5.75	6.51	4.60	5.03	1,66,790	27,299	1,39,491	62,571	2.29
T_5 = T_1+25% PK	5.82	7.21	4.62	4.84	1,68,650	25,004	1,43,646	66,726	2.67
T_6 = T_1+25% NPK	6.17	6.99	4.86	5.69	1,78,130	27,299	1,50,831	73,911	2.71
T_7 = 75% of T_1	4.87	6	3.49	4.68	1,36,080	16,709	1,19,371	42,451	2.54
T_8 = Control	2.60	3.7	2.09	2.87	76,920	-	76,920	-	-

Grain = 15 Tk. kg^{-1}; Straw = 1 Tk. kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk. kg^{-1}; K = 50 Tk. kg^{-1}; S = 55 Tk. kg^{-1} and Zn = 102 Tk. kg^{-1}, MBCR = Marginal benefit cost ratio

Changes in post harvest soil status at Trisal, Mymensingh

The changes in soil pH, organic matter and different nutrients due to the use of fertilizers in Boro-Fallow-T. aman pattern for two years are given in Table 15. It appeared the decreasing trend in soil pH and the organic matter content to some extent. The changes in soil N, P & S contents showed an increasing trend. On the other hand, a decreasing trend was observed in case of K content except T_3 & T_5 treatments. In general, control treatment had decreasing tendency of nutrients compared with initial status of soil.

Table 15. Changes in soil status at Trisal, Mymensingh after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	6.7	1.42	0.100	6.52	0.120	20.00
T_2 = T_1 + 25% N	6.5	1.41	0.100	6.96	0.120	19.12
T_3 = T_1 + 25% NP	6.7	1.63	0.080	6.72	0.140	20.42
T_4 = T_1 + 25% NK	6.7	1.50	0.100	6.72	0.130	22.47
T_5 = T_1+ 25% PK	6.6	1.65	0.070	6.92	0.140	20.20
T_6 = T_1 + 25% NPK	6.6	1.70	0.090	6.53	0.128	21.86
T_7 = 75% of T_1	6.7	1.43	0.090	6.95	0.120	20.89
T_8 = Control	6.9	1.55	0.080	6.34	0.122	14.59
Initial soil	6.9	1.57	0.079	5.70	0.130	19.80

(iv) Mustard-Boro-T. aman cropping pattern at Madhupur, Tangail (AEZ 28)

Nutrient uptake

Nutrient uptake by Mustard-Boro-T. aman rice was influenced due to the different treatments (Table 16). In case of average nutrient uptake of two years, the highest N uptake was found in treatment T_3 (236 kg ha^{-1}); P in T_3 (31 kg ha^{-1}) and T_6 (31 kg ha^{-1}), K (253 kg ha^{-1}) and S (26 kg ha^{-1}) in T_6. The lowest nutrient uptake was obtained in control plot (T_8).

Economics of fertilizers use

From the average yields (Table 17), the results of partial budget analysis of Mustard-Boro-T. aman rice at Madhupur, Tangail demonstrated the highest net benefit of Tk ha^{-1} 1,68,977 in T_6 treatment followed by Tk ha^{-1} 1,65,097 and 1,64,227 in T_3 and T_4 treatments. The highest MBCR (2.00) was obtained in T_3 followed by 1.99 and 1.98 in treatments T_6 and T_4, respectively. Based on the most profitable treatment, the recommended doses of fertilizers are $N_{106}P_{30}K_{60}S_{12}Zn_2B_1$–$N_{188}P_{25}K_{70}S_{10}$ $Zn_1B_{0.5}$–$N_{85}P_{15}K_{32}S_8$ for Mustard - Boro -T. aman cropping pattern at Madhupur, Tangail.

Table 16. Effects of fertilizers on nutrient uptake (kgha^{-1}) of crops in Mustard-Boro-T. aman cropping pattern (two years average) at Madhupur, Tangail

Treatments	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
T_1=100% (STB)	216	30	216	22
T_2=T_1+25% N	227	29	185	24
T_3=T_1+25% NP	236	31	234	25
T_4=T_1+25% NK	232	29	235	25
T_5=T_1+25% PK	221	30	235	25
T_6=T_1+25% NPK	233	31	253	26
T_7 = 75% of T_1	156	19	173	19
T_8 = Control	102	10	94	12

Table 17. Average yield and fertilizer use economy as affected by different nutrient combination at Madhupur, Tangail

Treatments	Average (2011-12 & 2012-13)						Gross return	Fert. cost	Net return	Marginal return	MBCR
	Mustard		Boro		T. aman						
	Seed	Stover	Grain	Straw	Grain	Straw	(Tkha^{-1})				
T_1 = 100% (STB)	1.18	1.2	4.08	5.87	4.95	5.48	1,83,400	32,493	1,50,907	61,937	1.91
T_2 = T_1+ 25% N	1.28	2.09	4.25	5.68	5.11	5.68	1,92,250	35,913	1,56,337	67,367	1.88
T_3 =T_1+25% NP	1.49	2.29	4.7	6.19	4.90	5.93	2,03,110	38,013	1,65,097	76,127	2.00
T_4 = T_1+25% NK	1.44	2.47	4.52	5.63	5.14	5.99	2,02,190	37,963	1,64,227	75,257	1.98
T_5 = T_1+25% PK	1.40	2.25	4.41	6.35	4.85	5.49	1,94,990	36,643	1,58,347	69,377	1.89
T_6 = T_1+25% NPK	1.50	2.44	4.45	6.03	5.53	5.87	2,09,040	40,063	1,68,977	80,007	1.99
T_7 = 75% of T_1	0.86	2.2	3.09	4.61	3.83	4.49	1,40,900	24,923	1,15,977	27,007	1.08
T_8 = Control	0.46	0.74	2.07	2.95	2.48	3.23	88,970	-	88,970	-	-

Grain = 15 Tk kg^{-1}; Straw = 1 Tk kg^{-1}; Mustard = 30 Tk kg^{-1}; N = 45 Tk kg^{-1}; P = 150 Tk kg^{-1}; K = 50 Tk kg^{-1}; S = 55 Tk kg^{-1} and Zn = 102 Tk kg^{-1}, MBCR = Marginal benefit cost ratio.

Changes in post harvest soil status at Madhupur, Tangail

The changes in soil pH, organic matter and different nutrients due to the use of fertilizers in Mustard-Boro-T. aman pattern over two years are given in Table 18. It appeared a negligible increasing tendency in all the soil characters under study. In general, control treatment had decreasing tendency of nutrient status compare with initial value.

Table 18. Changes in soil status at Madhupur, Tangail after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	6.8	1.12	0.070	9.56	0.090	14.42
$T_2 = T_1$ + 25% N	6.9	1.16	0.060	11.46	0.114	14.12
$T_3 = T_1$ + 25% NP	6.3	1.12	0.070	11.20	0.105	14.36
$T_4 = T_1$ + 25% NK	6.9	1.24	0.070	11.84	0.093	18.53
$T_5 = T_1$+ 25% PK	6.7	1.10	0.060	10.68	0.111	15.47
$T_6 = T_1$+25% NPK	6.8	1.16	0.070	11.00	0.117	15.88
T_7 = 75% of T_1	6.5	1.16	0.060	10.68	0.105	17.65
T_8 = Control	6.8	1.10	0.050	9.02	0.090	10.59
Initial soil	6.7	1.10	0.055	8.60	0.100	14.80

(v) Wheat-Mungbean-T. aman at Atgharia, Pabna (AEZ 11)

Nutrient uptake

Nutrient uptake by crops in Wheat-Mungbean-T.aman cropping pattern at Atgharia, Pabna was influenced by different treatments (Table 19). In case of average nutrient uptake of two years the highest N uptake (259 kg ha^{-1}) was found in treatment T_3; P in T_5 (44 kg ha^{-1}) and T_6 (44 kg ha^{-1}), K in T_6 (265 kg ha^{-1}) and S in T_4 (28 kg ha^{-1}). The lowest nutrient uptake was obtained in the control plot (T_8).

Table 19. Effects of fertilizers on nutrient uptake (kg ha^{-1}) by crops at Atgharia, Pabna

Treatments	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
T_1 = 100% (STB)	227	35	209	22
$T_2 = T_1$+25% N	237	40	232	25
$T_3 = T_1$+25%NP	259	42	238	24
$T_4 = T_1$+25% NK	237	39	232.	28
$T_5 = T_1$+25% PK	244	44	246	26
$T_6 = T_1$+25% NPK	253	44	265	26
T_7 = 75% of T_1	176	29	154	19
T_8 = Control	102	16	111	9

Economics of fertilizers use

From the average yields, the results of partial budget analysis of Wheat-Mungbean-T. aman cropping pattern (Table 20) demonstrated the highest net benefit of Tk ha^{-1} 2,62,682 was obtained in T_6 followed by Tk ha^{-1} 2,58,989 in T_3 treatment. The highest MBCR (4.08) was obtained in T_3 followed by treatment T_6 (4.00). Based on the most profitable treatment, the recommended doses of fertilizers are $N_{150}P_{23}K_{75}S_{10}Zn_2B_1$–$N_{23}P_{23}K_{30}S_{10}B_{0.5}$–$N_{80}P_{10}K_{24}S_6$ for Wheat-Mungbean-T. aman cropping pattern at Atgharia, Pabna.

Table 20. Average yield (t ha^{-1}) as affected by different nutrient combination at Atgharia, Pabna

Treatments	Average (2011-12 & 2012-13)						Gross return	Fert. cost	Net return	Marginal return	MBCR
	Wheat		Mungbean		T. aman		(Tk ha^{-1})				
	Grain	Straw	Seed	Stover	Grain	Straw					
T_1 = 100% (STB)	3.2	5.18	1.97	5.28	4.09	5.16	2,51,770	23,874	2,27,896	82,886	3.47
T_2 = T_1+ 25% N	3.55	6.06	2.04	5.91	4.50	6.06	2,73,630	26,146	2,47,484	1,02,474	3.92
T_3 = T_1+25% NP	3.82	6.79	2.1	5.52	4.69	5.60	2,86,860	27,871	2,58,989	1,13,979	4.08
T_4 = T_1+25% NK	3.72	6.38	1.99	5.58	4.56	5.70	2,77,260	27,633	2,49,627	1,04,617	3.79
T_5 = T_1+25% PK	3.65	6.06	1.99	6.15	4.54	5.81	2,75,220	27,086	2,48,134	1,03,124	3.81
T_6 = T_1+25% NPK	4.1	6.56	2.08	5.45	4.53	5.88	2,92,040	29,358	2,62,682	1,17,672	4.00
T_7 = 75% of T_1	2.78	4.97	1.81	4.91	3.50	4.69	2,22,870	18,388	2,04,482	59,472	3.23
T_8 = Control	1.29	2.56	1.61	2.67	2.17	2.59	1,45,010	-	1,45,010	-	-

Grain = 15 Tk kg^{-1}; Straw = 1 Tk kg^{-1}; Wheat = 30 Tk kg^{-1}; Mungbean = 40 Tk kg^{-1}; N = 45 Tk kg^{-1};
P = 150 Tk kg^{-1}; K = 50 Tk kg^{-1}; S = 55 Tk kg^{-1} and Zn = 102 Tk kg^{-1}, MBCR = Marginal benefit cost ratio

Changes in post harvest soil status at Atgharia, Pabna

The changes in soil pH, organic matter and different nutrients due to the use of fertilizers in Wheat-Mungbean-T.aman pattern over two years are given in Table 21. It appeared an increasing tendency in soil pH and N, P, K & S contents except a minor decrease in organic matter content. In general, control treatment had decreasing tendency of nutrient status compare with initial value.

Table 21. Changes in soil status at Atgharia, Pabna after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	7.3	1.50	0.100	16.51	0.167	18.60
T_2 = T_1 + 25% N	7.3	1.54	0.113	12.39	0.180	23.37
T_3 = T_1 + 25% NP	7.2	1.77	0.090	12.36	0.174	20.51
T_4 = T_1 + 25% NK	7.3	1.69	0.115	15.14	0.189	24.80
T_5 = T_1+ 25% PK	7.3	1.52	0.108	15.48	0.168	22.17
T_6 = T_1+25% NPK	7.3	1.59	0.116	16.24	0.171	21.94
T_7 = 75% of T_1	7.3	1.77	0.106	12.29	0.158	21.94
T_8 = Control	7.4	1.61	0.088	12.18	0.140	17.17
Initial soil	7.0	1.76	0.088	11.88	0.150	18.40

Fertilizer requirement for Garlic − B. aman crops/cropping pattern at Chalanbil area, Natore (AEZ 5)

Nutrient uptake

Nutrient uptake by B. aman rice at Chalanbil, Natore was influenced due to different treatments (Table 22). In case of average nutrient uptake of two years the highest N uptake (103 kg ha^{-1}) was in treatment T_6; P (14 kg ha^{-1}) in $T_{1,}$ $T_{3,}$ T_4 & T_6; K (164 kg ha^{-1}) in T_4 & T_6 and S (11 kg ha^{-1}) in T_4. The lowest nutrient uptake was obtained in the control plot (T_8).

Table 22. Effects of fertilizers on nutrient uptake (kg ha^{-1}) by B. aman rice at Chalanbil, Natore

Treatments	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
T_1 = 100% (STB)	95	14	155	10
T_2 = T_1+25% N	93	12	142	10
T_3 = T_1+25% NP	100	14	145	10
T_4 = T_1+25% NK	96	14	164	11
T_5 = T_1+25% PK	83	12	144	10
T_6 = T_1+25% NPK	103	14	164	10
T_7 = 75% of T_1	78	11	123	8
T_8 = Control	66	9	113	7

Economics of fertilizers use

The results of partial budget analysis of Garlic-B.aman rice pattern at Chalanbil, Natore (Table 23) demonstrated that the highest net benefit of Tk ha^{-1} 4,28,224 was obtained in T_6 followed by Tk ha^{-1} 4,25,824 in T_2. Another attempt was also been made to find out the marginal benefit cost ratio (MBCR) against the treatments. The highest MBCR (2.49) was obtained in T_2 followed by 2.28 in treatment T_4. Based on the most profitable treatment, the recommended doses of fertilizers are $N_{120}P_{44}K_{120}S_{25}Zn_2B_1$–$N_{31}P_{10}K_{13}S_6Zn_1$ for Garlic-B.aman cropping pattern at Chalanbil, Natore.

Table 23. Effects of fertilizers on the average yield (t ha^{-1}) of crops and fertilizer use economy in Garlic-B. aman cropping pattern

Treatments	Average (2011-12 & 2012-13)			Gross return	Fertilizer cost	Net return	Marginal return	MBCR
	Garlic Bulb	B. aman Grain	B. aman Straw	Tk ha^{-1}				
T_1= 100% (STB)	7.61	3.02	10.31	4,36,110	36,315	3,99,795	70,665	1.95
T_2 = T_1 + 25% N	8.15	3.15	9.92	4,64,670	38,846	4,25,824	96,684	2.49
T_3 = T_1 + 25% NP	8.01	3.31	9.61	4,59,760	41,771	4,17,989	88,849	2.13
T_4 = T_1 + 25% NK	8.21	2.99	9.93	4,65,280	41,471	4,23,809	94,669	2.28
T_5 = T_1 + 25% PK	8.16	2.90	9.29	4,60,790	41,865	4,18,925	89,785	2.14
T_6 = T_1 + 25% NPK	8.31	3.15	9.87	4,72,620	44,396	4,28,224	99,084	2.23
T_7 = 75% of T_1	6.96	2.75	8.95	3,98,200	28,236	3,69,964	40,824	1.44
T_8 = Control	5.68	2.44	8.54	3,29,140	-	3,29,140	-	-

Grain = 15 Tk kg^{-1}; Straw = 1 Tk kg^{-1}; Garlic = 50 Tk kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk kg^{-1};
K = 50 Tk kg^{-1}; S = 55 Tk kg^{-1} and Zn = 102 Tk kg^{-1}, MBCR = Marginal benefit cost ratio

Changes in post harvest soil status

The changes in soil pH, organic matter and different nutrients due to the use of fertilizers in Garlic-B. aman pattern over two years are given in Table 24. It appeared an increasing tendency in soil pH. On the contrary, changes in soil organic matter content, N, P, K and S contents showed an increasing trend. In general, control treatment had decreasing tendency of nutrient status compare with initial value.

Table 24. Changes in soil status at Chalanbil, Natore after two years of cropping

Treatments	pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
T_1 = 100% (STB)	6.3	1.54	0.092	15.89	0.22	19.07
T_2 = T_1 + 25% N	6.2	1.50	0.101	16.44	0.21	17.16
T_3 = T_1 + 25%NP	6.1	1.65	0.116	17.19	0.23	19.08
T_4 = T_1 + 25% NK	6.1	1.50	0.109	17.26	0.24	17.16
T_5 = T_1+ 25% PK	6.2	1.57	0.092	16.82	0.23	19.07
T_6 = T_1+25% NPK	6.0	1.54	0.100	16.92	0.23	19.93
T_7 = 75% of T_1	6.1	1.54	0.071	15.89	0.19	17.16
T_8 = Control	6.3	1.54	0.070	13.70	0.20	17.16
Initial soil	6.6	1.16	0.068	9.50	0.15	15.50

Fertilizer requirement for Boro-T. aman rice crops adapted in saline area at Shamnagar, Satkhira (AEZ 13)

Nutrient uptake

Nutrient uptake by Boro-Fallow-T. aman pattern Shamnagar, Satkhira was influenced due to different treatments (Table 25). In case of average nutrient uptake of two years the highest N uptake (187 kg ha^{-1}) was in treatment T_6; P (26 kg ha^{-1}) in T_3 & T_6; K (207 kg ha^{-1}) in T_5 and S (21 kg ha^{-1}) in T_4 & T_6. The lowest nutrient uptake was obtained in the control plot (T_8).

Table 25. Effects of fertilizers on nutrient uptake (kg ha^{-1}) by Boro−Fallow−T. aman cropping pattern

Treatments	Nutrient uptake (kg ha^{-1})			
	N	P	K	S
T_1 = 100% (STB)	158	24	183	19
T_2 = T_1+25% N	167	24	201	19
T_3 = T_1+25% NP	176	26	201	19
T_4 = T_1+25% NK	183	24	196	21
T_5 = T_1+25% PK	165	24	207	19
T_6 = T_1+25% NPK	187	26	201	21
T_7 = 75% of T_1	141	20	153	17
T_8 = Control	76	12	86	9

Economics of fertilizers use

The results of partial budget analysis of Boro-Fallow-T. aman cropping pattern at Shamnagar, Satkhira (Table 26) demonstrated that the highest net benefit of Tk ha^{-1} 1,33,208 was obtained in T_6 followed by Tk ha^{-1} 1,31,638 in T_3 treatment. The highest MBCR (3.13) was obtained in T_5 followed by 2.96 in treatment T_7. Based on the most profitable treatment, the recommended doses of fertilizers are $N_{120}P_{25}K_{16}S_4Zn_1B_{0.5}$-$N_{72}$ $P_{20}K_{40}S_4$ for Boro-Fallow-T.aman cropping pattern at Shamnagar, Satkhira.

Table 26. Effects of fertilizers on the average yield (t ha^{-1}) of crops and fertilizer use economy in Boro-Fallow-T. aman cropping pattern

Treatments	Average (2011-12 & 2012-13)				Gross return	Fertilizer cost	Net return	Marginal return	MBCR
	Boro		T. aman		Tk ha^{-1}				
	Grain	Straw	Grain	Straw					
T_1 = 100% (STB)	4.48	5.73	4.04	5.22	1,38,750	17,102	1,21,648	49,488	2.89
T_2 = T_1 + 25% N	4.62	5.75	4.04	5.69	1,41,340	19,262	1,22,078	49,918	2.59
T_3 = T_1 + 25% NP	5.13	6.2	4.18	5.04	1,50,890	20,612	1,30,278	58,118	2.82
T_4 = T_1 + 25% NK	4.72	6.17	4.10	5.79	1,44,260	19,812	1,24,448	52,288	2.64
T_5 = T_1+ 25% PK	4.87	5.74	4.42	5.55	1,50,640	19,002	1,31,638	59,478	3.13
T_6 = T_1+25% NPK	4.92	6.21	4.57	5.81	1,54,370	21,162	1,33,208	61,048	2.88
T_7 = 75% of T_1	4.13	5.23	3.46	4.72	1,23,800	13,042	1,10,758	38,598	2.96
T_8 = Control	2.29	3.38	2.1	2.93	72,160	-	72,160	-	-

Grain = 15 Tk kg^{-1}; Straw = 1 Tk kg^{-1}; N = 45 Tk kg^{-1}; P = 150 Tk kg^{-1}; K = 50 Tk kg^{-1}; S = 55 Tk kg^{-1} and Zn = 102 Tk kg^{-1}, MBCR = Marginal benefit cost ratio

Changes in post harvest soil status at Shamnagar, Satkhira

The changes in soil pH, organic matter and different nutrients due to the use of fertilizer packages in Boro-Fallow-T. aman pattern over two years are given in Table 27. It observed little increase or decrease in the status of soil characters under this study. In general, control treatment had decreasing tendency of nutrient status compared with initial value except the content of S.

Table 27. Changes in soil status at Shamnagar, Satkhira after two years of cropping

Treatments	pH	OM (%)	N (%)	P ($mgkg^{-1}$)	K ($cmolkg^{-1}$)	S ($mgkg^{-1}$)
T_1 = 100% (STB)	7.8	2.43	0.16	13.25	0.34	23.24
T_2 = T_1 + 25% N	7.3	2.54	0.16	13.44	0.31	20.30
T_3 = T_1 + 25% NP	7.5	2.64	0.14	13.44	0.27	17.65
T_4 = T_1 + 25% NK	7.7	2.55	0.14	13.25	0.31	21.18
T_5 = T_1 + 25% PK	7.4	2.58	0.16	13.25	0.29	25.89
T_6 = T_1 + 25% NPK	7.4	2.55	0.14	12.87	0.32	22.95
T_7 = 75% of T_1	7.4	2.42	0.14	13.62	0.31	19.42
T_8 = Control	7.7	2.38	0.12	13.06	0.27	21.47
Initial soil	7.8	2.60	0.14	13.60	0.29	20.20

Rabi experiments (2013-14)

Effects of fertilizers on the yield (t ha^{-1}) of potato at Debigonj, Panchagar (AEZ 1)

The tuber yield of potato during Rabi season of 2013-14 is shown in Table 28. The highest tuber yield (25.52 t ha^{-1}) of potato was obtained in treatment T_6 (T_1 + 25% NPK) at Debigonj, Panchagar; which was statistically similar with T_5 but higher than all other treatments. The lowest potato yield (8.74 t ha^{-1}) was recorded in treatment T_8.

Table 28. Effects of fertilizers on yield (t ha^{-1}) of potato at Debigonj, Panchagar (AEZ 1)

Treatments	Yield (t ha^{-1}) of potato
T_1 = 100% (STB)	22.10c
T_2 = T_1 + 25% N	22.62c
T_3 = T_1 + 25% NP	23.56bc
T_4 = T_1 + 25% NK	23.29bc
T_5 = T_1 + 25% PK	24.83ab
T_6 = T_1 + 25% NPK	25.52a
T_7 = 75% of T_1	16.86d
T_8 = Control	8.74e
CV (%)	5.09

STB: Cardinal = $N_{150}P_{18}K_{135}S_8Zn_2B_1$

Effects of fertilizers on the yield (t ha^{-1}) of wheat at Atgharia, Pabna (AEZ 11)

The grain and straw yields of wheat at Atgharia, Pabna during Rabi 2013-14 are shown in Table 29. The highest grain yield (3.63 t ha^{-1}) was obtained in treatment T_6 (T_1 + 25% NPK) which was statistically identical with treatments T_1, T_2 T_3, T_4 and T_5. The lowest grain yield (1.28 t ha^{-1}) was obtained in T_8. In case of straw, the highest yield (6.33 t ha^{-1}) was found in treatment T_6 (T_1 + 25% NPK) which was statistically identical with T_3 and T_5 but differed statistically with rest of the treatments. The lowest yield (2.28 t ha^{-1}) was obtained in T_8.

Table 29. Effects of fertilizers on the yield (t ha^{-1}) of crops in wheat at Atgharia, Pabna

Treatments	Wheat (t ha^{-1})	
	Grain	Straw
T_1 =100% (STB)	3.23a	4.93c
T_2 = T_1+ 25% N	3.27a	5.17bc
T_3 = T_1+25% NP	3.47a	5.53abc
T_4 = T_1+25% NK	3.57a	5.27bc
T_5 = T_1+25% PK	3.20a	5.90ab
T_6 = T_1+25% NPK	3.63a	6.33a
T_7 = 75% of T_1	2.47b	4.83c
T_8 = Control	1.28c	2.28d
CV (%)	11.91	9.62

STB: BARI Gom 26 = $N_{120}P_{18}K_{75}S_{10}Zn_2B_1$

Effects of fertilizers on the yield (t ha^{-1}) of Garlic at Chalanbil area, Natore (AEZ 5)

There was significant variation in garlic yield among the treatments at zero tillage for garlic production during 2013-14 (Table 30). The highest yield of garlic (8.93 t ha^{-1}) was recorded in treatment T_6 (T_1 + 25% NPK) which was statistically identical with T_2 and T_3 but higher than rest of the treatments. The lowest yield (4.95 t ha^{-1}) was noted in T_8.

Table 30. Effects of fertilizers on the bulb yield (t ha^{-1}) of garlic at Chalanbil, Natore

Treatments	Bulb yield (t ha^{-1})
T_1 = 100% (STB)	7.45bc
$T_2 = T_1$ + 25% N	8.09ab
$T_3 = T_1$ + 25% NP	8.20ab
$T_4 = T_1$ + 25% NK	7.56bc
$T_5 = T_1$ + 25% PK	7.60bc
$T_6 = T_1$ + 25% NPK	8.93a
T_7 = 75% of T_1	6.95c
T_8 = Control	4.95d
CV (%)	6.97

STB: Garlic (Amana) = $N_{100}P_{35}K_{100}S_{25}Zn_2B_1$

Integrated soil fertility and nutrient management for increased crop production

Monitoring and management of saline soil for increased crop production

The experiment was conducted at farmer's field of Shamnagar, Satkhira district in saline area during Rabi season 2014. There were six treatments Viz. T_1= Control, T_2 = Fertilizer for MYG, T_3 = Fertilizer for MYG + CD (5 t ha^{-1}), T_4 = Fertilizer for HYG, T_5 = Fertilizer for HYG + CD (5 t ha^{-1}) based on IPNS, T_6 = Farmers practices. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each replication represented a block. There were 18 (6×3) unit plots. Full dose of P, K, S, Zn and B fertilizers and ⅓ of N fertilizer were applied at the time of final land preparation. The rest of N fertilizer was applied in two equal split, i.e. 20 and 50 days of transplanting. Weeding, irrigation and insecticide was applied as and when necessary.

Table 31. Nutrient status of initial soil at farmer's field, Shamnagar, Satkhira

pH	OM (%)	Total N (%)	Available nutrients (ppm)				Exch. cation (meq %)	EC (dS/m)
			P	S	Zn	B	K	
7.8	2.60	0.14	13.6	20.2	-	-	0.29	4.6
Critical level	-	0.12	10	10	0.6	0.2	0.12	-

T. aman 2013

Application of different packages of fertilizers increased yields significantly over absolute control treatment (Table 32). The grain yields of Binadhan-8 ranged from 2.80 to 5.46 t ha^{-1}. The highest grain (5.46 t ha^{-1}) yield were recorded in treatment T_5 [Fertilizer for HYG + CD (5 t ha^{-1}) based on IPNS] and the lowest yield was obtained in treatment T_1. The straw yield ranged from from 3.15 to 7.31 t ha^{-1}. The highest straw (7.31 t ha^{-1}) were recorded in treatment T_5 [Fertilizer for HYG + CD (5 t ha^{-1})] and the lowest yield was obtained in treatment T_1. Suitable management practices of saline soil would be very crucial for crop production and combination of organic manure and chemical fertilizer was found to be better for higher crop production. From the result it may be concluded that the treatment T_5= Fertilizer for HYG + CD (5 t ha^{-1}) based on IPNS is the best which produced the highest yield of Binadhan-8.

Table 32. Grain and straw yields (t ha^{-1}) of T. aman rice at farmer's field, Shamnagar, Satkhira

Treatments	Grain			Straw		
	2012	2013	Mean	2012	2013	Mean
T_1	2.58	2.80d	2.69	3.52	3.15c	3.34
T_2	3.72	4.06c	3.89	4.27	5.47b	4.87
T_3	4.04	4.77b	4.41	5.13	6.47a	5.80
T_4	4.46	4.71b	4.59	6.86	6.87a	6.87
T_5	4.56	5.46a	5.01	6.58	7.31a	6.95
T_6	4.22	4.90b	4.56	5.07	6.71a	5.89
CV%		6.61			7.94	

Means with common letter(s) are not significantly different at 5% level of probality by DMRT.

Boro 2014

The grain yield of Binadhan-8 ranged from 2.70 to 5.72 t ha^{-1}. The highest grain yield (5.72 t ha^{-1}) was recorded in treatment T_5 [Fertilizer for HYG + CD (5t ha^{-1}) based on IPNS] and the lowest was obtained from treatment T_1. The straw yield ranged from 4.30 to 7.60 t ha^{-1}. The highest straw yield (7.60 t ha^{-1}) were recorded in treatment T_5 [Fertilizer for HYG + CD (5 t ha^{-1})] and the lowest was obtained from treatment T_1. Suitable management practices of saline soil would be very crucial for crop production and combination of organic manure and chemical fertilizers was found to be better for higher crop production. From the result it may be concluded that the treatment T_5 based on IPNS is the best, which produced the highest yield of Binadhan-8.

Mean yield of the crops

Result (Tables 32 & 34) revealed that application of different packages of fertilizers increased yield of crops over absolute control. The highest grain yield was obtained from treatment T_5, which is remarkably different from all other treatments. The lowest yields were recorded in absolute control treatment in all the cases.

Table 33. Soil salinity level of boro rice growing period during 2014 at farmer's field Shamnagar, Satkhira

Period	8th December 2013	23th January 2014	10th February 2014	1st March 2014	15th March 2014	1th April 2014	13th April 2014
Salinity (dS/m)	2.77	3.92	3.82	5.60	5.33	6.73	7.68

Table 34. Grain and straw yields (t ha^{-1}) of Boro rice during 2014 at farmer's field, Shamnagar, Satkhira

Treatments	Grain Yield			Straw Yield		
	2013	2014	Mean	2013	2014	Mean
T_1	3.58	2.70d	3.14	3.80	4.30d	4.05
T_2	5.90	3.57c	4.74	6.14	5.56c	5.85
T_3	5.80	4.86b	5.33	6.50	6.50bc	6.50
T_4	5.44	5.56a	5.50	5.81	7.46ab	6.64
T_5	6.05	5.72a	5.89	6.63	7.60a	7.12
T_6	4.70	4.88b	4.79	5.65	6.56b	6.11
CV%		7.42			8.72	

Means with common letter(s) are not significantly different at 5% level of probality by DMRT.

Nutrient uptake

The amounts of N, P, K and S uptake by Boro-T. aman rice as affected by different treatments combination are presented in Table 35. Nutrient uptake increased with increase of yield. The highest uptake of N, P, K and S were found in T_5 treatment. The nutrient uptake ranged among the nutrients is N (114-234), P (21-48), K (112-233) and S (8.6-26.6) kg ha^{-1}. It is especially important to note that the highest nutrient depletion occurred in the case of N and K. So due attention needs to be given to the addition of N and K fertilizer scheduling.

Table 35. Fertilization on nutrient uptake (kg ha^{-1}) due to Boro-T. aman effect cropping

Treatments	Nutrient uptake			
	N	P	K	S
T_1	114	21	112	8.6
T_2	181	35	186	15.6
T_3	208	43	207	20.7
T_4	216	38	229	23.2
T_5	234	48	233	26.6
T_6	195	44	191	19.7
Range	114-234	21-48	112-233	8.6-26.6

Economic analysis

Data in Table 36 shows the cost and benefit of different treatments used in the experiment. The highest gross margin of Tk. 1,58,170 ha^{-1} was obtained from the treatment T_5 followed by Tk 1,47,960 ha^{-1} and 1,44,925 ha^{-1} from the treatment T_4 and T_3, respectively. Among the treatments, T_3 treatment gave the highest marginal benefit cost ratio (3.58). The second highest marginal benefit-cost ratio was found in treatment T_5 (3.26).

Table 36. Economics of fertilizer use of the Boro-T. aman rice cropping pattern

Treatments	Economic yield (kg ha^{-1}) Rice (Boro + Aman)		Gross return (Tk ha^{-1})	Variable cost (Tk ha^{-1})	Gross margin (Tk ha^{-1})	Marginal gross margin (Tk ha^{-1})	MBCR
	Grain	Straw					
T_1	5,830	7,390	94,840	-	94,840	-	-
T_2	8,630	10,720	1,40,170	11,475	1,28,695	33,855	2.95
T_3	9,740	12,300	1,58,900	13,975	1,44,925	50,085	3.58
T_4	10,090	13,510	1,64,860	16,900	1,47,960	53,120	3.14
T_5	10,900	14,070	1,77,570	19,400	1,58,170	63,330	3.26
T_6	9,350	12,000	1,52,250	20,730	1,31,520	36,680	1.77

Grain = 15 Tk kg^{-1}; Straw = 1 Tk kg^{-1}; N = 45 Tk kg^{-1}; P = 150 Tk kg^{-1}; K = 50 Tk kg^{-1}; S = 55 Tk kg^{-1} and Zn = 102 Tk kg^{-1}, Cow dung = 500 Tk t^{-1}, MBCR = Marginal benefit cost ratio.

Determination of optimum and economic doses of nutrients for major crops developed by BINA under different environment

(a) Yields of Boro rice mutant lines at BINA farm, Mymensingh

Field trial of four mutant lines of Boro rice were conducted at BINA farm, Mymensingh during 2014 to determine the amount of fertilizer requirement for higher crop production. There were six treatments viz; T_1 = Control, $T_2 = N_{100}P_{16}K_{40}S_8Zn_2B_1$, $T_3 = N_{120}P_{20}K_{50}S_{12}Zn_2B_1$, $T_4 = N_{140}P_{24}K_{60}S_{16}Zn_2B_1$, $T_5 = N_{150}P_{28}K_{70}S_{20}Zn_2B_1$ and $T_6 = N_{160}P_{32}K_{80}S_{24}Zn_2B_1$ (kg ha^{-1}). The trails were laid out in a Randomized Complete Block Design (RCBD) with three replications. Results indicated that application of different levels of fertilizers increased yield significantly over control (Table 37). In mutant line RM (2)-40(c)-1-1-10, the highest grain yield (4.72 t ha^{-1}) was obtained from treatment T_6 and the highest straw (5.27 t ha^{-1}) yields were obtained from treatment T_5. The lowest yield was found in control treatment. In mutant line RC-(2)-2-4-1-2, the highest grain yield (4.74 t ha^{-1}) was obtained from treatment T_4 and the highest straw (6.16 t ha^{-1}) yields was obtained from treatment T_5. The lowest yield was found in control treatment.

Regarding mutant line RC-(2)-2-4-1-4, the highest grain (5.16 t ha^{-1}) and straw (6.22 t ha^{-1}) yields were obtained from treatment T_4. The lowest yield was found in control treatment. Regarding mutant line RC-(2)-2-4-3-1, the highest grain (5.60 t ha^{-1}) was obtained from treatment T_4 and the highest straw (6.52 t ha^{-1}) yield was obtained from treatment T_5. The lowest yield was found in control treatment.

Table 37. Grain and straw yields (t/ha) of four mutant lines at BINA farm, Mymensingh

Treatments	RM(2)-40(c)-1-1-10		RC-(2)-2-4-1-2		RC-(2)-2-4-1-4		RC-(2)-2-4-3-1	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	2.74b	2.98c	2.55c	2.67d	2.50d	2.80c	2.34d	4.62c
T_2	4.14a	4.88b	3.42b	4.54c	3.66c	4.33b	3.75c	5.81b
T_3	4.32a	4.75b	4.21a	5.26b	4.42b	5.64a	4.06c	6.32a
T_4	4.61a	5.00b	4.74a	5.98a	5.16a	6.22a	5.60a	6.25a
T_5	4.51a	5.27a	4.52a	6.16a	5.02ab	5.93a	5.43a	6.52a
T_6	4.72a	4.97b	3.48b	5.31b	4.545ab	5.59a	4.61b	6.45a
CV %	10.37	6.28	8.88	5.44	8.35	8.08	7.07	2.79

Mean with common letter(s) are not significantly different at 5% level by DMRT.

(b) Yields of soyabean mutants at BINA substation, Magura

Field trails were conducted at BINA substation, Magura to determine the amount of fertilizers requirement and to recommend different fertilizers for four Soybean mutants. There were six treatments viz; T_1=control, $T_2=N_{16}P_{20}K_{32}S_{12}Zn_2B_1$, $T_3=N_{24}P_{25}K_{40}S_{16}Zn_2B_1$, $T_4= N_{32}P_{30}K_{48}S_{20}Zn_2B_1$, $T_5 = N_{40}P_{35}K_{56}S_{24}Zn_2B_1$ and $T_6 = N_{48}P_{40}K_{64}S_{28}Zn_2B_1$. Results indicated that application of different fertilizers increased yield significantly over absolute control treatment (Table 38). In mutant line SBM-9, the highest grain (1.71 t ha^{-1}) and stover yields (4.0 t ha^{-1}) were obtained from treatment T_5 and the lowest grain and stover yields (1.06 & 1.4 t ha^{-1}) were found in control. In mutant line SBM-17, the highest grain yield (1.73 t ha^{-1}) was obtained from treatment T_4 and the highest stover yields (4.1 t ha^{-1}) was obtained from treatment T_5. The lowest grain and stover yields (0.86 & 1.17 t ha^{-1}) were found in control treatment.

In mutant line SBM-18, the highest grain (1.87 t ha^{-1}) was obtained from treatment T_5 and the highest stover yield (3.70 t ha^{-1}) was obtained from treatment T_4. The lowest grain and stover yields (1.03 and 2.66 t ha^{-1}) were found in control treatment. In mutant line SBM-22, the highest grain (1.73 t ha^{-1}) and stover yields (3.23 t ha^{-1}) were obtained from treatment T_3 and the lowest grain and stover yields (1.13 & 2.53 t ha^{-1}) were found in control treatment.

Table 38. Seed and Stover yields (t ha^{-1}) of soyabean mutants at BINA sub-station, Magura

Treatments	SBM-9		SBM-17		SBM-18		SBM-22	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
T_1	1.06c	1.4c	0.86b	1.17c	1.03c	2.66c	1.13b	2.53c
T_2	1.25bc	3.0b	1.57a	1.7bc	1.13c	2.63c	1.17b	2.6bc
T_3	1.5a	3.12b	1.43a	2.5b	1.6ab	3.33ab	1.73a	3.23a
T_4	1.60a	2.93b	1.73a	3.80a	1.50b	3.70a	1.30b	3.13abc
T_5	1.71a	4.0a	1.70a	4.10a	1.87a	3.5ab	1.30b	3.17ab
T_6	1.47ab	3.2b	1.42a	4.10a	1.23bc	3.00bc	1.1b	2.97abc
CV %	7.85	13.43	9.37	6.07	13.17	10.53	11.03	10.97

Mean with common letter(s) are not significantly different at 5% level by DMRT.

(c) Fertilizer recommendation for sesame at BINA sub-station, Magura

Field trail was conducted at BINA substation, Magura for Binatill-3 in kharif-I during 2014 to observe the response of different level of inorganic fertilizers for higher yield of sesame. There were six treatments viz; T_1= control, T_2= $N_{60}P_{15}K_{32}S_{12}Zn_2B_1$, T_3= $N_{75}P_{20}K_{40}S_{16}Zn_2B_1$, T_4= $N_{90}P_{25}K_{48}S_{20}Zn_2B_1$, T_5= $N_{105}P_{30}K_{56}S_{24}Zn_2B_1$ and T_6= $N_{120}P_{35}K_{64}S_{28}Zn_2B_1$ for the experiments. Results indicated that application of different inorganic fertilizers increased yield significantly over control (Table 39). The highest seed (1340 kg ha^{-1}) and stover yields (3600 kg ha^{-1}) were obtained from treatment T_4 and T_6, respectively. While, the lowest seed yield (700 kg ha^{-1}) was found in control (T_1). From the result it might be concluded that treatment T_4 found as the best fertilizer packages for higher production of Binatil-3.

Table 39. Yield (kg ha^{-1}) of sesame at BINA substation, Magura

Treatments	Seed yield	Stover yield
T_1	700b	2200b
T_2	1000ab	3160a
T_3	1330a	3500a
T_4	1340a	3360a
T_5	1060ab	3430a
T_6	1160a	3600a
CV %	11.72	15.44

Mean with common letter(s) are not significantly different at 5% level by DMRT.

(d) Fertilizer recommendation for Binadhan-9 at BINA farm, Mymensingh

Field trail was conducted at BINA farm, Mymensingh for Binadhan-9 to observe the response of fertilizers for higher yield of rice. There were eight treatments viz; T_1= control, T_2= STB fertilizer, T_3= STB fertilizer + 200% ZnB, T_4= 100% Organic fertilizer (OF, 16 t/ha), T_5= 75% STB + 25% OF, T_6= 50% STB + 50% OF, T_7 = 25% STB + 75% OF and T_8 = 100% STB + CD (5 t/ha) for the experiments. The trail was laid out in a Randomized Complete Block Design (RCBD) with three replications. Results indicated that application of different organic and inorganic fertilizers increased yield significantly over control (Table 40). The highest grain yield (2.61 t ha^{-1}) was obtained from treatment $T_{3,}$ while the lowest grain yield (1.55 t ha^{-1}) was found in control (T_1). On the other hand, the highest straw yield (3.49 t ha^{-1}) was found in treatment T_5 whereas, the lowest straw yields (2.29 t ha^{-1}) was obtained from control. From the result it might be concluded that treatment T_3 found as the best fertilizer packages for higher production of Binadhan-9.

Table 40. Effect of different levels of organic manure and inorganic fertilizer on yield and yield contributing characters of Binadhan-9 (kharif I) during 2014

Treatments	Plant height (cm)	Tiller/ hill (no.)	Panicle length (cm)	Filled grain/ panicle (no.)	Unfilled grain/ panicle (no.)	1000 seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1: Control	83	6.9	25.3	60	20	18.0	1.55	2.29
T_2: MYG STB fertilizer	94	9.8	26.6	75	22	18.1	2.54	3.28
T_3: HYG STB fertilizer + 200% ZnB	95	11.0	26.3	78	23	19.2	2.61	3.31
T_4: 100% Organic fertilizer (OF, 16 t ha^{-1})	87	7.1	25.9	70	23	19.3	1.79	2.50
T_5: 75% STB + 25% OF	94	10.4	26.5	83	22	17.9	2.27	3.49
T_6: 50% STB + 50% OF	89	9.8	25.7	83	22	18.0	2.07	3.20
T_7: 25% STB + 75% OF	95	10.7	27.4	92	23	18.9	2.56	3.18
T_8: 100% STB + CD (5 t/ha)	94	9.3	26.3	89	23	18.6	2.51	3.24

STB dose: $N_{80}P_{10}K_{25}S_{10}$

Contribution of rice straw to potassium supply and its impact on soil fertility in Boro rice

The experiment was conducted at the farmers' field of satkhira district. Seedbed was prepared in non-saline area of Satkhira district by using cowdung (@500 kg for 1000 m^2 seedbed). Chemical fertilizers were applied as N-P-K @ 10-5-5 kg ha^{-1}. Nitrogen was applied in two equal splits; 5 kg as basal and 5 kg as top dressing at 12 days after sowing. Main experiment was conducted at saline area of Satkhira and Patuakhali districts. The experiment was laid out in randomized complete block design and replicated thrice using a rice cultivar Binadhan-8 with six treatments (Table 41). Each replication represented a block. Full dose of P-K-S and $1/3^{rd}$ of N were applied as basal. The rest N was applied in two equal splits, at 30 and 60 days of transplanting. The salinity record was done at every fifteen days interval.

Table 41. Treatments detail of the experiment

Treatments	Details
T_1	Control (No fertilizer)
T_2	N-P-K-S @ 160-30-60-18
T_3	N-P-S @ 160-30-18+ RS @ 1.25 t ha^{-1} + K @ 30
T_4	N-P-S @ 160-30-18 + RS @ 1.25 t ha^{-1} + K @ 45
T_5	N-P-S @ 160-30-18+ RS @ 2.5 t ha^{-1} + K @ 30
T_6	N-P-S @ 160-30-18+ RS @ 2.5 t ha^{-1} + K @ 45

*RS: Rice straw; Fertilizer rate kg ha^{-1} (FRG-2012)

Results

T. aman 2013

The yield and yield contributing characters of T.aman rice (var. Binadhan-8) were influenced significantly by the different treatments with K fertilizer along with residual effect of rice straw incorporation (Table 42). The grain yield ranged from 2.65 to 5.36 t ha^{-1}. The highest grain yield was observed in treatment T_6 N-P-S @ 90-12-10+ RS @ 2.5 t ha^{-1} + K @ 27 which was statistically identical to T_4 N-P-S @ 90-12-10 + RS @ 1.25 t ha^{-1} + K @ 27. In treatment T_6, 27 kg ha^{-1} (75% of recommended dose) potassium fertilizer was applied along with 2.5 t ha^{-1} rice straws and in treatment T_4 same amount of potassium fertilizer was applied with 1.25 t ha^{-1} rice straws that supplied sufficient amount of K and treatment T_6 gave the highest yield. It revealed that rice straw can compensate the K nutrient from the soil. The lowest grain yield (2.65 t ha^{-1}) was obtained in treatment T_1 (control). Like grain yield, the straw yield also differed significantly due to the treatments (Table 31). The straw yield varied from 3.80 to 7.26 t ha^{-1}. The highest straw yield (7.26 t ha^{-1}) was obtained in treatment T_6 N-P-S @ 90-12-10+ RS @ 2.5 t ha^{-1} + K @ 27 and the lowest straw yield (3.80 t ha^{-1}) was found in treatment T_1 (control).

Table 42. Yield and yield attributes of Binadhan-8 at farmers field, Khori Villa, Satkhira

Treatments	Plant height (cm)	Panicle length (cm)	Tillers hill^{-1} (no.)	1000-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	84.53d	22.1b	13.83b	22.0b	2.993d	3.76c
T_2	91.56bc	23.86a	17.53a	24.16a	5.1abc	6.7ab
T_3	89.86c	23.2ab	17.1a	23.5a	4.73c	6.13b
T_4	93.66ab	24.6a	17.46a	24.36a	5.63ab	7.16a
T_5	92.26b	24.13a	17.53a	24.06a	4.83bc	6.2b
T_6	94.80a	24.53a	17.93a	24.5a	5.76a	7.13a
CV%	1.45	3.79	6.74	3.42	9.62	8.33

Mean with common letter(s) in a column are not significantly different at the 5% level by DMRT.

Salinity Status

The salinity status is very important throughout the growing season. The salinity status of the experiment site ranged from 1.18 to 2.46 (dS m^{-1}) during the whole growing season (July to October) (Table 43). This aman season is considered as wet season and abundant rainfall occurred and creates suitable condition of low salinity in saline areas for crop growth.

Table 43. Soil salinity level of boro rice growing period during 2013 at farmer's field, Khori Villa, Satkhira

Period	23th July	8th August	23th August	8th September	23th September	8th October	23th October
Salinity (dSm^{-1})	1.18	1.54	2.13	1.66	2.45	2.19	2.46

Fertility status

The coastal regions of Bangladesh are quite low in soil fertility. The levels of soil pH, O.C., N, P, S and K content prior to and after completion of T. aman rice are presented in Table 44 and 45. The changes in soil pH, O.M., N, P, S and K contents were very low due to the treatments and one season cultivation. Thus, in addition to salinity, plant nutrients in soils affect plant growth. Soil reaction values (pH) range from 6.9-7.5 (Table 45) and the pH values of the surface soils being lower than those of the sub-surface soils. In places with higher pH values, micronutrients' deficiencies may have existed. The soils are in general poor in organic matter content and the top soils organic matter content ranges from 2 to 2.5%. The total N contents of the soils are generally low, mostly around 0.10 - 0.12%. The low N content may be attributed to low organic matter contents of most of the soils. Available P and S status of the soils ranges from 13.8-15.6 ppm and 16.85-25.40 ppm, respectively. The potassium content ranged from 0.18-0.24 meq%.

Table 44. Nutrient status of initial and nursery bed soils at Satkhira

Soils	pH	O.M. (%)	Total N (%)	Available (ppm)		Exchangeable K (meq %)	EC (dS m^{-1})
				P	S		
Initial soil (experimental field)	7.5	2.24	0.11	14.6	18.43	0.19	1.21
Nursery bed soil	7.2	1.90	0.10	12.2	21.11	0.23	1.12

Table 45. Soil Nutrient status of post-harvest soil

Treatments	pH	OM (%)	N (%)	P (ppm)	K (meq %)	S (ppm)
T_1	7.5	2.12	0.10	15.4	0.18	16.85
T_2	7.5	2.00	0.11	14.4	0.22	22.75
T_3	6.9	2.00	0.11	14.2	0.20	22.50
T_4	7.0	2.50	0.12	15.1	0.24	24.70
T_5	7.3	2.30	0.12	15.6	0.24	24.00
T_6	7.3	2.40	0.11	13.8	0.23	25.40
Range	6.9-7.5	2.00-2.50	0.10-0.12	13.8-15.6	0.18-0.24	16.85-25.40

Nutrient uptake

The nutrient uptake by the plant is presented in Table 46. The total N uptake by grain and straw varied from 61.4 to 88.5 kg ha^{-1}. The highest total N uptake was recorded in treatment T_6 and the lowest N uptake was found in treatment T_1. The highest total P uptake (38.4 kg ha^{-1}) was recorded in treatment T_6 while the lowest (13.6 kg ha^{-1}) was found in treatment T_1. The total K uptake by grain and straw also varied from 36.4 to 75.3 kg ha^{-1}. The highest total K uptake (75.3 kg ha^{-1}) was recorded in treatment T_6 and the lowest (36.4 kg $ha^{-}1$) was found in treatment T_1. The total S uptake by grain and straw also varied from 4.4 to 19.6 kg ha^{-1}. The highest total S uptake (19.6 kg ha^{-1}) was recorded in treatment T_6 and the lowest S uptake (4.4 kg ha^{-1}) was found in treatment T_1. The uptake of S increased significantly with increase in K levels in rice.

Table 46. Nutrients uptake by grain and straw

Treatments	Nutrients uptake (kgha^{-1}) by grain and straw			
	N	P	K	S
T_1	61.4c	13.6c	36.4c	4.4c
T_2	80.5b	36.7b	72.4b	17.1b
T_3	81.4b	32.0c	72.7b	17.1b
T_4	87.2a	37.5.ab	73.7b	19.0ab
T_5	82.6b	36.2b	73.0b	19.0ab
T_6	88.5a	38.4a	75.3a	19.6a
CV (%)	8.3	12.3	12.4	8.2

In a column, figure(s) followed by the same letter(s) do not differ significantly at 5% level by DMRT.

Boro 2014 at Satkhira

The yield and yield contributing characters of Boro rice (var. Binadhan-8) were influenced significantly by the different treatments with K fertilizer along with residual effect of rice straw incorporation (Table 47). The grain yield ranged from 2.93 to 5.76 t ha^{-1}. The highest grain yield was observed in treatment T_6 (N-P-S @ 90-12-10+ RS @ 2.5 t ha^{-1} + K @ 27). In treatment T_6, 27 kg ha^{-1} (75% of recommended dose) potassium fertilizer was applied along with 2.5 t ha^{-1} rice straws and in treatment T_4 same amount of potassium fertilizer was applied with 1.25 t ha^{-1} rice straws that supplied sufficient amount of K and treatment T_6 gave the highest yield. It revealed that rice straw can compensate the K nutrient from the soil. The lowest grain yield (2.65 t ha^{-1}) was obtained in treatment T_1 (control). Like grain yield, the straw yield also differed significantly due to the treatments (Table 47). The straw yield varied from 3.76 to 7.16 t ha^{-1}. The highest straw yield (7.16 t ha^{-1}) was obtained in treatment T_4 which was statistically identical to T_4 and the lowest straw yield (3.76 t ha^{-1}) was found in treatment T_1 (control).

Table 47. Yield and yield attributes of Binadhan-8 at farmers field, Debhata, Satkhira

Treatments	Plant height (cm)	Panicle length (cm)	Tillers $hill^{-1}$ (no.)	1000-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	84.53d	22.1b	13.83b	22.00b	2.93d	3.76c
T_2	91.56bc	23.86a	17.53a	24.16a	5.10abc	6.70ab
T_3	89.86c	23.2ab	17.10a	23.50a	4.73c	6.13b
T_4	93.66ab	24.6a	17.46a	24.36a	5.63ab	7.16a
T_5	92.26b	24.13a	17.53a	24.06a	4.83bc	6.20b
T_6	94.8a	24.53a	17.93a	24.50a	5.76a	7.13a
CV%	1.45	3.79	6.74	3.42	9.62	8.33

Boro 2014 at Patuakhali

The yield and yield contributing characters of Boro rice (var. Binadhan-8) were influenced significantly by the different treatments with K fertilizer along with residual effect of rice straw incorporation (Table 48). The grain yield ranged from 2.50 to 5.8 t ha^{-1}. The highest grain yield was observed in treatment T_6 (N-P-S @ 90-12-10+ RS @ 2.5 t ha^{-1} + K @ 27).

In treatment T_6, 27 kg ha^{-1} (75% of recommended dose) potassium fertilizer was applied along with 2.5 t ha^{-1} rice straws and in treatment T_2 full dose of potassium was applied but treatment T_6 gave the highest yield. It revealed that rice straw can compensate the K nutrient from the soil. The lowest grain yield (2.50 t ha^{-1}) was obtained in treatment T_1 (control). Like grain yield, the straw yield also differed significantly due to the treatments (Table 48). The straw yield varied from 3.70 to 7.00 t ha^{-1}. The highest straw yield (7.00 t ha^{-1}) was obtained in treatment T_6 and the lowest straw yield (3.70 t ha^{-1}) was found in treatment T_1 (control).

Table 48. Yield and yield attributes of Binadhan-8 at farmers field, Kolapara, Patuakhali

Treatments	Plant height (cm)	Panicle length (cm)	Tillers $hill^{-1}$ (no.)	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	83.1b	18.53b	11.3b	22.0c	2.50c	3.70d
T_2	90.36a	23.5a	17.0a	24.0ab	5.20ab	6.20bc
T_3	90.23a	22.0a	16.6a	23.5b	4.60b	5.80c
T_4	92.16a	23.4a	17.4a	24.13a	5.50ab	6.60ab
T_5	92.16a	23.0a	17.03a	24.0ab	4.80b	6.00bc
T_6	92.96a	23.4a	17.6a	24.26a	5.80a	7.00a
CV%	3.42	3.37	8.09	1.24	11.21	7.21

Conclusion

Rice straw contains more potassium compared to the other nutrients, which can be used as a source of K supply to crops. In treatment T_6, 27 kg ha^{-1} (75% of recommended dose) potassium fertilizer was applied along with 2.5 t ha^{-1} rice straws and in treatment T_4 same amount of potassium fertilizer was applied with 1.25 t ha^{-1} rice straws that supplied sufficient amount of K and treatment T_6 gave the highest yield. But in treatment T_2 where full dose of chemical fertilizer was applied but yield was not higher than that of T_6 and T_4. It revealed that rice straw can compensate the K nutrient from the soil. Thus, rice straw application can be used as a source of organic matter to improve nutrient status of the soil and enhance the fertility of the coastal saline areas which otherwise are poor in soil OM status.

Assessing the effect of split application of potassium on T. aman rice in saline area

The experiment was conducted to observe the split application of potassium along with cowdung in the saline area of Noakhali district. Seedbed was prepared in non-saline area of Noakhali district by using cowdung (@500 kg for 1000 m^2 seedbed). Chemical fertilizers were applied as N-P-K @ 10-5-5 kg ha^{-1}. Nitorgen was applied in two equal splits; 5 kg as basal and 5 kg as top dressing at 12 days after sowing. The date of sowing was 1st July 2013 and transplanting was done on 30th July 2013 in the main field. Main experiment was conducted in saline area of Noakhali district. The experiment was laid out in randomized block design and replicated thrice using a rice cultivar Binadhan-8 with five treatments consisting of split application of nutrient (Table 49). Each replication represented a block. Full dose of P, S and 1/3rd of N were applied as basal. The rest N was applied in two equal splits, at 25th and 45th days of transplanting. Potassium was applied in two equal splits (as basal and at 25 DAT) and three splits (as basal, at 25 DAT and 45 DAT) according to the plan of the experiment. Cowdung was added before final land preparation. The salinity was recorded at every fifteen days interval. The crop was harvested on 28th October 2013.

Table 49. Treatments detail of the experiment

Treatments	Detail
T_1	Control (N-P-K-S @ 90-12-36-10)
T_2	NPS+ K in two split
T_3	NPS+ K in two split + CD*
T_4	NPS+ K in three split
T_5	NPS+ K in three split + CD

*CD: Cowdung@ 5 t ha^{-1}; Fertilizer rate kg ha^{-1}

Results

The yield and yield contributing characters of T.aman rice was influenced significantly by the different treatments with split application of K fertilizer (Table 50). The grain yield ranged from 3.78 to 4.67 t ha^{-1}. The highest grain yield was observed in treatment T_3 (N-P-S+ K in two split + cowdung) which was statistically identical to all other treatment except T_1 where whole potassium was applied as basal. The increased yield of rice due to potassium fertilizer application in two equal splits (half at basal and half at maximum tillering stage) was attributed directly to continuous supply of K to the crop during crop growth stages. This cause a significant increase in panicle length, number of grains per panicle and 1000 grain weight ultimately resulted in maximum paddy yield. Like grain yield, the straw yield also differed significantly due to the treatments (Table 50). The straw yield varied from 4.33 to 6.60 t ha^{-1}. The highest straw yield (6.60 t ha^{-1}) was obtained in treatment T_3 and the lowest straw yield (4.33 t ha^{-1}) was found in treatment T_1 (control).

Table 50. Yield and yield attributes of Binadhan-8 at farmers field, Companygonj, Noakhali

Treatments	Plant height (cm)	Panicle length (cm)	Tiller $hill^{-1}$ (no.)	1000-seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	88.43	24.5b	10.47b	22.5	3.78b	5.13b
T_2	92.53	24.9b	11.93ab	24.3	4.21a	5.76ab
T_3	95.0	25.1ab	13.0a	24.2	4.67a	6.60a
T_4	90.8	24.5b	11.87ab	25.2	3.98ab	5.56b
T_5	92.47	26.3a	12.07ab	25.1	4.55a	6.30ab
CV%	4.01	2.83	10.92	6.15	13.32	9.41

Mean with common letter(s) are not significantly different at the 5% level by DMRT.

Salinity Status

The monitoring of salinity status is very important throughout the growing season. The salinity status of the experimental site ranged from 2.45 to 4.12 (dS m^{-1}) during the whole growing season (July to October) of the experiment (Table 51). The aman season is considered as wet season and abundant rainfall occurred which lowered the salinity level in saline areas suitable for crop growth.

Table 51. Soil salinity level of T.aman rice growing period during 2013 at farmer's field Companyganj, Noakhali

Period	30^{th} July	14^{th} August	30^{th} August	14^{th} September	30^{th} September	14^{th} October	28^{th} October
Salinity (dS m^{-1})	3.95	2.45	3.11	3.75	3.55	3.85	4.12

Fertility status

The levels of soil pH, O.M., N P K and S in initial soil and in soils after completion of T. aman rice are presented in Table 52 and 53. The changes in soil pH, O M, N P K and S were very small due to the treatments and the cropping system. The coastal regions of Bangladesh are quite low in soil fertility. Thus in addition to salinity, nutrients in soils affect plant growth. Soil reaction values (pH) range from 6.9-7.1 and the pH value of the surface soils was lower than those of the sub-surface soils. The soils are in general poor in organic matter content and the top soils organic matter content ranges from 1.80 to 1.90%. The total N contents of the soils are generally low, mostly around 0.10 - 0.12%. The low N content may be attributed to low organic matter contents of most of the soils. Available P and S status of the soils ranges from 2.75-2.94 ppm and 16.5-17.8 ppm respectively. The potassium content ranged from 0.38-0.48 meq%.

Table 52. Initial nutrient status of soils in main field and nursery bed at Companyganj, Noakhali

Soils	pH	O M (%)	Total N (%)	Available (ppm)		Exchangeable K (meq %)	EC (dS m^{-1})
				P	S		
Initial soil (experimental field)	6.9	1.80	0.10	2.94	15.2	0.42	4.95
Nursery bed soil	7.2	1.75	0.11	3.45	21.11	0.27	2.13

Table 53. Post-harvest soil nutrient status of main field

Treatments	pH	O.M. (%)	N (%)	P (ppm)	K (meq%)	S (ppm)
T_1	7.0	1.80	0.10	2.90	0.38	16.8
T_2	7.1	1.85	0.11	2.88	0.40	16.5
T_3	7.0	1.86	0.10	2.87	0.48	16.9
T_4	6.9	1.85	0.11	2.75	0.40	17.2
T_5	7.1	1.90	0.12	2.75	0.47	17.6
Range	6.9-7.1	1.80-1.90	0.10-0.12	2.75-2.94	0.38-0.48	16.5-17.8

Conclusion

In Bangladesh, wet season rice crop is important one to meet the ever increasing demand of the rice. Suitable nutrient management practices can maximize the yield potential of theBinadhan-8 in saline conditions. Split application of K with biocompost in the form of cowdung is the suitable and economical practices to harness the productivity potential of the degraded land with suitable cultivar(s). To obtain maximum benefit, K application in two splits (½ at basal and remaining ½ at 25 DAT) may be promoted. However, it needs further investigation in subsequent studies, involving more number of rice varieties to formulate a general recommendation.

Effect of different organic matter on the yield of T. aman rice in saline areas

The experiment was conducted to observe the effect of different organic matter in the saline area of Patuakhali district. Seedbed was prepared in non-saline area of Patuakhali district by using cowdung (@500 kg for 1000 m^2 seedbed). Chemical fertilizers were applied as N-P_2O_5-K_2O @ 10-5-5 kg ha^{-1}. N was applied in two equal splits; 5 kg as basal and 5 kg as top dressing at 12 days after sowing. The date of sowing was 2nd July 2013 and transplanting was done on 31st July 2013 in the main field. Main experiment was conducted at farmer's field of saline area of Patuakhali district. The experiment was laid out in randomized block design and replicated thrice using a rice cultivar Binadhan-8 with six treatments (Table 54). Each replication represented a block. Full dose of P, K, S and 1/3rd of N were applied as basal. The rest N was applied in two equal split, at 25 and 45 days of transplanting. The organic matter/residues were applied well before final land preparation. The nutrient composition of organic manures is presented in Table 55. The salinity was recorded at every fifteen days interval during the crop season. The crop was harvested on 30th October 2013.

Table 54. Treatments detail of the experiment

Treatments	Detail
T_1	Control (No fertilizer)
T_2	Chemical fertilizer (N-P-K-S @ 90-12-36-10)
T_3	T_2 + Cowdung @ 5 t ha^{-1}
T_4	T_2 + Poultry manure @ 3 t ha^{-1}
T_5	T_2 + Rice straw @ 5 t ha^{-1}
T_6	T_2 + De-oiled rice bran @ 5 t ha^{-1}

Fertilizer rate kg ha^{-1}

Table 55. Nutrient composition of applied organic manures

Organic manure	Moisture (%)	N (%)	P (%)	K (%)	S (%)
Cowdung	35	1.0	0.3	0.45	-
Poultry manure	35	1.25	0.7	0.1	-
Rice straw	30	0.4	0.1	1.5	-
De-oiled rice bran	20	1.15	2.25	0.1	0.15

Results

Results indicated that application of different dose of fertilizers increased grain and straw yields of rice which differed significantly over control (Table 56). The grain yield ranged from 2.10 to 5.28 t ha^{-1} and the highest grain yield (5.28 t ha^{-1}) was recorded in treatment T_6 which was statistically identical with all other treatment except T_1 with lowest yield (2.10 t ha^{-1}). Use of cowdung, poultry manure and rice straw with chemical fertilizer increased the grain yield in treatment, T_3 (4.91 t ha^{-1}), T_4 (5.16 t ha^{-1}) and T_5 (5.20 t ha^{-1}) respectively. De-oiled rice bran, as a organic manure had more pronounced effect than, rice straw, poultry manure and cowdung. Like grain yield, the straw yield of T. aman rice was also affected significantly by the application of fertilizers and manures in different treatments. The straw yield were ranged from 4.63 to 7.43 t ha^{-1} and the highest straw yield (7.43 t ha^{-1}) was recorded in treatment T_5 (N-P-K-S@ 90-12-36-10+ rice straw@ 5 t ha^{-1}) while; the lowest (4.63 t ha^{-1}) was obtained in treatment T_1 (control).

Table 56. Yield and yield attributes of Binadhan-8 at farmers field, Patuakhali

Treatments	Plant height (cm)	Panicle length (cm)	Tiller $hill^{-1}$ (no.)	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	87.07c	19.93b	12.40cd	21.6	2.10b	4.63c
T_2	91.67bc	24.47a	13.53abc	23.5	4.86a	6.68b
T_3	87.47c	23.30a	12.87bcd	24.3	4.91a	6.86ab
T_4	97.95a	24.07a	13.93ab	25.6	5.16a	6.85ab
T_5	93.47ab	23.53a	11.93d	25.4	5.20a	7.43a
T_6	93.8ab	24.06a	14.40a	25.1	5.28a	7.13a
CV%	3.03	3.86	5.35	7.31	10.92	4.95

Mean with common letter(s) are not significantly different at the 5% level by DMRT.

Salinity Status

The salinity status in the field is very important throughout the growing season. The salinity status of the experiment site ranged from 1.18 to 2.46 (dS m^{-1}) during the crop season (July to October) (Table 57). Aman season is considered as wet season with abundant rainfall creating suitable condition of low salinity in saline areas for crop growth.

Table 57. Soil salinity level of T.aman during 2013 at farmer's field, Patuakhali

Period	1st August	15th August	1st September	15th September	1st October	15th October	30th October
Salinity (dS m^{-1})	1.18	1.54	2.13	1.66	2.45	2.19	2.46

Fertility status

The levels of soil pH, OM, N, P, K and S in initial soil before start of experiment with T. aman rice are presented in Table 58. Application of organic manure and crop residue with chemical fertilizer increased the OM., P, K and S contents of soil (Table 58). The changes in soil pH, OM, N, P, K and S contents were very low due to the treatments and the cropping system. The organic matter status was considerably improved due to the application of organic manure or crop residue which varied from 2.00 to 2.50 over the treatments. Increase in exchangeable K due to the application of organic manure might be attributed to the release of K to the available pool of the soil besides the reduction of K fixation.

Table 58. Nutrient status of initial and nursery bed soils at Patuakhali

Soils	pH	OM (%)	Total N (%)	Available (ppm)		Exchangeable K (meq %)	EC (dS m^{-1})
				P	S		
Initial soil (experimental site)	7.8	2.18	0.12	15.85	28.4	0.38	2.10
Nursery bed soil	6.9	2.45	0.12	16.6	23.18	0.28	1.27

Table 59. Soil Nutrient status of post-harvest soil

Treatments	pH	OM (%)	N (%)	P (ppm)	K (meq %)	S (ppm)
T_1	7.5	2.12	0.09	13.5	0.21	25.5
T_2	7.8	2.00	0.11	15.8	0.35	29.75
T_3	6.9	2.00	0.10	16.2	0.36	29.50
T_4	7.8	2.50	0.12	16.6	0.33	29.70
T_5	7.5	2.30	0.11	16.7	0.35	29.00
T_6	7.3	2.40	0.10	16.6	0.34	29.40
Range	6.9-7.8	2.00-2.50	0.09-0.12	13.5-16.7	0.21-0.38	25.5-29.70

Conclusion

Integrated use of inorganic fertilizers with the organic manures is advocated to minimize complete dependence on inorganic fertilizers. Organic manures are generally made up of by-products of the crops, animal litters, household garbage and other miscellaneous organic substance which have sufficient amount of the nutrients to provide complimentary nutrition and maintain the fertility status of the soil. The obtained results clearly depicted highest grain yield (5.28 t ha^{-1}) in treatment T_6 (chemical fertilizers with de-oiled rice bran@ 5 t ha^{-1}) fallowed by (5.20 t ha^{-1}) in treatment T_5 (chemical fertilizers with rice straw@ 5 t ha^{-1}) as organic matter. It is concluded that de-oiled rice bran and rice straw can be used as potential bio-organic matter to maintain the soil fertility along with the higher yield potential of the degraded lands.

Evaluation of ACI and Kazi organic fertilizers for tomato production at two locations of Bangladesh

Organic fertilizer (OF) has various positive effects on soil, particularly soil fertility and productivity. Two experiments were conducted at BINA Head quarter farm Mymensingh and Magura to observe the effect of ACI organic fertilizers on tomato production during second week of November 2013 to last week of March, 2014. There were seven fertilizer treatments viz: T_1: RCF (N_{120} P_{35} K_{70} S_{15} Zn_2 $B_{0.5}$), T_2 : 85% RCF, T_3 : 70% RCF, T_4 : 85% RCF + 3 t ha^{-1} OF, T_5 : 85% RCF + 1t ha^{-1} OF, T_6 : 70% RCF + 3 t ha^{-1} OF and T_7 : 70% RCF + 1 t ha^{-1} OF. The experiments were laid out in a RCBD (Randomized Complete Block Design) with three replications. The fruits were harvested three times at different plant growth. The fresh weight of tomato ranged from 44.6 to 61.0 t ha^{-1} at Mymensingh and 42.0 to 59.5 t ha^{-1} at Magura, respectively. The highest yield was recorded in treatment T_4 (85% T_1 + 3 t ha^{-1} ACI OF) at both the locations. The highest yield of 61.0 t ha^{-1} was recorded in treatment T_4 (85% RCF + 3 t ha^{-1} ACI OF) at Mymensingh and 59.5 t ha^{-1} at Magura. The highest MBCR was obtained in T_4 treatment by ACI organic fertilizer at Mymensingh 2.54 and 2.46 at Magura, respectively.

Table 60. Effect of ACI organic fertilizer on tomato production (t ha^{-1}) at Mymensingh and Magura

Treatments	Fresh Yield of Tomato (t ha^{-1})				Yield increase/ decrease (%)	MBCR
	First harvest	Second harvest	Third harvest	Total		
Mymensingh						
T_1 : RCF ($N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$)	7.6ab	19.8c	21.0cd	48.4cde	-	-
T_2: 85% RCF	7.0ab	19.3c	20.0d	46.3de	-4.33	-
T_3: 70% RCF	6.5b	18.5c	19.6d	44.6e	-7.85	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	8.0ab	25.6a	27.4a	61.0a	26.03	2.54
T_5 : 85% T_1 + 1 t ha^{-1} OF	8.0ab	21.8bc	23.6bc	53.5bc	10.53	2.04
T_6 : 70% T_1 + 3 t ha^{-1} OF	8.1a	23.8ab	25.0ab	56.9ab	17.56	1.49
T_7 : 70% T_1 + 1 t ha^{-1} OF	7.0ab	20.8bc	22.2bcd	50.0cd	3.30	0.53
CV (%)	10.46	8.16	7.07	5.41	-	-
SE (±)	0.45	1.00	0.92	1.60	-	-
Magura						
T_1 : RCF ($N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$)	7.0ab	19.7bc	20.5bc	47.2cd	-	-
T_2: 85% RCF	7.4ab	18.3c	20.5bc	46.2cd	-2.11	-
T_3: 70% RCF	6.2b	17.6c	18.2c	42.0d	-11.01	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	8.1a	24.1a	27.3a	59.5a	26.05	2.46
T_5 : 85% T_1 + 1 t ha^{-1} OF	8.2a	21.8abc	23.6abc	53.6abc	13.55	1.93
T_6 : 70% T_1 + 3 t ha^{-1} OF	7.8a	23.4ab	25.0ab	56.2ab	19.06	1.71
T_7 : 70% T_1 + 1 t ha^{-1} OF	7.4ab	19.2bc	22.0abc	48.6bcd	2.96	0.41
CV (%)	9.24	11.12	13.08	8.83	-	-
SE (±)	0.39	1.32	1.69	2.57	-	-

Figure in a column, having common letter (s) do not differ significantly at 5% level of probability.

*Chemical fertilizer @ $N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$ kg ha^{-1} at Magura & Mymensingh. Tomato = Tk 10 kg^{-1}, Urea=Tk 16 kg^{-1}, TSP = Tk 22 kg^{-1}, MP = Tk 20 kg^{-1}, Gypsum = Tk 10 kg^{-1}, "ACI" Organic fertilizer = Tk 12 kg^{-1}

Kazi organic fertilizer

Two experiments were conducted at BINA head quarter farm Mymensingh and substation farm Rangpur to observe the effect of Kazi organic fertilizers on tomato production during second week of November 2013 to last week of March, 2014. There were seven fertilizer treatments viz: T_1: RCF (N_{120} P_{35} K_{70} S_{15} Zn_2 $B_{0.5}$), T_2 : 85% RCF, T_3 : 70% RCF, T_4 : 85% RCF + 3 t ha^{-1} OF, T_5 : 85% RCF + 1t ha^{-1} OF, T_6 : 70% RCF + 3 t ha^{-1} OF and T_7 : 70% RCF + 1 t ha^{-1} OF. The experiments were laid out in a RCBD (Randomized Complete Block Design) with three replications. The fruits were harvested three times at different plant growth. The fresh weight of Tomato ranged from 37.1 to 57.2 t ha^{-1} at Mymensingh and 42.6 to 62.5 t ha^{-1} at Rangpur, respectively. The highest yield was recorded in treatment T_4 (85% T_1 + 3 t ha^{-1} Kazi OF) at both the locations. The highest yield of 57.2 t ha^{-1} was recorded in treatment T_4 (85% RCF + 3 t ha^{-1} Kazi OF) at Mymensingh and 62.5 t ha^{-1} at Rangpur. The highest MBCR was obtained in T_4 treatment by Kazi organic fertilizer at Mymensingh 2.53 and 3.72 at Rangpur, respectively.

Table 61. Effect of Kazi organic fertilizer on tomato production (t ha^{-1}) at Mymensingh and Rangpur

Treatments	Fresh Yield of Tomato (t ha^{-1})				Yield increase/ decrease (%)	MBCR
	First harvest	Second harvest	Third harvest	Total		
Mymensingh						
T_1 : RCF ($N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$)	7.5a	18.4bcd	20.5cd	46.4cd	-	0.00
T_2: 85% RCF	5.7b	16.3cd	18.2cd	40.2d	-13.62	-
T_3: 70% RCF	5.1b	15.5d	16.5d	37.1d	-20.0	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	7.5a	23.2a	26.5a	57.2a	23.27	2.53
T_5 : 85% T_1 + 1 t ha^{-1} OF	5.8a	18.7bc	23.1bc	47.6bc	2.58	0.31
T_6 : 70% T_1 + 3 t ha^{-1} OF	6.6a	20.5ab	23.6ab	50.7b	9.26	0.66
T_7 : 70% T_1 + 1 t ha^{-1} OF	7.0ab	19.1bc	21.3cd	47.4cd	2.15	0.30
CV (%)	15.07	15.74	17.1	12.39	-	-
SE (±)	0.56	1.71	2.11	3.33	-	-
Rangpur						
T_1 : RCF ($N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$)	8.2a	19.0bcd	20.2bc	47.4bc	-	0.0
T_2: 85% RCF	6.7bc	17.5cd	20.0cd	44.2c	-6.75	-
T_3: 70% RCF	6.7c	16.8d	19.1d	42.6c	-10.12	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	8.4a	25.6a	28.5a	62.5a	31.85	3.72
T_5 : 85% T_1 + 1 t ha^{-1} OF	8.1bc	21.0bc	23.5ab	52.6b	10.97	2.70
T_6 : 70% T_1 + 3 t ha^{-1} OF	8.1ab	21.4b	25.0ab	54.5b	14.97	1.53
T_7 : 70% T_1 + 1 t ha^{-1} OF	7.5a	18.4bcd	20.5bc	46.4b	-2.11	-
CV (%)	16.48	19.47	16.70	10.95	-	-
SE (±)	0.73	2.24	2.16	3.64	-	-

Figure in a column, having common letter (s) do not differ significantly at 5% level of probability.

*Chemical fertilizer @ N_{120} P_{35} K_{70} S_{15} Zn_2 $B_{0.5}$ kg ha^{-1} at Rangpur & Mymensingh. Tomato = Tk 10 kg^{-1}, Urea = Tk 16 kg^{-1}, TSP = Tk 22 kg^{-1}, MP = Tk 20 kg^{-1}, Gypsum = Tk 10 kg^{-1}, "KAZI" Organic fertilizer = Tk 10 kg^{-1}

Evaluation of Mukti and GTS organic fertilizers for Cabbage production at two locations of Bangladesh

Two experiments were conducted at BINA head quarter farm Mymensingh and BINA substation farm Ishurdi to observe the effect of Mukti organic fertilizers on cabbage production during rabi season 2014. There were seven fertilizer treatments viz: T_1: RCF (N_{150} P_{50} K_{100} S_{16} Zn_2 $B_{0.5}$), T_2 : 85% RCF, T_3 : 70% RCF, T_4 : 85% RCF + 3 t ha^{-1} OF, T_5 : 85% RCF + 1t ha^{-1} OF, T_6 : 70% RCF + 3 t ha^{-1} OF and T_7 : 70% RCF + 1 t ha^{-1} OF. The experiments were laid out in a RCBD (Randomized Complete Block Design) with three replications. The cabbage was harvested three times. The fresh weight of cabbage ranged from 32.3 to 49.5 t ha^{-1} at Mymensingh and 31.4 to 50.5 t ha^{-1} at Ishurdi, respectively. The highest yield was recorded in treatment T_4 (85% T_1 + 3 t ha^{-1} Mukti OF) at both the locations. The highest yield of 49.5 t ha^{-1} was recorded in treatment T_4 (85% RCF + 3 t ha^{-1} Mukti OF) at Mymensingh and 50.5 t ha^{-1} at Ishurdi. The highest MBCR was obtained in T_4 treatment by Mukti organic fertilizer at Mymensingh 1.26 and 2.05 at Ishurdi, respectively.

Table 62. Effect of Mukti organic fertilizer on cabbage production (t ha^{-1}) at mymensingh and Ishurdi

Treatments	Fresh Yield of Tomato (t ha^{-1})				Yield increase/ decrease (%)	MBCR
	First harvest	Second harvest	Third harvest	Total		
Mymensingh						
T_1 : RCF ($N_{150}P_{50}K_{100}S_{16}Zn_2B_{0.5}$)	6.5abc	14.2cd	15.3cd	36.0c	-	-
T_2: 85% RCF	5.6cd	12.5d	16.0bcd	34.1cd	-5.27	-
T_3: 70% RCF	4.7d	13.0d	14.6d	32.3d	-10.27	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	7.1ab	19.0a	23.4a	49.5a	37.50	1.26
T_5 : 85% T_1 + 1 t ha^{-1} OF	7.0ab	15.5bc	17.8bc	40.3b	11.94	0.77
T_6 : 70% T_1 + 3 t ha^{-1} OF	7.2a	16.5b	18.8b	42.5b	18.05	0.37
T_7 : 70% T_1 + 1 t ha^{-1} OF	6.1bc	14.cd	16.3bcd	36.4c	1.11	-
CV (%)	8.96	7.60	9.48	4.69	-	-
SE (±)	0.32	0.65	0.95	1.04	-	-
Ishurdi						
T_1 : RCF ($N_{150}P_{50}K_{100}S_{16}Zn_2B_{0.5}$)	6.2abc	13.8bcd	14.8d	34.8c	-	-
T_2: 85% RCF	5.5bc	13.2cd	14.7d	33.4cd	-4.02	-
T_3: 70% RCF	5.0c	12.6d	13.8d	31.4d	-9.77	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	7.5a	20.0a	23.0a	50.5a	42.24	2.05
T_5 : 85% T_1 + 1 t ha^{-1} OF	7.5a	16.5bc	18.4bc	42.4b	21.83	2.00
T_6 : 70% T_1 + 3 t ha^{-1} OF	7.0a	17.0ab	19.6ab	43.6b	25.28	1.00
T_7 : 70% T_1 + 1 t ha^{-1} OF	6.5ab	14.0bcd	15.1cd	35.5c	2.01	0.06
CV (%)	12.49	12.78	11.43	4.48	-	-
SE (±)	0.46	1.12	1.11	0.99	-	-

Figure in a column, having common letter (s) do not differ significantly at 5% level of probability.

*Chemical fertilizer @ $N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$ kg ha^{-1} at Ishurdi & Mymensingh. Cabbage = Tk 10 kg^{-1}, Urea= Tk 16 kg^{-1}, TSP = Tk 22 kg^{-1}, MP = Tk 20 kg^{-1}, Gypsum = Tk 10 kg^{-1}, “MUKTI” Organic fertilizer = Tk 8 kg^{-1}

GTS organic fertilizers

Two experiments were conducted at BINA head quarter farm Mymensingh and BINA substation farm Ishurdi to observe the effect of GTS organic fertilizers on cabbage production during rabi season 2014. There were seven fertilizer treatments viz: T_1: RCF (N_{150} P_{50} K_{100} S_{16} Zn_2 $B_{0.5}$), T_2 : 85% RCF, T_3 : 70% RCF, T_4 : 85% RCF + 3 t ha^{-1} OF, T_5 : 85% RCF + 1t ha^{-1} OF, T_6 : 70% RCF + 3 t ha^{-1} OF and T_7 : 70% RCF + 1 t ha^{-1} OF. The experiments were laid out in a RCBD (Randomized Complete Block Design) with three replications. The cabbage was harvested three times. The fresh weight of cabbage ranged from 32.8 to 46.2 at Mymensingh and 30.4 to 47.5 t ha^{-1} at Ishurdi, respectively. The highest yield was recorded in treatment T_4 (85% T_1 + 3 t ha^{-1} GTS OF) at both the locations. The highest yield of 46.2 t ha^{-1} was recorded in treatment T_4 (85% RCF + 3 t ha^{-1} GTS OF) at Mymensingh and 47.5 t ha^{-1} at Ishurdi. The highest MBCR was obtained in T_4 treatment by GTS organic fertilizer at Mymensingh 1.71 and 1.83 at Ishurdi, respectively.

Table 63. Effect of CP organic fertilizer on cabbage production (t ha^{-1}) at Mymensingh and Ishurdi

Treatments	Fresh Yield of Tomato (t ha^{-1})				Yield increase/ decrease (%)	MBCR
	First harvest	Second harvest	Third harvest	Total		
Mymensingh						
T_1 : RCF ($N_{150}P_{50}K_{100}S_{16}Zn_2B_{0.5}$)	6.2abc	14.0b	15.5bc	38.8c		-
T_2: 85% RCF	5.5bc	14.3b	15.0bc	37.5c	-3.35	-
T_3: 70% RCF	5.0c	13.2b	14.6c	32.8c	-15.46	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	7.0a	18.6a	20.6a	46.2a	19.07	1.71
T_5 : 85% T_1 + 1 t ha^{-1} OF	7.2a	15.4ab	16.8bc	39.4bc	1.54	0.97
T_6 : 70% T_1 + 3 t ha^{-1} OF	7.1a	17.0ab	18.5ab	42.6ab	9.79	0.67
T_7 : 70% T_1 + 1 t ha^{-1} OF	6.5ab	15.0ab	16.1bc	37.6bc	-3.09	0.01
CV (%)	11.38	15.52	12.00	10.02	-	-
SE (±)	0.41	1.37	1.15	2.22	-	-
Ishurdi						
T_1 : RCF ($N_{150}P_{50}K_{100}S_{16}Zn_2B_{0.5}$)	6.2ab	14.2cd	15.2c	35.6c	-	-
T_2: 85% RCF	5.3bc	13.4cd	15.1c	33.8cd	-5.05	-
T_3: 70% RCF	5.0c	12.0d	13.4c	30.4d	-14.60	-
T_4 : 85% T_1 + 3 t ha^{-1} OF	6.5a	19.6a	21.4a	47.5a	33.42	1.83
T_5 : 85% T_1 + 1 t ha^{-1} OF	6.0abc	17.2ab	20.0ab	43.2b	21.34	1.75
T_6 : 70% T_1 + 3 t ha^{-1} OF	6.0abc	18.6a	20.1ab	44.7ab	24.56	1.00
T_7 : 70% T_1 + 1 t ha^{-1} OF	5.8abc	15.1bc	16.8bc	37.7c	5.89	-
CV (%)	11.34	9.28	13.56	5.97	-	-
SE (±)	0.38	0.84	1.36	1.34	-	-

Figure in a column, having common letter (s) do not differ significantly at 5% level of probability.

*Chemical fertilizer @ $N_{120}P_{35}K_{70}S_{15}Zn_2B_{0.5}$ kg ha^{-1} at Ishurdi & Mymensingh. Cabbage = Tk 10 kg^{-1}, Urea = Tk 16 kg^{-1}, TSP = Tk 22 kg^{-1}, MP = Tk 20 kg^{-1}, Gypsum = Tk 10 kg^{-1}, "CP" Organic fertilizer = Tk 6 kg^{-1}

LANDSCAPE SALINITY AND WATER MANAGEMENT IN COASTAL REGION OF BANGLADESH FOR IMPROVING AGRICULTURAL PRODUCTIVITY

Effect of Irrigation and sloping bed transplanting approach on rice production in saline area of Bangladesh

The experiment was conducted at Subarnachar, Noakhali district of saline area during Boro season. The test crop was Binadhan-10 with salinity level 8-10 ds/m.The experiment was laid out in a split-plot design along with two irrigation treatments (main plot) and three slopping bed transplanting techniques (subplots) with three replications. The main plot treatments were, I_1=Continuous flooding, I_2=Alternate wetting and drying (AWD) and the subplot treatments were, T_0=Control (No. slope/flat land), T_1=Transplanting in a single row sloping bed and T_2=Transplanting in a double row sloping bed. A common basal dose of $N_{90}P_{10}K_{35}S_{10}Zn_1$ was applied to each plot (BARC, 2012) and full dose of P, K, S, Zn and 1/3rd of N fertilizer were applied at the time of land preparation. The rest of N fertilizer was applied in two equal splits, i.e. 30 days of transplanting and 60 days after sowing.

Results and Discussion:

Effect of irrigation and slopping on yield of Rice

Grain and straw yield of rice were significantly affected by different irrigation and slopping bed transplanting approaches in Subarnachar, Noakhali during 2013-14 (Table 64-67). From the Table 64 highest grain and straw yield was observed under continuous flooding as 4.95 and 5.83 t ha^{-1} respectively. Considering the mean effect of slopping bed approaches the maximum grain yield of rice was observed as 5.42 tha^{-1} when rice seedlings were transplanted in single row slopping bed, which was also showed an identical result (5.22 t ha^{-1}) with T_2 treatments, *i.e.* rice seedlings were transplanted in a double row slopping bed. In case of straw yield similar trends were found and the maximum straw yield of 6.43 t ha^{-1} was observed under treatment T_1 (Table 65).

Considering the interaction effect of both different irrigation and slopping bed approaches, the maxmum grain yield of rice was observed under the treatment combination I_1T_1 as 5.73 tha^{-1} (Table 66) Similarly, in case of straw yield of rice the highest yield was noticed (6.58 t ha^{-1}) under the treatment combination I_1T_1 (Table 67).

Table 64. Mean effect of irrigation on grain and straw yield of Rice

Treatment	GY (t ha^{-1})	SY (t ha^{-1})
I_1 = Continuous flooding	4.95	5.83
I_2 = Alternate wetting and drying (AWD)	4.76	5.64
*Significant at 5% level	*	*
CV (%)	6.70	3.65

Table 65. Mean effect of Slopping on grain and straw yield of Rice

Treatment	GY (t ha^{-1})	SY (t ha^{-1})
T_0 = Control (No slope/flat land)	3.89 b	4.75 c
T_1 = Transplanting in a single row sloping bed	5.42 a	6.43 a
T_2 = Transplanting in a double row sloping bed	5.26 a	6.03 b
*Significant at 5% level	*	*
CV (%)	6.70	3.65

Table 66. Interaction effect of irrigation and slopping on grain yield of Rice

Treatment	I_1	I_2
T_0	3.94 b	3.84 b
T_1	5.73 a	5.27 a
T_2	5.35 a	5.17
*Significant at 5% level	*	*
CV (%)	6.70	

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 67. Interaction effect of irrigation and slopping on straw yield of Rice

Treatment	I_1	I_2
T_0	4.72 c	4.78 c
T_1	6.58 a	6.28 ab
T_2	6.20 ab	5.87 b
*Significant at 5% level	*	*
CV (%)	3.65	

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

I_1 = Continuous flooding

I_2 = Alternate wetting and drying (AWD)

T_0 = Control (No slope/flat land)

T_1 = Transplanting in a single row sloping bed

T_2 = Transplanting in a double row sloping bed

Conclusion

The study shows that, rice production is higher when the field under saturated condition and the seedlings were planted in single row.

SOIL WATER AND NITROGEN MANAGEMENT FOR SUSTAINABLE CROP PRODUCTION USING TRACER TECHNIQUE IN DROUGHT PRONE AREAS OF BANGLADESH

Isotope aided studies of different irrigation and nitrogen levels on the growth and yield of Wheat

Test Crop	:	Wheat
Sowing/transplanting distance	:	Wheat: 10 cm × 20 cm, Rice 15 cm × 20 cm
Design with replication	:	Split-plot with 3 replications (in wheat)
Note	:	All treatments will be assigned in the first crop wheat.

Main plot treatments (Soil water regimes): Nos. 3

W_1 = Irrigation as Farmer's practices

W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)

W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

N.B. CRI (Crown root initiation) stage (21-23 days), flag leaf ligule emergence stage (45-48 days) and before flowering/anthesis stage (65-68 days) after wheat sowing.

Split-plot Treatments (N levels) : Nos. 4

N_0 = No Nitrogen (control)

N_1 = 50 kg N/ha,

N_2 = 100 kg N/ha

N_3 = 150 kg N/ha

N.B. For isotopic study, ^{15}N labeled nitrogen fertilizer was applied in the isotopic micro-plot.
Size of the plot: Main plot size: 9 m × 13 m, Sub-plot size: 6 m × 4 m, Isotope micro-plot size = 1m × 1m

Note:

a. Each sub-plot was divided into two parts, a. Yield plot (3m × 4m) and b. sampling plot (3m × 4m).

b. Each sampling plot consist of two Isotope micro plots, a. one micro-plot (1 m × 1 m) was used for ^{15}N application in two splits and b. the 2nd micro-plot (1m × 1m) was used for ^{15}N application in three splits.

c. Each micro-plot surrounded by iron sheet (inserted into the soil up to 15cm depth) for prevention of N loss by seepage.

^{15}N Fertilizer application:

a. ^{15}N urea was applied into two ways, for micro-plot A, two splits: i. 1/3 N as basal dose after final land preparation, ii. 2/3 N as top dress during crown root initiation stage (CRI) and for micro-plot B, three splits, such as – i.1/3 N as basal dose after final land preparation, ii. 1/3 N as top dress during crown root initiation stage (CRI) and iii. The rest 1/3 N as top dress during flowering/ anthesis stage.

b. Normal N fertilizer will be applied (same amount and same time of ^{15}N) into the yield plot and rest of the sampling plot.

Data recorded:

1. Total analysis of the initial soil.
2. ^{15}N analysis of the isotope labeled plant and soil samples
3. Yield and yield contributing data for crop
4. Meteorological data.

Results and Discussion:

Isotope aided studies of different irrigation and nitrogen levels on the growth and yield of wheat

Two field experiments were completed for the consecutive 2 years of 2011-2012 and 2012-2013, in wheat-rice cropping pattern under the Barind area. Wheat seeds were sown on the 4th December and 26th November for 2011 and 2012, respectively. Wheat harvest was completed on 29th March, 2012 and 3rd April, 2013. During harvest, the data for yield and yield contributing characters were recorded and analyzed statistically. Plant and soil samples from the non-isotopic and isotopic plots were collected and analyzed in the laboratory of Soil Science Division of BINA. At wheat harvest, ^{15}N plant (grain and straw) and soil samples were collected from each isotopic microplot and determined the %^{15}Na.e. in both plant and soil samples by using NO17 Emission Spectrometer. The initial soil characteristics of the experimental field are given in Table 68. The data for yield and yield parameters, the amount of total N uptake by wheat and the soil analytical results are given in Table 69-75.

a. Mean effect of different irrigations on the yield of wheat:

Different levels of irrigation practices significantly influenced on the grain and straw yield of wheat for both the year of 2011-2012 and 2012-2013 (Table 69). From the two years study it was revealed that the highest grain yield was observed as 3.86 and 3.82 tha^{-1} from W_3 plot, where the wheat irrigated at 3 times. The minimum yield of 3.21 and 3.07 t ha^{-1} were noticed under the plots where irrigation was given as farmer practice. Similarly, maximum straw yield of wheat was recorded as 5.13 and 4.94 t ha^{-1} from W_3 treatment for the year of 2011-2012 and 2012-2013, respectively. In both the years, the minimum wheat straws were produced under farmer practiced irrigation (W_1). Considering the mean data for both two years it was noticed that highest yield was recorded for wheat grain and straw as 3.84 and 5.04 t ha^{-1}, respectively (Fig. 1).

b. Mean effect of different N levels on the yield of wheat

Different levels of N fertilizer significantly affected on the grain and straw yield of wheat grown at Rajshahi during the year of 2011-2012 (Table 70). During 2011-2012, the highest grain yield was observed in N_2 treatment (4.21 tha^{-1}) which was also statistically identical with treatment of N_3 (4.02 t ha^{-1}) and N_1 (3.56 t ha^{-1}). In 2012-2013 the maximum wheat grain produced under N_3 (4.20 t ha^{-1}) which also statistically similar to N_2 (4.15 t ha^{-1}). The minimum wheat grain was observed under control as 2.06 and 1.97 tha^{-1} for the year of 2011-2012 and 2012-2013, respectively. Incase of wheat straw, more or less similar results were observed (Table 70) and highest value of 5.40 and 5.18 tha^{-1} straw yield was noticed under N_2 treatment in 2011-2012 and 2012-2013, respectively. In all cases, the minimum results were shown under control (N_0) treatment as 2.88 and 2.68 t ha^{-1}. Considering the 2 years mean data it was clearly observed that, the highest amount of grain and straw were produced as 4.09 and 5.23 t ha^{-1}, respectively (Fig. 2).

c. Interaction effect of irrigation and Nitrogen on the yield and yield attributes of wheat:

Different irrigation approaches combinedly with the different N levels significantly influenced on the grain and straw yield of wheat at Barind area during the year of 2011-12 and 2012-2013 (Table 71). Considering the grain yield of wheat the highest yield was observed in the treatment combination of W_3N_2 as 4.97 and 4.94 t ha^{-1} for the year of 2011-12 and 2012-2013, respectively. In both years, the lowest grain yield was noted as 2.12 and 1.94 tha^{-1} from the treatment combination W_1N_0. Similar results were noticed in case of straw yield of wheat and the maximum values were recorded in the treatment combination W_3N_2 as 6.64 and 6.22 t ha^{-1} from the year of 2011-2012 and 2012-2013 respectively.

Isotope related results (% ^{15}Na.e, %Ndff etc.):

From the ^{15}N study, percent ^{15}N atom excess (%^{15}Na.e), percent nitrogen derived from fertilizer (%Ndff), percent nitrogen derived from soil (%Ndfs) were analyzed (Table 72-76). From the table 72, it was noted that % ^{15}Na.e and %Ndff in both wheat grain and straw were varied due to the interaction effect of different irrigation and N levels. Among the treatment combinations, the maximum portion of Ndff was observed as 49.54 and 42.52% in wheat grain and straw, respectively. Due to split application of N fertilizer the %Ndff was varied even in same dose. Under the treatment combination W_2 N_3B the Ndff increased up to as 49.54%, while the N fertilizer applied in three splits. This was comparatively showed 17.81% higher value than the treatment where N applied in two splits. Through ^{15}N isotopic study it was noted that the total residual fertilizer N present in soil at wheat harvest was affected due to different irrigation practices and nitrogen levels (Table 73-76). Among the different N levels, comparatively the higher amount of TRN always found under the treatments where N fertilizers were applied into two splits.

Considering the total value (grain plus straw), it was revealed that total N uptake, Ndff and Ndfs values were highly influenced by the different levels of N with split application. From the ^{15}N data it was clear that, when N was applied into 3 splits, the total N uptake by wheat was comparatively higher than the N uptake in 2 splits. Due to the different treatment and split application system, the maximum total nitrogen uptake (mean value) by wheat plant was observed as 125.31 kg ha^{-1} under N_3B treatment, where 150 kg Nha^{-1} were applied into 3 equal splits. The minimum total N uptake was found as 93.75 in N_1A treatment i.e. N was applied as 50 $kgha^{-1}$ into 2 splits (Table 75). From the nuclear aided study, the quantity of ^{15}N fertilizer was determined from wheat plant uptake and the maximum amount of Ndff was showed in N_3B treatment (54.26 kg ha^{-1}). The minimum ^{15}N value was found under N_1A (16.12 kg ha^{-1}). From the study, it was observed that, due to 3 split application of N fertilizer, the N uptake by wheat from the fertilizer sources was increased in all treatments. Similarly, from the Fig. 4, it was noticed that, the highest and lowest value of TNdfs were observed as 80.17 and 69.10 kg ha^{-1} under the treatment N_3A and N_2B, respectively. From this result, it was revealed that, comparatively higher N uptake by wheat plant occurred under the treatment where N application was done in minimum split i.e. N use efficiency was increased under maximum split application.

The quantity as well as the relative proportion of the N uptake by wheat was presented in the Fig. 5. From the result, it was observed that due to different split application, the total N uptakes by wheat from different sources were varied. In this study, when N fertilizer applied in two splits, the total N uptake from fertilizer sources were 25%, 28% and 27% under the treatment of N_1, N_2 and $N_{3,}$ respectively. But when the N fertilizer applied in 3 splits then total N uptake by wheat were increase as 28%, 39% and 43% from the same treatments, respectively. Thus, from this isotopic study, it was clearly observed, due to split application i) fertilizer N use efficiency was increased and ii) plant takes N from soil sources as minimum portion.

Table. 68. Initial physico-chemical properties of soil collected from wheat experimental field at Barind area (Godagari), Rajshahi during 2011-12.

Soil properties	0-15cm depth	15-30cm depth	30-50cm depth
Soil Texture	clay loam	clay	clay
% Sand	34.44	28.44	34.44
% Silt	36.00	28.00	18.00
% Clay	29.56	43.56	47.56
Soil O.C (%)	1.59	0.88	0.56
Soil pH	6.30	6.66	6.45
EC (dSm^{-1})	2.15	1.47	1.80
Total N (%)	0.10	0.06	0.05
Available P (ppm)	16	14	13
Exchangeable K meq/100	0.28	0.31	0.28
WHC (%)	30.64	25.37	-

Table 69. Mean effect of different irrigation levels on the grain and straw yield of wheat at Barind area (Godagari), Rajshahi.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean
W_1	3.21	3.07 c	3.14	4.28	4.08 b	4.18
W_2	3.32	3.35 b	3.34	4.55	4.26 b	4.41
W_3	3.86	3.82 a	3.84	5.13	4.94 a	5.04
**Significant at 1% level	NS	**	-	NS	**	-
CV (%)	2.79	5.45	-	18.18	5.47	-

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)
NS = Not significant

Table 70. Mean effect of different N levels on on the grain and straw yield of wheat at Barind area (Godagari), Rajshahi.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean
N_0	2.06b	1.97 c	2.02	2.88b	2.68 c	2.78
N_1	3.56a	3.51 b	3.54	5.05b	4.67 b	4.86
N_2	4.21a	4.15 a	4.18	5.40a	5.18 a	5.29
N_3	4.02a	4.17 a	4.09	5.28a	5.17 a	5.23
*Significant at 1% level	**	**	-	**	**	-
CV (%)	18.18	5.45	-	23.66	5.47	-

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

N_0 = No Nitrogen (control) N_1 = 50 kg N/ha,
N_2 = 100 kg N/ha N_3 = 150 kg N/ha

Table 71. Interaction effect of different irrigation and N levels on the grain and straw yield of wheat at Barind area (Godagari), Rajshahi.

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean
W_1N_0	2.12 cd	1.94 f	2.03	2.74	2.58 f	2.66
W_1N_1	3.13 bc	3.10 e	3.12	4.45	4.24 e	4.35
W_1N_2	3.57 b	3.38 de	3.48	4.35	4.34 e	4.34
W_1N_3	4.02 ab	3.86 c	3.94	5.57	5.17 c	5.37
W_2N_0	1.91 d	2.02 f	1.97	2.78	2.57 f	2.68
W_2N_1	3.59 b	3.45 d	3.57	5.57	4.91 cd	5.24
W_2N_2	4.09 ab	4.15 bc	4.12	5.21	4.98 cd	5.09
W_2N_3	3.70 b	3.80 c	3.75	4.64	4.58 de	4.61
W_3N_0	2.17 cd	1.96 f	2.07	3.13	2.91 f	3.02
W_3N_1	3.96 ab	3.99 c	3.98	5.13	4.88 cd	5.01
W_3N_2	4.97 a	4.94 a	4.96	6.64	6.22 a	6.43
W_3N_3	4.36 ab	4.41 b	4.39	5.62	5.77 b	5.69
Level of significance	*	**			**	
CV (%)	6.50	5.45		7.10	5.47	

*Significant at 5% level; **Significant at1% level
In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

N_1A = 50 kg Nha^{-1} applied in two splits N_1B = 50 kg Nha^{-1} applied in three splits
N_2A = 100 kg Nha^{-1} applied in two splits N_2B = 100 kg Nha^{-1} applied in three splits
N_3A = 150 kg Nha^{-1} applied in two splits N_3B = 150 kg Nha^{-1} applied in three splits
W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

Table 72. % ^{15}Na.e. and % Ndff in wheat grain and straw affected by different levels of irrigation and N split application

Treatment		Grain		Straw	
		%^{15}Na.e.	%Ndff	%^{15}Na.e.	%Ndff
W$_1$	N$_1$A	1.397	13.37	1.679	16.07
	N$_1$B	2.855	27.32	2.757	26.38
	N$_2$A	2.867	27.44	3.068	29.36
	N$_2$B	3.992	38.20	4.128	39.50
	N$_1$A	3.025	28.95	2.653	25.39
	N$_3$B	4.846	46.37	4.443	42.52
W$_2$	N$_1$A	1.277	12.22	1.157	11.07
	N$_1$B	2.358	22.56	2.964	28.36
	N$_2$A	3.394	32.48	2.989	28.60
	N$_2$B	4.301	41.16	3.673	35.15
	N$_1$A	3.316	31.73	2.383	22.80
	N$_3$B	5.177	49.54	4.341	41.54
W$_3$	N$_1$A	2.534	24.25	2.378	22.76
	N$_1$B	2.563	24.53	2.617	25.04
	N$_2$A	2.677	25.62	2.883	24.52
	N$_2$B	4.277	40.93	2.562	27.59
	N$_1$A	2.503	23.95	2.469	23.63
	N$_3$B	4.373	41.85	2.807	26.86

Table 73. N yield, Ndff and Ndfs in wheat grain affected by different levels of irrigation and nitrogen split applications at Rajshahi.

Treatment		% N	N yield (kg ha^{-1})	Ndff (kg ha^{-1})	Ndfs (kg ha^{-1})
W$_1$	N$_1$A	1.74	65.6	8.77	56.83
	N$_1$B	2.11	79.55	21.73	57.81
	N$_2$A	2.17	105.9	29.05	76.84
	N$_2$B	2.19	106.87	40.83	66.05
	N$_1$A	2.13	107.99	31.26	76.73
	N$_3$B	2.21	112.05	51.96	60.09
W$_2$	N$_1$A	2.13	78.87	9.63	69.18
	N$_1$B	2.14	79.18	17.87	61.31
	N$_2$A	2.14	80.25	26.06	54.19
	N$_2$B	2.22	83.25	34.26	48.99
	N$_1$A	2.43	80.19	25.45	54.74
	N$_3$B	2.54	83.82	41.52	42.3
W$_3$	N$_1$A	2.19	89.13	21.61	67.52
	N$_1$B	1.98	80.59	19.76	60.82
	N$_2$A	2.11	75.54	19.35	56.19
	N$_2$B	2.15	76.97	31.5	45.47
	N$_1$A	2.42	93.9	22.49	71.41
	N$_3$B	2.58	100.10	41.89	58.21

Legend:

N$_1$A	=	50 kg Nha^{-1} applied in two splits	N$_1$B	=	50 kg Nha^{-1} applied in three splits
N$_2$A	=	100 kg Nha^{-1} applied in two splits	N$_2$B	=	100 kg Nha^{-1} applied in three splits
N$_3$A	=	150 kg Nha^{-1} applied in two splits	N$_3$B	=	150 kg Nha^{-1} applied in three splits

W$_1$ = Irrigation as Farmer's practices

W$_2$ = Two irrigations (at CRI and before flowering/anthesis stage of wheat)

W$_3$ = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

Table 74. N yield, Ndff and Ndfs in wheat straw affected by different levels of irrigation and N split application

Treatment		% N	N yield (kg ha^{-1})	Ndff (kg ha^{-1})	Ndfs (kg ha^{-1})
W_1	N_1A	0.25	13.13	2.11	11.02
	N_1B	0.29	15.23	4.02	11.21
	N_2A	0.38	26.60	7.81	18.79
	N_2B	0.42	29.40	11.61	17.79
	N_1A	0.29	19.29	4.90	14.39
	N_3B	0.35	23.28	9.90	13.38
W_2	N_1A	0.28	14.00	1.55	12.45
	N_1B	0.45	22.50	6.38	16.12
	N_2A	0.36	16.74	4.79	11.95
	N_2B	0.49	22.79	8.01	14.78
	N_1A	0.37	15.54	3.54	12.00
	N_3B	0.37	15.54	6.46	9.08
W_3	N_1A	0.33	20.59	4.69	15.91
	N_1B	0.36	22.46	5.63	16.84
	N_2A	0.44	18.04	4.42	13.62
	N_2B	0.48	19.68	5.43	14.25
	N_1A	0.24	14.74	3.48	11.25
	N_3B	0.67	41.14	11.05	30.09

Legend:

N_1A = 50 kg Nha^{-1} applied in two splits
N_2A = 100 kg Nha^{-1} applied in two splits
N_3A = 150 kg Nha^{-1} applied in two splits
N_1B = 50 kg Nha^{-1} applied in three splits
N_2B = 100 kg Nha^{-1} applied in three splits
N_3B = 150 kg Nha^{-1} applied in three splits

W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

Table 75. Total N yield, Ndff and Ndfs in wheat plant affected by different levels of irrigation and N split application.

Treatment		% N	N yield (kg ha^{-1})	Ndff (kg ha^{-1})	Ndfs (kg ha^{-1})
W_1	N_1A	0.87	78.72	10.88	67.84
	N_1B	1.05	94.77	25.75	69.02
	N_2A	1.12	132.50	36.86	95.63
	N_2B	1.15	136.25	52.44	83.83
	N_1A	1.09	127.28	36.16	91.12
	N_3B	1.15	135.32	61.86	73.47
W_2	N_1A	1.07	92.81	11.18	81.63
	N_1B	1.17	101.68	24.25	77.43
	N_2A	1.15	96.99	30.85	66.14
	N_2B	1.26	106.04	42.27	63.76
	N_1A	1.28	95.73	28.99	66.74
	N_3B	1.32	99.36	47.98	51.38
W_3	N_1A	1.06	109.73	26.30	83.43
	N_1B	1.00	103.05	25.39	77.66
	N_2A	1.22	93.58	23.77	69.80
	N_2B	1.26	96.65	36.93	59.72
	N_1A	1.08	108.63	25.97	82.66
	N_3B	1.41	141.24	52.94	88.30
Mean value from different 3 irrigation levels		N_1A	93.75	16.12	77.63
		N_1B	99.83	25.13	74.70
		N_2A	107.69	30.49	77.19
		N_2B	112.98	43.88	69.10
		N_3A	110.55	30.37	80.17
		N_3B	125.31	54.26	71.05

Legend:

N_1A = 50 kg Nha^{-1} applied in two splits
N_2A = 100 kg Nha^{-1} applied in two splits
N_3A = 150 kg Nha^{-1} applied in two splits
N_1B = 50 kg Nha^{-1} applied in three splits
N_2B = 100 kg Nha^{-1} applied in three splits
N_3B = 150 kg Nha^{-1} applied in three splits

W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

Table 76. Total soil residual N at wheat harvest affected by different levels of irrigation and split application of nitrogen at Barind area Rajshahi.

Irrigation x N level		% N in soil	% ^{15}Na.e. in soil	Total residual ^{15}N in soil (gha^{-1})
W_1	N_1A	0.11	0.055	1252.35
	N_1B	0.11	0.079	1798.83
	N_2A	0.11	0.043	979.11
	N_2B	0.11	0.095	2163.15
	N_1A	0.12	0.118	2931.12
	N_3B	0.11	0.1643	3741.11
W_2	N_1A	0.11	0.053	1206.81
	N_1B	0.11	0.069	1571.13
	N_2A	0.09	0.054	1006.02
	N_2B	0.08	0.079	1308.24
	N_1A	0.09	0.165	3073.95
	N_3B	0.08	0.173	2864.88
W_3	N_1A	0.1	0.021	434.7
	N_1B	0.09	0.066	1229.58
	N_2A	0.11	0.082	1867.14
	N_2B	0.1	0.091	1883.7
	N_1A	0.1	0.153	3167.1
	N_3B	0.09	0.16	2980.8

Legend:

N_1A = 50 kg Nha^{-1} applied in two splits N_1B = 50 kg Nha^{-1} applied in three splits
N_2A = 100 kg Nha^{-1} applied in two splits N_2B = 100 kg Nha^{-1} applied in three splits
N_3A = 150 kg Nha^{-1} applied in two splits N_3B = 150 kg Nha^{-1} applied in three splits

W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering / anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

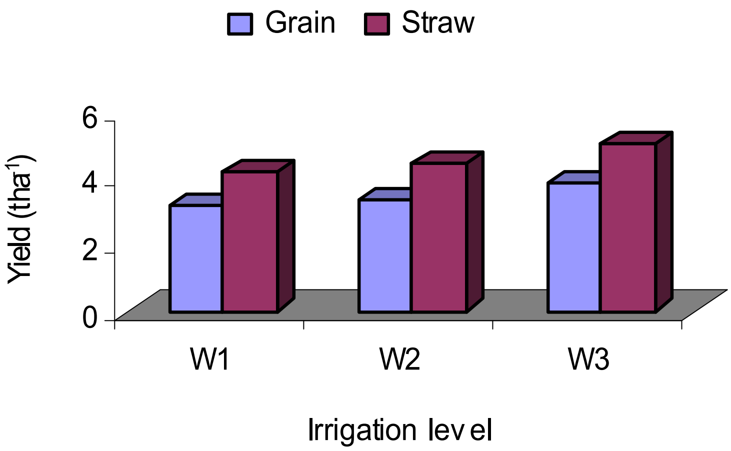


Fig. 1. Mean effect of irrigation on the grain and straw yield of wheat (mean of 2 years data) at Barind area, Rajshahi.

Legend:

W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

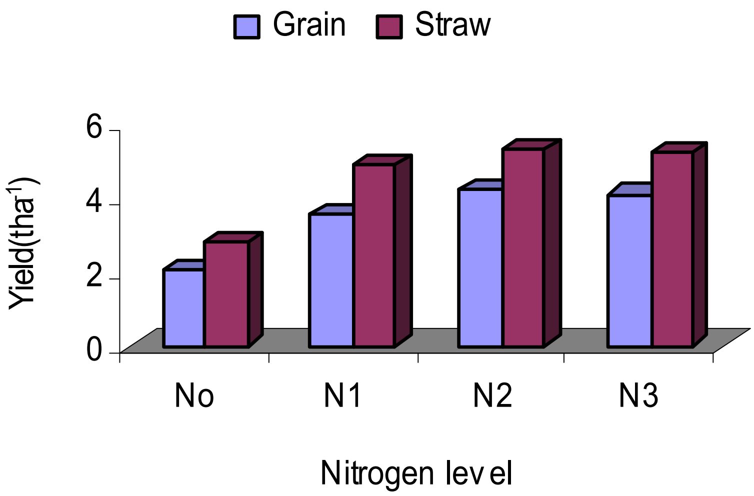


Fig. 2. Mean effect of nitrogen levels on the grain and straw yield of wheat (mean of 2 years data) at Barind area, Rajshahi.

Legend:

N_0 = No Nitrogen (control) N_1 = 50 kg N/ha,
N_2 = 100 kg N/ha N_3 = 150 kg N/ha

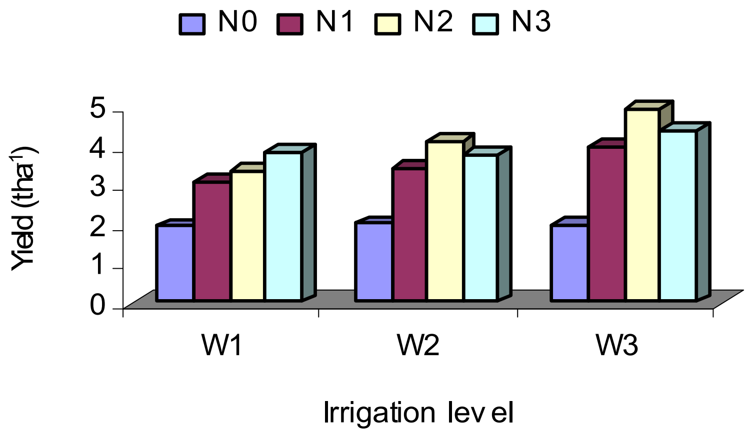


Fig. 3. Interaction effect of irrigation and nitrogen level on the grain and straw yield of wheat (mean of 2 years data) at Barind area, Rajshahi.

Legend:

W_1 = Irrigation as Farmer's practices
W_2 = Two irrigations (at CRI and before flowering/anthesis stage of wheat)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and before flowering/anthesis stage of wheat)

N_0 = No Nitrogen N_1 = 50 kg N/ha, N_2 = 100 kg N/ha N_3 = 150 kg N/ha

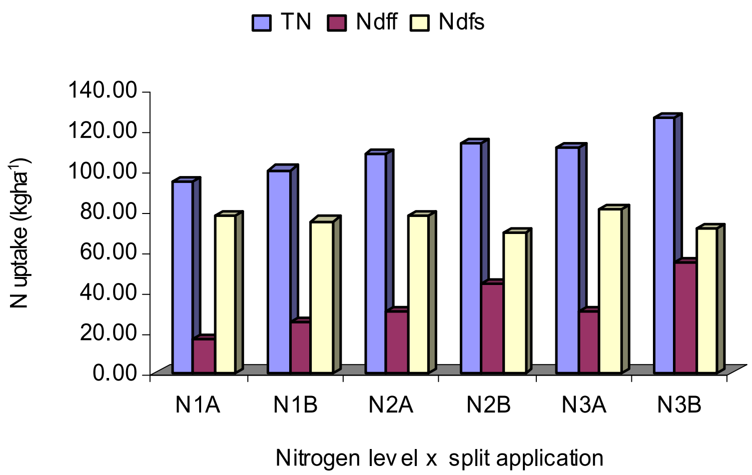


Fig. 4. Total N, Total Ndff and total Ndfs in wheat affected by different nitrogen level x split application at Barind area, Rajshahi.

Legend:

N_1A	=	50 kg Nha^{-1} applied in two splits	N_1B	=	50 kg Nha^{-1} applied in three splits
N_2A	=	100 kg Nha^{-1} applied in two splits	N_2B	=	100 kg Nha^{-1} applied in three splits
N_3A	=	150 kg Nha^{-1} applied in two splits	N_3B	=	150 kg Nha^{-1} applied in three splits
TNdff	=	Total N derived from fertilizer	TNdfs	=	Total N derived from soil

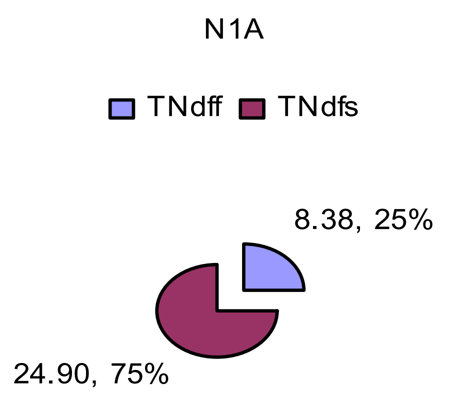


Fig. 5. Comparative amount (kgha^{-1}) and proportion (%) of TNdff and Ndfs value affected by nitrogen fertilizer with split application N_{1A}.

Legend:

N_1A	=	50 kg Nha^{-1} applied in two splits
TNdff	=	Total N derived from fertilizer
TNdfs	=	Total N derived from soil

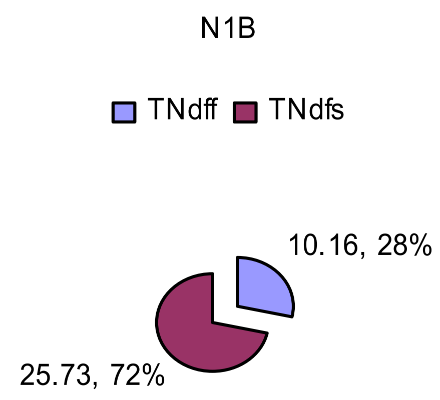


Fig. 6. Comparative amount (kgha^{-1}) and proportion (%) of TNdff and Ndfs value affected by nitrogen fertilizer with split application N_{1B}

Legend:

N_1A	=	50 kg Nha^{-1} applied in two splits
TNdff	=	Total N derived from fertilizer
TNdfs	=	Total N derived from soil

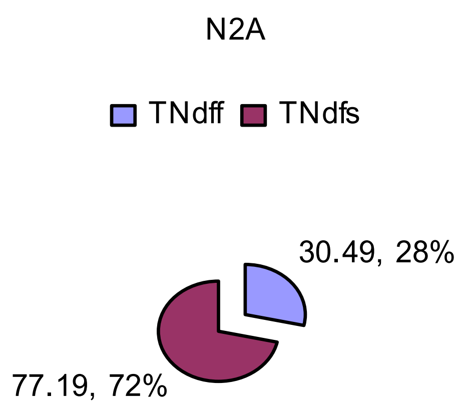


Fig. 7. Comparative amount (kgha^{-1}) and proportion (%) of TNdff and Ndfs value affected by nitrogen fertilizer with split application N_{2A}

Legend:

N_1A	=	100 kg Nha^{-1} applied in two splits
TNdff	=	Total N derived from fertilizer
TNdfs	=	Total N derived from soil

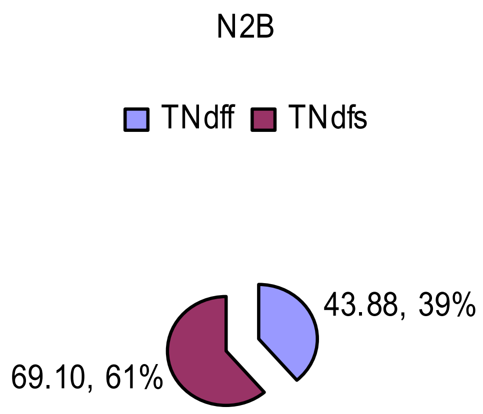


Fig. 8. Comparative amount (kgha^{-1}) and proportion (%) of TNdff and Ndfs value affected by nitrogen fertilizer with split application N_{2B}

Legend:

N_2B	=	100 kg Nha^{-1} applied in three equal splits
TNdff	=	Total N derived from fertilizer
TNdfs	=	Total N derived from soil

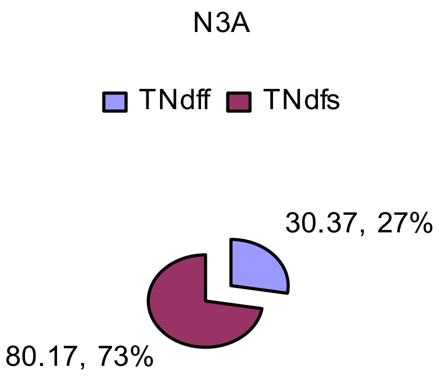


Fig. 9. Comparative amount (kgha^{-1}) & proportion (%) of TNdff and Ndfs value affected by nitrogen fertilizer with split application N_{3A}

Legend:

N_3A	=	150 kg Nha^{-1} applied in two splits
TNdff	=	Total N derived from fertilizer
TNdfs	=	Total N derived from soil

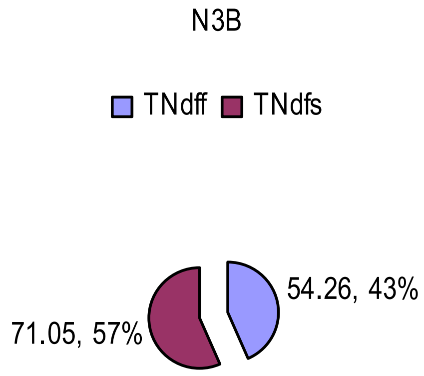


Fig. 10. Comparative amount (kgha^{-1}) & proportion (%) of TNdff and Ndfs value affected by nitrogen fertilizer with split application N_{3B}

Legend:

N_3B	=	150 kg Nha^{-1} applied in three splits
TNdff	=	Total N derived from fertilizer
TNdfs	=	Total N derived from soil

Table 77. Mean effect of irrigation on yield and yield parameters of wheat at Barind area during 2013-14

Treatment	Plant height (cm)	Panicle length (cm)	Plant/hill (no.)	Grain yield (tha^{-1})	Straw yield (tha^{-1})
W_1	76.77 b	6.55	3.18	2.31	4.55
W_2	80.30 a	7.53	3.12	2.46	4.61
W_3	78.85 ab	7.65	3.18	2.45	4.47
*Significant at 5% level	*	NS	NS	NS	NS
CV (%)	3.41	6.67	9.15	28.91	13.85

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

W_1 = One irrigation (at flag leaf ligule emergence stage)
W_2 = Two irrigations (at crown root, CRI and anthesis stage)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and anthesis stage)
NS = Non significant

Table 78. Mean effect of nitrogen on yield and yield parameters of wheat at Barind area during 2013-14

Treatment	Plant height (cm)	Panicle length (cm)	Plant/hill (no.)	Grain yield (tha^{-1})	Straw yield (t ha^{-1})
No Nitrogen	72.36 c	6.42 c	2.49 d	1.39 c	2.26 d
60 kg Nha^{-1}	78.38 b	7.18 b	2.91 c	2.23 b	4.22 c
120 kg Nha^{-1}	80.84 ab	7.75 a	3.36 b	2.77 ab	5.20 b
180 kg Nha^{-1}	82.98 a	7.62 ab	3.89 a	3.23 a	6.49 a
*Significant at 5% level	*	*	*	*	*
CV (%)	3.41	6.67	9.15	28.91	13.85

Table 79. Interaction effect of irrigation and nitrogen on grain yield of wheat at Barind area during 2013-14

Treatment	N_0	N_1	N_2	N_3
W_1	1.42 cd	2.03 bcd	2.67 abc	3.12 ab
W_2	1.50 cd	2.58 a-d	3.00 ab	2.76 abc
W_3	1.27 d	2.07 bcd	2.63 abc	3.83 a
*Significant at 5% level	*	*	*	*
CV (%)		28.91		

Table 80. Interaction effect of irrigation and nitrogen on straw yield of wheat at Barind area during 2013-14

Treatment	N_0	N_1	N_2	N_3
W_1	2.08 f	4.63 cde	5.47 bc	6.00 b
W_2	2.62 f	4.25 de	5.33 bcd	6.23 ab
W_3	2.07 f	3.77 e	4.80 cde	7.23
*Significant at 5% level	*	*	*	*
CV (%)		13.85		

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

W_1 = One irrigation (at flag leaf ligule emergence stage)
W_2 = Two irrigations (at crown root, CRI and anthesis stage)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and anthesis stage)

Economic analysis of the study:

The economic analysis of wheat production affected by different levels of irrigation and nitrogen fertilizer in Barind area, Rajshahi are presented in Table 81. From the table it was observed that the maximum total return (Tk. 1,36,860/-) was noted under the treatment combination W_3N_2, where 100 kg Nha^{-1} was applied with 3 irrigations. The minimum total return was noticed as Tk. 54,610/- under W_2N_0. The highest and lowest benefit-cost ratio was observed as 1.44 in W_3N_2 and 0.62 in W_2N_0, respectively.

Table 81. Economic analysis of wheat production affected by different levels of irrigation and N fertilizer in Barind area, Rajshahi.

Treatment	Fixed Cost (Tk ha^{-1})	Variable Cost (Tk ha^{-1})	Total Cost (Tk ha^{-1})	Yield (grain) t ha^{-1}	Yield (straw) t ha^{-1}	*Total Return	BCR
W_1N_0	30000	54880	84880	2.03	2.66	56070	0.66058
W_1N_1	30000	57387	87387	3.12	4.34	86680	0.99191
W_1N_2	30000	59894	89894	3.48	4.34	95680	1.064365
W_1N_3	30000	62401	92401	3.94	5.37	109240	1.182238
W_2N_0	30000	57380	87380	1.97	2.68	54610	0.624971
W_2N_1	30000	59887	89887	3.57	5.24	99730	1.109504
W_2N_2	30000	62394	92394	4.12	5.09	113180	1.224971
W_2N_3	30000	64901	94901	3.75	4.61	102970	1.085025
W_3N_0	30000	59880	89880	2.07	3.02	57790	0.642968
W_3N_1	30000	62387	92387	3.98	5.01	109520	1.185448
W_3N_2	30000	64894	94894	4.96	6.43	136860	1.442241
W_3N_3	30000	67401	97401	4.39	5.69	121130	1.243622

* Total return = Return (Grain + Straw). Details are shown in appendix 1-3.

Legend:

W_1 = One irrigation (at flag leaf ligule emergence stage)
W_2 = Two irrigations (at crown root, CRI and anthesis stage)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and anthesis stage)

N_0 = No Nitrogen N_2 = 100 kg Nha^{-1}
N_1 = 50 kg Nha^{-1} N_3 = 150 kg Nha^{-1}

Conclusion & Recommendations:

From the above three years study, the following conclusions may be drawn:

1. Different irrigation and N levels showed a significant effect on the growth and yield of wheat. Maximum grain and straw yield of wheat noted from the treatment where 100 kg Nha^{-1} was applied with three irrigation practices.

2. Application of nitrogen fertilizer with different rate and splits highly influenced on the amount of total N uptake, Ndff and Ndfs in wheat plant. Maximum total N uptake was noticed as 125.31 kg ha^{-1} under the treatment, where nitrogen fertilizer was applied in three equal splits.

3. From the isotopic study, it was found that wheat plant received the highest amount of nitrogen as 54.26 kg ha^{-1} from fertilizer sources when N applied in three equal splits, i,e. N use efficiency increased to maximum.

5. Comparatively, the minimum amount of soil nitrogen used by wheat plant when nitrogen fertilizer was applied in 3 equal splits.

6. From the economic point of view, the highest profit (Tk. 41,966/- per ha) and benefit-cost ratio (1.44) were obtained from the treatment W_3N_2 for production of wheat in Barind area, where 100 kg Nha^{-1} was applied with three irrigations.

Study the use efficiency of soil water and nitrogen for sustainable wheat production in drought prone areas of Bangladesh

Location	:	Sarail, Godagari (Rajshahi)	Year	:	2012-13
Date of sowing	:	December, 2013	Crop/Variety	:	BARI GOM-28
Design of Experiment	:	RCBD split plot	Replication	:	3
Main plot treatment	:	Irrigation (4 Nos.)	Size of plot	:	4 m × 5 m
Sub-plot treatment	:	Nitrogen level (6 Nos.)			

Main plot treatments (soil water regimes): Nos. 4

W_0 = No irrigation
W_1 = One irrigation (at flag leaf ligule emergence stage)
W_2 = Two irrigations (at crown root, CRI and anthesis stege)
W_3 = Three irrigation (at CRI, flag leaf ligule emergence and anthesis stege)

Sub-plot treatments (Nitrogen fertilizer): Nos. 6

N_0 = 0 kg Nha^{-1}	N_2 = 90 kg Nha^{-1}	N_4 = 180 kg Nha^{-1}
N_1 = 60 kg Nha^{-1}	N_3 = 120 kg Nha^{-1}	N_5 = 210 kg Nha^{-1}

Fertilizer application:

a. Nitrogen fertilizer was applied as treatments into three splits as: i) 1/3N as basal dose after final land preparation, ii) 1/3 N as top dress during crown root initiation stage (CRI) and iii) The rest 1/3 N as top dress during flowering/anthesis stage.

b. Others fertilizer such as TSP, MP, gypsum etc. was applied as recommended dose at the final land preparation

Data recorded:

1. Total analysis of the initial soil.
2. Yield and yield contributing data for crop
3. Meteorological data.

N.B. i) A common irrigation will be done for wheat seed germination in all plots uniformly
ii) According to the suggestions of the 2nd year workshop at BARC, 2013 the experimental treatments were revised for the year of 2013-14 as follows:

Results

Effect of irrigation and nitrogen levels on **wheat:**

Different levels of irrigation along with different rate of N significantly influenced on the grain and straw yield of wheat (Table 82-85). Considering the mean effect of irrigation maximum grain and straw yield was recorded as 3.68 and 4.71 t ha^{-1} in W_2 treatment where 2 irrigations were applied for wheat production. The grain yield was also showed an identical value as 3.10 t ha^{-1} in W_1 treatment, where only one irrigation was applied. Incase of different N levels the highest grain and straw yield of wheat were recorded in N_5 treatment as 3.64 and 4.73 t ha^{-1}, respectively. In both cases, the yields were statistically identical with the treatment N_4 (grain: 3.48 t ha^{-1}; straw: 4.24 t ha^{-1}), N_2 (grain: 3.49 t ha^{-1}; straw: 4.45 t ha^{-1}) and N_3 (grain: 3.43 t ha^{-1}; straw: 4.26 t ha^{-1}).

Considering the interaction effect, the maximum grain yield of wheat was recorded as 4.68 t ha^{-1} in treatment combination of W_2N_5, where 210 kg Nha^{-1} was applied with 2 irrigations. But this result is statistically identical with the treatment W_2N_2 (3.82 t ha^{-1}).

Table 82. Mean Effect of different Irrigation practices on the yield of wheat grown at Barind area during 2012-13.

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
W_0 = No irrigation	2.761 b	3.37 c
W_1 = One irrigation (at flag leaf ligule emergence stage)	3.097ab	3.96 bc
W_2 = Two irrigations (at crown root, CRI and anthesis stage)	3.683 a	4.71 a
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and anthesis stage	3.293 ab	4.41 ab
*Significant at 5% level	*	*
CV (%)	16.34	18.53

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 83. Mean Effect of different N levels on the yield of wheat grown at Barind area during 2012-13

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N_0 = 0 kg N/ha	2.37 c	3.29 c
N_1 = 60 kg N/ha	2.85 b	3.70 bc
N_2 = 90 kg N/ha	3.49 a	4.45 a
N_3 = 120 kg N/ha	3.43 a	4.26 ab
N_4 = 180 kg N/ha	3.48 a	4.24 ab
N_5 = 210 kg N/ha	3.64 a	4.73 a
*Significant at 5% level	*	*
CV (%)	16.34	18.53

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 84. Interaction Effect of different Irrigation and N levels on grain yield of wheat grown at Barind area during 2012-13.

Treatment	W_0	W_1	W_2	W_3	Mean
N_0	2.44 ghi	2.38 hi	2.40 hi	2.26 i	2.37
N_1	2.60 f-i	2.38 hi	3.44 c-g	2.99 d-i	2.85
N_2	2.70 e-i	2.98 d-i	3.82 a-d	4.47 ab	3.49
N_3	2.95 d-i	3.38 c-h	3.74 a-d	3.63 b-e	3.42
N_4	2.91 d-i	3.56 b-f	4.04 a-c	3.40 c-h	3.48
N_5	2.96 d-i	3.91 a-d	4.68 a	3.00 d-i	3.64
Mean	2.76	3.10	3.68	3.29	
**Significant at 1% level	**	**	**	**	**
CV (%)			16.34		

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 85. Interaction Effect of different Irrigation and N levels on the straw yield of wheat grown at Barind area during 2012-13.

Treatment	W_0	W_1	W_2	W_3	Mean
N_0	2.38	3.10	4.41	3.26	3.29
N_1	3.69	3.53	3.85	3.74	3.70
N_2	3.16	4.10	4.72	5.81	4.45
N_3	3.37	4.62	4.51	4.52	4.25
N_4	3.27	4.14	4.89	4.64	4.23
N_5	4.35	4.24	5.86	4.48	4.73
Mean	3.37	3.95	4.71	4.41	
*Significant at 5% level	NS	NS	NS	NS	NS
CV (%)			18.53		

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Legend:

W_0 = No irrigation
W_1 = One irrigation (at flag leaf ligule emergence stage)
W_2 = Two irrigations (at crown root, CRI and anthesis stage)
W_3 = Three irrigations (at CRI, flag leaf ligule emergence and anthesis stage

N_0 = 0 kg N/ha
N_1 = 60 kg N/ha,
N_2 = 90 kg N/ha
N_3 = 120 kg N/ha
N_4 = 180 kg N/ha
N_5 = 210 kg N/ha
NS = Non significant

Effect of nitrogen split application on the growth and yield of wheat at Barind area of Bangladesh

Location	:	Godagari (Rajshahi)	Year	:	2013-14
Date of sowing	:	December, 2013	Design of Experiment	:	RCBD
Size of plot	:	3 × 3m^2	Replication	:	3

Treatment Description:

N_{1A} = 1/3rd N (60 kg ha^{-1}) at CRI stage + 2/3rd N (60 kg ha^{-1}) at anthesis stage
N_{1B} = 1/3rd N (60 kg ha^{-1}) at CRI stage + 1/3rd N (60 kg ha^{-1}) at FL stage +1/3rd N (60 kg ha^{-1}) at anthesis stage
N_{1C} = 60 kg ha^{-1} at the time of wheat sowing
N_{2A} = 1/3rd N (120 kg ha^{-1}) at CRI stage + 2/3rd N (120 kg ha^{-1}) at anthesis stage
N_{2B} = 1/3rd N (120 kg ha^{-1}) at CRI stage + 1/3rd N (120 kg ha^{-1}) at FL stage + 1/3rd N (120 kg ha^{-1}) at anthesis stage
N_{2C} = 120 kg ha^{-1} at the time of wheat sowing
N_{3A} = 1/3rd N (180 kg ha^{-1}) at CRI stage + 2/3rd N (180 kg ha^{-1}) at anthesis stage
N_{3B} = 1/3rd N (180 kg ha^{-1}) at CRI stage + 1/3rd N (60 kg ha^{-1}) at FL stage + 1/3rd N (180 kg ha^{-1}) at anthesis stage
N_{3C} = 180 kg ha^{-1} at the time of wheat sowing

Data recorded:

1. Climate data round the year (temp-min & max, average rainfall & RH)
2. Yield and yield contributing data

Effect of nitrogen split application on the growth and yield of wheat at Barind area of Bangladesh

Different levels of nitrogen along with different split application approaches significantly influenced on the grain and straw yield of wheat (Table 86). Among the different treatment combinations the maximum grain yield (5.17 t ha^{-1}) of wheat was observed from the treatment combination N_{3A}, where 120kg Nha^{-1} was applied in 3 equal splits. The minimum wheat yield of 2.77 t ha^{-1} was recorded in N_{1C}, where the total nitrogen was applied at the time of wheat sowing. Similar trend was noticed regarding the straw yield of wheat. Hence, the highest and lowest straw yield of wheat was noted from the treatment combination N_{3A} as 8.37 t ha^{-1} and N_{1C} as 3.92 t ha^{-1}, respectively.

Table 86. Effect of different nitrogen levels along with different split application approaches on the grain and straw yield of wheat at Godagari, Rajshahi during 2013-14.

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N_{1A} = 1/3rd N (60 kg ha^{-1}) at CRI stage + 2/3rd N (60 kg ha^{-1}) at anthesis stage	3.35	6.87
N_{1B} = 1/3rd N (60 kg ha^{-1}) at CRI stage + 1/3rd N (60 kg ha^{-1}) at FL stage +1/3rd N (60 kg ha^{-1}) at anthesis stage	3.18	4.13
N_{1C} = 60 kg ha^{-1} at the time of wheat sowing	2.77	3.92
N_{2A} = 1/3rd N (120 kg ha^{-1}) at CRI stage + 2/3rd N (120 kg ha^{-1}) at anthesis stage	4.46	7.23
N_{2B} = 1/3rd N (120 kg ha^{-1}) at CRI stage + 1/3rd N (120 kg ha^{-1}) at FL stage + 1/3rd N (120 kg ha^{-1}) at anthesis stage	3.93	5.97
N_{2C} = 120 kg ha^{-1} at the time of wheat sowing	3.52	5.25
N_{3A} = 1/3rd N (180 kg ha^{-1}) at CRI stage + 2/3rd N (180 kg ha^{-1}) at anthesis stage	5.17	8.37
N_{3B} = 1/3rd N (180 kg ha^{-1}) at CRI stage + 1/3rd N (60 kg ha^{-1}) at FL stage + 1/3rd N (180 kg ha^{-1}) at anthesis stage	4.83	7.31
N_{3C} = 180 kg ha^{-1} at the time of wheat sowing	3.81	6.13

Effect of Irrigation and Nutrient Management approach on rice production in saline area of Bangladesh

The experiment was conducted at Subarnachar, Noakhali district of saline area during Boro season. The test crop was Binadhan-8 with salinity level 8-10 dS/m in field condition. The experiment was laid out in split-plot design along with two irrigation treatment and five nutrient management approaches Viz. main plot treatment I_1 = Continuous flooding, I_2 = Alternate wetting and drying (AWD) and the subplot treatments were M_1 = Recommended dose as 125, 20, 35, 6 & 1.5 kg ha^{-1} for N, P, K, S & Zn; M_2 = M_1 + Additional Gypsum @ 125 kg ha^{-1}, M_3 = M_2 + Additional K @ 40 kg ha$^{-1,}$ M_4 = M_1 + Additional Gypsum @ 175 kg ha^{-1} and M_5 = M_4 + Additional K @ 40 kg ha^{-1}. There were 6 (2x3) main plot of irrigation treatment and 18 (3x2x3) unit subplot of slopping bed approaches. Full dose of P, K, S, Zn and 1/3rd of N fertilizer were applied at the time of land preparation. The rest of N fertilizer was applied in two equal splits, i.e. 30 days of transplanting and 60 days after sowing.

Result and Discussion:

Effect of irrigation and nutrient management on yield of Rice:

Mean effect of irrigation and nutrient management and their interaction significantly affected on the grain and straw yield of rice (Table 87-90). From the table 87 it was observed that, among the different irrigation treatments the maximum rice grain and straw yield of rice was recorded under AWD though the results were statistically not significant (Table 87). From table 6, the different nutrient management practices showed significant effects on both grain and straw yield of rice. The maximum grain and straw yield were recorded as 5.12 and 6.05 tha^{-1} under the treatment M_5. Considering the interaction effect of irrigation and nutrient management practice the maximum grain yield of rice was recorded under the treatment combination of I_1M_5 as 5.22 t ha^{-1}. Similar trends were observed in case of straw yield of rice and the maximum straw yield of rice was recorded as 6.21 t ha^{-1} under I_1M_5 (Table 90).

Table 87. Mean effect of irrigation on grain and straw yield of Rice

Treatment	GY (t ha^{-1})	SY (t ha^{-1})
I_1 = Continuous flooding	4.64	5.55
I_2 = Alternate wetting and drying (AWD)	4.69	5.44
*Significant at 5% level	.05	
CV (%)	3.45	5.08

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 88. Mean effect of nutrient management on grain and straw yield of Rice

Treatment	GY (t ha^{-1})	SY GY (t ha^{-1})
: Recommended dose as 125, 20, 35, 6 & 1.5 kg ha^{-1} for N, P, K, S & Zn	4.09 d	4.92 d
: M_1 + Addtional Gypsum @ 125 kg ha^{-1}	4.44 c	5.34 c
: M_2 + Addtional K @ 40 kg ha^{-1}	4.75 b	5.46 bc
M_4 : M_1 + Addtional Gypsum @ 175 kg ha^{-1}	4.92 b	5.72 ab
M_5 : M_4 + Addtional K @ 40 kg ha^{-1}	5.12 a	6.05 a
*Significant at 5% level	*	*
CV (%)	3.45	5.08

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 89. Interaction effect of irrigation and nutrient management on grain yield of Rice

Treatment	M_1	M_2	M_3	M_4	M_5
I_1 = Continuous flooding	4.04 d	4.27 d	4.74 bc	4.92 ab	5.22 a
I_2 = Alternate wetting and drying (AWD)	4.14 d	4.61 c	4.45 bc	4.92 b	5.02 ab
*Significant at 5% level	*	*	*	*	*
CV (%)			3.45		

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Table 90. Interaction effect of irrigation and nutrient management on straw yield of Rice

Treatment	M_1	M_2	M_3	M_4	M_5
I_1 = Continuous flooding	5.07 de	5.37 bcd	5.45 bcd	5.66 bc	6.21 a
I_2 = Alternate wetting and drying (AWD)	4.77 e	5.31 cd	5.47 bcd	5.78 abc	5.89 ab
Level of significance	*	*	*	*	*
CV (%)			5.08		

In a column, means followed by common letter(s) do not significantly at 1% level by DMRT.

Sub-plot treatment

M_1 : Recommended dose as 125, 20, 35, 6 & 1.5 kg ha^{-1} for N, P, K, S & Zn
M_2 : M_1 + Addtional Gypsum @ 125 kg ha^{-1}
M_3 : M_2 + Addtional K @ 40 kg ha^{-1}
M_4 : M_1 + Addtional Gypsum @ 175 kg ha^{-1}
M_5 : M_4 + Addtional K @ 40 kg ha^{-1}

Conclusion

From the above study it can be concluded that production of rice higher when higher dose of gypsum and potassium applied along with recommended fertilizer dose.

Monitoring the degree and extent of salinity level in Noakhali area of Bangladesh

Under the IAEA/CRP 17732 project, from the Soil Science Division, Bangladesh Institute of Nuclear (BINA), we have conducted the study to monitor the soil and water salinity status in the three experimental sites such as - Subarnachar, Darmapur and Hazirhat of Noakhali district, Bangladesh at one month interval during the year of 2013-14. Data of salinity are presented in the Fig. 11-12. From the Fig. 11 it was observed that at the month of July the water salinity ranged from 2.97 dS/m in Subarnachar site to 3.42 ds/m in Hazirhat site and the value was decreased to 1.89 - 2.25 ds/m upto the month of October, 2013. Later on the water salinity showed an increasing trend and the maximum salinity was noted in the month of April as 8.02 - 8.79 dS/m. After the month of April, the water salinity again decreased to 3.02 -5.23 dS/m at the month of December, 2014.

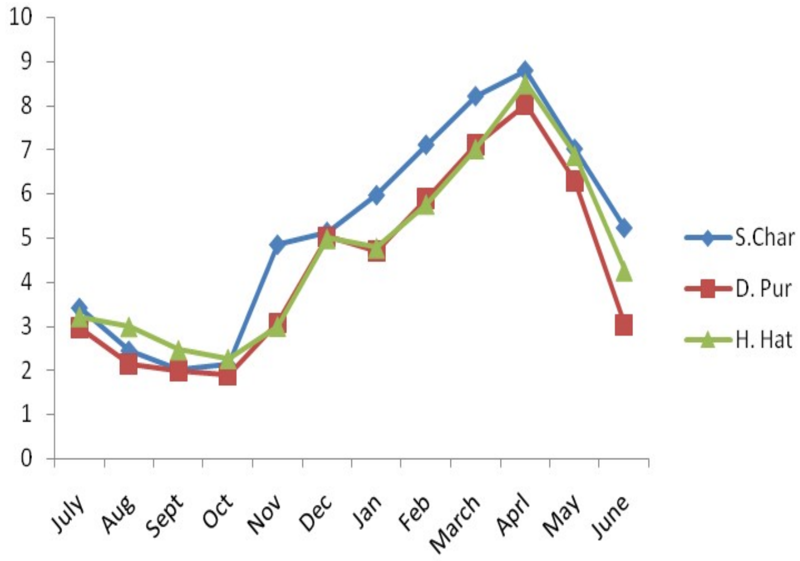


Fig. 11. Water salinity status of three experimental sites collected from Noakhali, Bangladesh during 2013-14

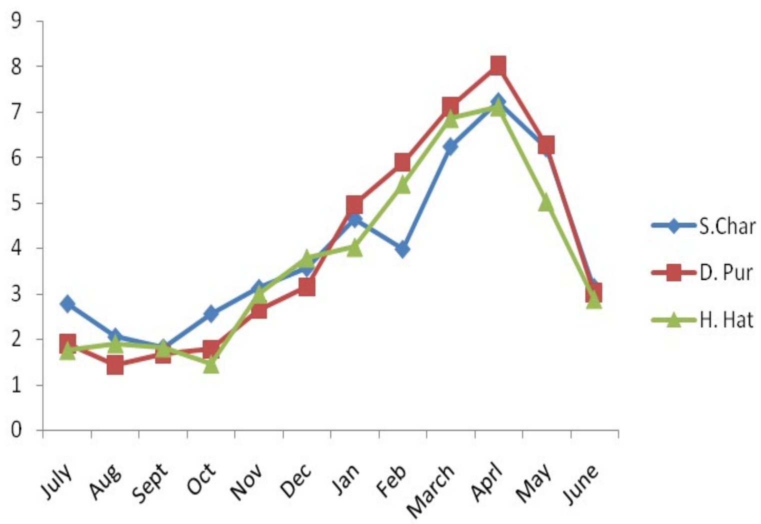


Fig. 12. Soil salinity status of three experimental sites in Noakhali, Bangladesh during 2013-14.

Legend: S. Char = Subarnachar; D. Pur = Darmapur and H. Hat = Hazirhat

Assessment of existing carbon stock in soils of 10 AEZs in Bangladesh

Experiment was conducted to quantify the existing carbon status from different AEZs of Bangladesh. Soil samples were collected from ten (10) AEZs: AEZ 11. High Ganges River Floodplain, AEZ 12. Low Ganges River Floodplain, AEZ 13. Ganges Tidal Floodplain, AEZ 14. Gopalganj-Khulna Bils, AEZ 15. Arial Bil, AEZ 16. Middle Meghna River Floodplain, AEZ 17. Lower Meghna River Floodplain, AEZ 18. Young Meghna Estuarine Floodplain, AEZ 19. Old Meghna Estuarine Floodplain and AEZ 20. Eastern Surma-Kusiyara Floodplain. A total of 2400 soil samples were collected during 2010–2013. Upazila, mouja and land type were selected using “Thana Nirdeshika” of Soil Resource Development Institute (SRDI) of Bangladesh. Two hundred forty (240) soil samples were collected from (2 upazilas × 3 moujas × 10 samples per available land types × 4 depths) each AEZ of Bangladesh. Four depths of soil were considered (0-5, 5-10, 10-15 and 15-20 cm) for each sampling site. Soil samples were analyzed to find out the bulk density, organic carbon content and its storage in different depths with different land types irrespective of different AEZs.

Bulk density and organic carbon content results are presented in Table 91 in respect of different land types and depths of AEZs 11–12 soils. The highest bulk density was found in AEZ 12. Minimum bulk density was observed 0.67, 0.76, 0.73 and 0.69 g cm^{-3} in 0-5, 5-10, 10-15 and 15-20 cm at AEZ 14, respectively. At 0-5 cm soil depth, bulk density was decreased in the order of HL<MHL<MLL<LL <VLL in soil except AEZ 17 and 18. Based on the results, it may be concluded that bulk density is increased with the increase of soil depth at different AEZs of Bangladesh. Organic carbon content was more in lower bulk density than higher bulk density containing soil. The highest organic carbon content was observed in 0- 5 cm depth in all AEZs except AEZ 14 and the lowest organic carbon was found in 15-20 cm depth of soil. SOC content (%) in highland was medium in AEZ 11, 12, 13, 18 & 19 and very low in AEZ 16 and 17, as per soil organic carbon ranking in Fertilizer Recommendation Guide of BARC. Organic carbon content in very lowland soil was very high in AEZ 14 and 15. From the study, it was clear that organic carbon content gradually decreased with the increase of soil depth. Depth and land type wise soil organic carbon stock results are presented (Table 92). Maximum organic carbon stock (74.50 t ha^{-1}) was obtained from 10 – 15 cm depth in AEZ 14. Among the AEZs, AEZ 16, 17 and 18 contained minimum organic carbon in soil compared to other studied AEZs. According to land type, the range of soil organic carbon stock in AEZ 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 was 6.57-11.06, 9.31-33.49, 8.29-9.37, 17.68-69.61, 22.23-34.87, 3.55-8.30, 3.93-5.23, 5.10-6.63, 9.23-11.84 and 5.08-8.52 t ha^{-1}, respectively. The highest SOC stock was observed in surface soil (0-5 cm) and the lowest SOC stock was found in 15-20 cm soil depth. It appeared that SOC stock decreased gradually with the increase of soil depth irrespective of land types. Organic carbon content and stocks results in respect of land type in different AEZs are summarized (Table 93). The highest organic carbon content was found in very lowland soil in AEZ 12, 14, 16, 19 and 20. The lowest organic carbon content was found in highland soil in all AEZs. Maximum organic carbon stock (1.40 million tones) was observed in AEZ 13 and the lowest organic carbon stock (0.01 million tonnes) was found in AEZ 15 irrespective of AEZ basis. Soil organic carbon stock was increased in the order of VLL>LL>MLL>MHL>HL in soil in different AEZs. Soil organic carbon stock was observed in the order of AEZ 13>11>12>19>18>20>14>16>17>15. The tendency of carbon density increase with the decrease of altitude means sea level from the studied AEZs may be due to better stabilization of SOC at lowland and very lowland soils in Bangladesh because lowland remained submerged condition most of the time of the year.

Table 91. Land type and area, bulk density (g cm^{-3}) and organic carbon content (%) at different depths of soils in different AEZs of Bangladesh

AEZ	Area, land type and coverage			Bulk density in different depths (g cm^{-3})				Organic carbon in different depths (cm)			
	(ha)	LT	(%)	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
11	1320549	HL	43	1.30±0.015	1.31±0.016	1.39±0.021	1.54±0.019	1.14±0.119	1.06±0.118	0.74±0.077	0.77±0.117
		MHL	32	1.28±0.031	1.32±0.027	1.42±0.030	1.59±0.024	1.67±0.267	1.37±0.171	1.15±0.205	0.94±0.127
		MLL	12	1.23±0.031	1.32±0.046	1.43±0.050	1.55±0.026	1.95±0.218	1.46±0.229	1.07±0.225	1.03±0.126
		LL	2	1.12±0.155	1.07±0.105	1.19±0.235	1.26±0.285	2.40±0.290	2.36±0.210	1.76±0.625	1.58±0.640
12	796851	HL	13	1.39±0.029	1.43±0.045	1.41±0.067	1.64±0.048	1.66±0.135	1.48±0.101	1.25±0.152	0.76±0.205
		MHL	29	1.32±0.035	1.32±0.026	1.38±0.028	1.56±0.031	2.42±0.217	2.30±0.250	1.76±0.211	1.14±0.193
		MLL	31	1.23±0.050	1.30±0.045	1.33±0.005	1.51±0.060	3.23±0.155	2.67±0.080	2.81±0.840	2.88±1.075
		LL	14	1.21±0.012	1.26±0.017	1.35±0.023	1.56±0.029	4.03±0.011	2.27±0.058	2.40±0.023	2.28±0.035
		VLL	2	1.08±0.011	1.26±0.018	1.33±0.012	1.39±0.040	7.90±0.231	6.85±0.375	4.49±0.167	2.68±0.116
13	1706573	HL	2	1.30±0.021	1.37±0.019	1.46±0.020	1.50±0.019	1.48±0.121	1.41±0.112	1.05±0.107	0.90±0.111
		MHL	78	1.25±0.033	1.30±0.027	1.47±0.040	1.50±0.028	1.86±0.183	1.67±0.198	1.00±0.138	0.73±0.099
		MLL	2	1.33±0.027	1.52±0.031	1.52±0.016	1.48±0.036	1.41±0.134	1.83±0.649	0.86±0.091	1.03±0.155
14	224700	HL	3	1.25±0.012	1.19±0.040	1.29±0.023	1.50±0.023	2.73±0.017	2.60±0.058	2.52±0.058	2.81±0.066
		MHL	13	1.21±0.015	1.21±0.012	1.22±0.019	1.12±0.098	5.46±0.294	5.95±0.416	5.93±0.185	7.11±0.352
		MLL	41	1.02±0.040	1.05±0.052	1.11±0.029	1.19±0.017	9.38±0.185	9.58±0.577	8.15±0.067	8.40±0.546
		LL	28	0.91±0.028	0.92±0.023	0.92±0.011	0.95±0.017	12.60±0.635	15.87±0.207	14.50±1.131	12.64±0.814
		VLL	11	0.67±0.063	0.76±0.057	0.73±0.046	0.69±0.040	21.90±1.293	20.51±1.784	20.41±1.258	15.17±0.542
15	14436	MLL	13	1.36±0.058	1.51±0.092	1.45±0.040	1.60±0.098	5.00±0.017	3.63±0.020	2.45±0.075	1.22±0.075
		LL	73	1.16±0.040	1.23±0.069	1.35±0.080	1.47±0.069	7.56±0.912	6.14±0.121	4.90±0.191	3.37±0.109

AEZ = Agroecological zone, LT = Land type, HL = Highland, MHL = Medium highland, MLL = Medium lowland, LL = Lowland and VLL = Very lowland and SE (±) = standard error

Table 91. Contd.

AEZ	Area, land type and coverage			Bulk density in different depths (g cm^{-3})				Organic carbon in different depths (cm)			
	(ha)	LT	(%)	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
16	155464	MHL	8	1.25±0.021	1.34±0.027	1.42±0.016	1.43±0.054	0.81±0.197	0.64±0.087	0.40±0.049	0.33±0.044
		MLL	29	1.26±0.067	1.33±0.057	1.40±0.038	1.47±0.050	0.50±0.115	0.26±0.095	0.24±0.044	0.57±0.115
		LL	25	1.14±0.035	1.31±0.051	1.38±0.029	1.26±0.115	1.18±0.149	1.09±0.133	0.50±0.093	0.79±0.370
		VLL	11	1.16±0.100	1.18±0.080	1.24±0.077	1.32±0.056	2.24±0.330	2.26±0.350	1.15±0.305	0.74±0.040
17	90934	HL	14	1.15±0.046	1.28±0.028	1.45±0.019	1.48±0.016	1.07±0.119	0.74±0.120	0.38±0.079	0.31±0.072
		MHL	28	1.19±0.035	1.24±0.037	1.37±0.037	1.44±0.031	1.12±0.082	0.87±0.084	0.64±0.063	0.32±0.036
		MLL	31	1.16±0.028	1.14±0.033	1.34±0.039	1.44±0.040	1.32±0.114	1.04±0.118	0.73±0.111	0.47±0.100
18	926885	MHL	45	1.10±0.031	1.23±0.029	1.42±0.019	1.45±0.012	1.46±0.054	1.12±0.042	0.50±0.027	0.33±0.015
		MLL	7	1.18±0.032	1.27±0.062	1.41±0.012	1.52±0.048	0.94±0.115	1.13±0.041	1.39±0.516	0.55±0.075
19	774026	HL	2	1.27±0.026	1.25±0.029	1.40±0.031	1.46±0.023	1.62±0.172	1.67±0.171	1.21±0.103	1.10±0.153
		MHL	24	1.10±0.047	1.21±0.043	1.40±0.050	1.44±0.031	2.89±0.257	2.48±0.391	1.57±0.335	0.98±0.141
		MLL	33	1.09±0.041	1.15±0.064	1.26±0.065	1.34±0.070	2.13±0.247	1.84±0.282	1.39±0.268	1.28±0.253
		LL	21	1.03±0.026	1.18±0.059	1.33±0.037	1.44±0.015	2.43±0.286	1.94±0.338	1.34±0.333	1.15±0.329
		VLL	3	0.90±0.034	1.09±0.046	1.16±0.031	1.24±0.018	2.39±0.277	2.04±0.322	1.41±0.355	0.93±0.358
20	462159	HL	5	1.18±0.034	1.02±0.066	1.22±0.062	1.52±0.030	1.16±0.149	1.03±0.123	0.72±0.132	0.58±0.200
		MHL	25	1.18±0.044	1.12±0.052	1.31±0.059	1.37±0.071	1.11±0.136	0.95±0.152	0.66±0.107	0.94±0.195
		MLL	20	0.96±0.061	1.10±0.045	1.18±0.077	1.17±0.066	1.95±0.302	1.32±0.207	0.94±0.212	1.22±0.259
		LL	36	1.00±0.061	0.99±0.064	1.09±0.057	1.15±0.044	1.68±0.232	1.97±0.308	1.77±0.237	1.50±0.235

AEZ = Agroecological zone, LT = Land type, HL = Highland, MHL = Medium highland, MLL = Medium lowland, LL = Lowland and VLL = Very lowland and SE (±) = standard error

Table 92. Land type and area, organic carbon stock (t ha^{-1}) at different depths (cm) of soils in different AEZs of Bangladesh

AEZ	Area, land type and coverage			Organic carbon stock in different depths (t ha^{-1})			
	(ha)	LT	(%)	0-5	5-10	10-15	15-20
11	1320549	HL	43	7.83±0.841	7.16±0.775	5.20±0.496	6.09±0.920
		MHL	32	10.02±1.732	8.91±1.055	8.00±1.382	7.44±1.009
		MLL	12	11.87±1.154	9.37±1.227	7.44±1.439	7.91±0.923
		LL	2	13.15±0.235	12.41±0.115	9.69±1.645	8.99±1.775
12	796851	HL	13	11.59±1.035	10.86±0.735	8.76±1.003	6.02±1.556
		MHL	29	15.76±1.232	15.09±1.519	12.02±1.221	8.56±1.205
		MLL	31	20.32±0.275	17.83±0.795	18.76±4.230	21.73±5.290
		LL	14	23.98±0.057	14.15±0.574	16.15±1.126	17.74±0.748
		VLL	2	42.66±1.813	43.16±1.097	29.51±0.548	18.63±1.183
13	1706573	HL	2	9.42±0.069	9.44±0.673	7.50±0.726	6.81±0.772
		MHL	78	11.59±1.114	10.83±1.246	7.20±0.963	5.42±0.661
		MLL	2	9.41±0.095	13.94±2.117	6.53±0.725	7.60±1.029
14	224700	HL	3	17.06±1.154	15.47±1.527	16.25±0.882	21.92±0.577
		MHL	13	33.03±0.577	36.00±1.333	36.17±0.433	39.82±1.154
		MLL	41	47.84±1.527	50.30±1.327	45.23±1.154	49.98±1.453
		LL	28	57.42±1.847	73.00±0.635	66.70±0.692	60.04±1.160
		VLL	11	73.67±1.733	77.94±1.362	74.50±1.293	52.34±1.091
15	14436	MLL	13	34.00±0.641	27.41±1.125	17.76±1.963	9.76±0.271
		LL	73	43.85±0.814	37.76±1.656	33.08±2.211	24.77±0.843
16	155464	MHL	8	5.00±1.243	4.13±0.554	2.74±0.337	2.35±0.335
		MLL	29	2.72±0.057	1.67±0.425	1.53±0.277	0.46±0.360
		LL	25	6.81±0.972	7.14±0.924	3.37±0.641	2.81±0.806
		VLL	11	10.44±0.280	11.21±0.335	6.76±0.838	4.80±0.590
17	90934	HL	14	6.22±0.622	4.51±0.665	2.69±0.536	2.31±0.430
		MHL	28	6.57±0.496	5.29±0.451	4.51±1.189	2.32±0.239
		MLL	31	7.39±0.537	5.72±0.540	4.67±0.567	3.14±0.520
18	926885	MHL	45	7.81±0.324	6.75±0.281	3.51±0.204	2.32±0.129
		MLL	7	5.38±0.525	7.20±0.332	9.87±1.673	4.06±0.380
19	774026	HL	2	10.12±1.014	10.35±1.081	8.38±0.677	8.05±1.115
		MHL	24	15.68±1.461	14.18±2.048	10.46±2.247	7.04±1.085
		MLL	33	11.25±1.422	9.96±1.321	8.01±1.249	7.89±1.361
		LL	21	12.84±1.509	11.45±1.917	9.63±2.089	6.62±1.984
		VLL	3	9.87±1.437	9.64±1.571	6.44±1.535	3.61±0.959
20	462159	HL	5	6.71±0.715	5.03±0.443	4.11±0.576	4.45±1.594
		MHL	25	6.29±0.576	5.03±0.600	3.97±0.524	5.60±0.888
		MLL	20	8.92±1.111	6.96±0.950	5.04±0.852	6.55±1.165
		LL	36	8.87±0.856	8.61±1.087	8.49±1.131	8.11±1.130

AEZ = Agroecological zone, LT = Land type, HL = Highland, MHL = Medium highland
MLL = Medium lowland LL = Lowland and VLL = Very lowland and SE (±) = standard error

Table 93. Organic carbon content (%), organic carbon stock (t ha^{-1}) at different land types and carbon stock (million tonnes per AEZ) in different AEZs of Bangladesh

AEZ/ LT	Organic carbon content (%)					Organic carbon stock (t ha^{-1})					C stock (AEZ)
	HL	MHL	MLL	LL	VLL	HL	MHL	MLL	LL	VLL	(t ×10^6)
11	0.93±0.101	1.28±0.156	1.38±0.214	2.03±0.208	-	6.57±0.580	8.59±0.564	9.15±0.996	11.06±1.015	-	1.18±0.123
12	1.29±0.195	1.91±0.293	2.90±0.119	2.75±0.429	5.48±1.174	9.31±1.249	12.86±1.648	19.66±0.860	18.01±2.123	33.49±5.875	0.71±0.043
13	1.21±0.139	1.32±0.268	1.28±0.216	-	-	8.29±0.672	8.76±1.469	9.37±1.635	-	-	1.40±0.432
14	2.67±0.065	6.11±0.351	8.88±0.354	13.90±0.792	19.50±1.482	17.68±1.452	36.26±1.389	48.34±1.171	64.29±3.499	69.61±5.831	0.22±0.015
15	-	-	3.08±0.809	5.49±0.892	-	-	-	22.23±5.329	34.87±4.023	-	0.01±0.004
16	-	0.55±0.111	0.39±0.084	0.89±0.154	1.60±0.386	-	3.55±0.615	1.60±0.462	5.03±1.129	8.30±1.518	0.11±0.008
17	0.63±0.176	0.74±0.170	0.89±0.185	-	-	3.93±0.901	4.67±0.892	5.23±0.894	-	-	0.07±0.005
18	-	0.85±0.264	1.00±0.177	-	-	-	5.10±1.301	6.63±1.258	-	-	0.48±0.176
19	1.40±0.144	1.98±0.433	1.66±0.198	1.72±0.292	1.69±0.325	9.23±0.589	11.84±1.940	9.28±0.811	10.14±1.343	7.39±1.483	0.64±0.047
20	0.87±0.134	0.92±0.093	1.36±0.213	1.73±0.098	-	5.08±0.577	5.22±0.490	6.87±0.799	8.52±0.158	-	0.40±0.030

AEZ = Agroecological zone, LT = Land type, HL = Highland, MHL = Medium highland, MLL = Medium lowland, LL = Lowland and VLL = Very lowland and SE (±) = standard error

Assessment of depth distributed fallout radionuclide (FRN) and soil erosion/deposition on a hill slope in Khagrachari, Bangladesh

Objectives:

a. Sampling of reference locations to establish the reference inventory.

b. Comprehensive soil sampling to document the depth distribution of FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$) and total inventory.

c. Estimation of erosion and sedimentation rates by comparing the ^{137}Cs inventories measured for individual sampling points with the reference inventory.

The study site

This study was conducted on a hill slope at hill research centre, Khagrachari, ($23^0$8.509' E, $092^0$00.059' N - $23^0$08.492' E, $092^0$00.047' N), Bangladesh. The elevation was approximately 242 ft above mean sea level. The climate was classified as semi-arid continental monsoon, the annual average temperature was maximum 34.6 °C and the minimum 13 °C, average rainfall was 3031 mm.

Soil sampling

To determine the depth distribution of FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$), soil samples have collected from five positions as summit (S) upper slope (US), middle slope (MS) lower slope (LS) and bottom (B) on the slope. The slope was 60 m long and 75 m wide. Five sampling points were selected from each position to make a composite soil sample. Samples were collected using an 8-cm diameter hand-operated core sampler at 10 m intervals along each hill slope transect and 15 m intervals along the down slope transect on terraces. One core was collected at each sampling point and was then bulked to make a composite sample. To ensure complete FRN inventories of the soil profile, soil sampling depths at summit were 0–30 cm, at upper and middle position were 0–45 cm, at lower position in the slope were 0-60 cm and the bottom were 0-100 cm with 5 cm increment.

The establishment of a reference inventory is of critical importance in using ^{137}Cs measurements to quantify catchment erosion and sedimentation. In response to these concerns, a potential reference location was identified 200 m far from the study catchment ($23^0$08.293' E, $91^0$59.815'N) and elevation was 382 ft above mean sea level. A total of 12 cores were collected at 0-60 cm depth with 5 cm increment from a 10×10 square, with three replicate samples. The site was located within the study catchment and characterized by minimal slope, no erosion/deposition and fully vegetated.

Analysis

Soil samples were air-dried, weighed, and passed through a 2 mm sieve. ^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$ concentrations were measured using a hyper pure coaxial Ge detector coupled to a multi channel analyzer. ^{137}Cs concentration of samples was detected at 661.7 keV using counting time over 80,000 s, which provided an analytical precision of ± 6% for ^{137}Cs. Soil erosion-deposition rate was calculated using mass balance model 2 (Walling and He, 1997).

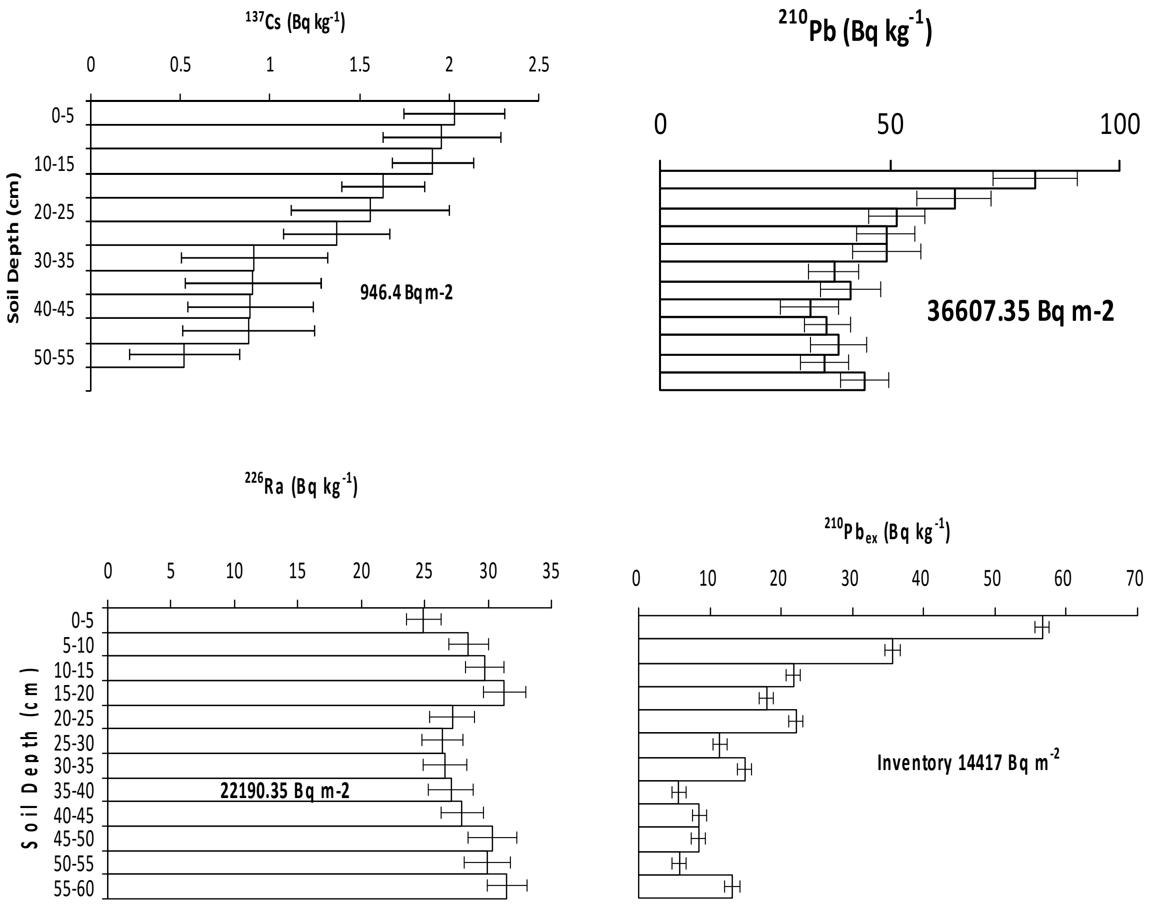


Fig. 13. Depth distribution of ^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$ activity in an undisturbed soil/ reference site

Result and discussion

Depth redistribution of FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$) activity in reference site:

The depth distribution of the ^{137}Cs activities and total inventories for the reference profiles sampled are given in Fig. 13. The ^{137}Cs activities of the reference profiles declined sharply from 2.03 Bq kg^{-1} in the 0-5 cm to 0.52 Bq kg^{-1} at 50-55 cm, 55-60 cm soil didn't contain any ^{137}Cs. The ^{137}Cs profile distribution with depth showed a decrease down to 55 cm, below this depth no ^{137}Cs activities were found. An average value of 946.4 Bq m^{-2} was obtained for the local reference inventory. It is recommended to check these levels measured in the reference site with the estimated value of global distribution of ^{137}Cs for the location. In this case the measured reference inventory was slightly lower than the ^{137}Cs values of global distribution in Argentina given by Bujan *et al.* (2003).

Quantifying depth redistribution of FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$) in study slope:

^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$ were found distributed in the top 0-30 cm at summit position (Fig. 14). ^{137}Cs activity varied from 1.72 ± 0.21 to 0.44±0.21 Bq kg^{-1}, ^{210}Pb from 79.7 ± 8.59 to 42.51 ± 6.11 Bq kg^{-1}, ^{226}Ra from 28.39 ± 1.48 to 2.71 ± 1.37 Bq kg^{-1} and ^{210}Pb$_{ex}$ from 55.23 ± 8.68 to 13.38 ± 6.33 Bq kg^{-1}.

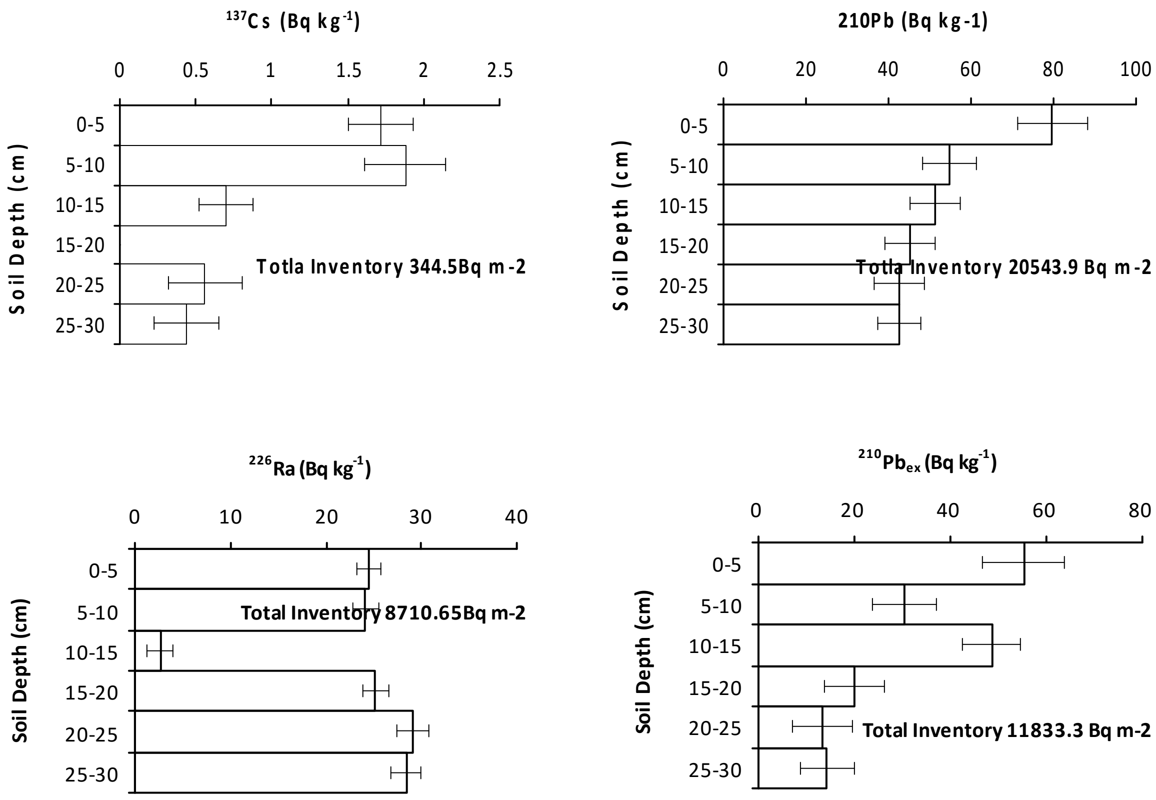


Fig. 14. Depth distribution of ^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$ activity in summit position

At upper slope position, ^{137}Cs were found distributed in the top 0-40 cm and ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$ in the 0-45 cm (Fig. 15). ^{137}Cs activity varied from 2.11 ± 0.26 to 0.87±0.2 Bq kg^{-1}, ^{210}Pb from 76.83 ± 8.91 to 30.55 ± 5.29 Bq kg^{-1}, ^{226}Ra from 27.03 ± 1.39 to 24.27 ± 1.37 Bq kg^{-1} and ^{210}Pb$_{ex}$ from 51.53 ± 9.02 to 6.28 ± 5.46 Bq kg^{-1}.

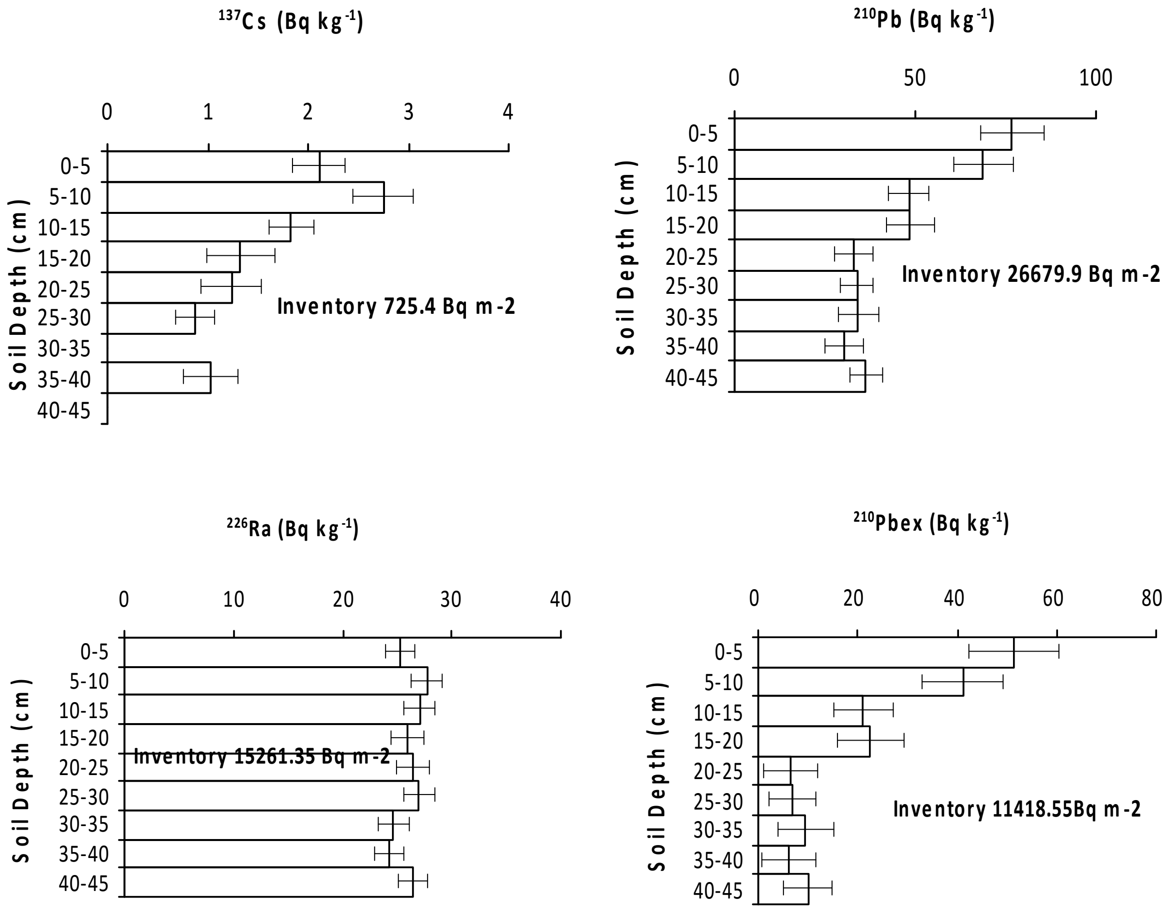


Fig. 15. Depth distribution of ^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$ activity in upper slope position

FRN were found distributed in the top 0-45 cm soil at middle slope (Fig. 16). ^{137}Cs activity varied from 4.19 ± 0.32 to 0.29 ± 0.15 Bq kg^{-1}, ^{210}Pb from 83.92 ± 9.6 to 35.77 ± 4.71 Bq kg^{-1}, ^{226}Ra from 28.77 ± 1.6 to 24.96 ± 1.27 Bq kg^{-1} and ^{210}Pb$_{ex}$ from 58.18 ± 9.7 to 7.86 ± 5.88 Bq kg^{-1}.

At lower slope position FRN were found in the top 0-60 cm soil (Fig. 17). ^{137}Cs activity varied from 6.13 ± 0.38 to 0.39 ± 0.17 Bq kg^{-1}, ^{210}Pb from 88.66 ± 9.81 to 25.84 ± 4.08 Bq kg^{-1}, ^{226}Ra from 30.31 ± 1.65 to 25.4 ± 1.38 Bq kg^{-1} and ^{210}Pb$_{ex}$ from 60.02 ± 9.94 to 2.28 ± 4.14 Bq kg^{-1}.

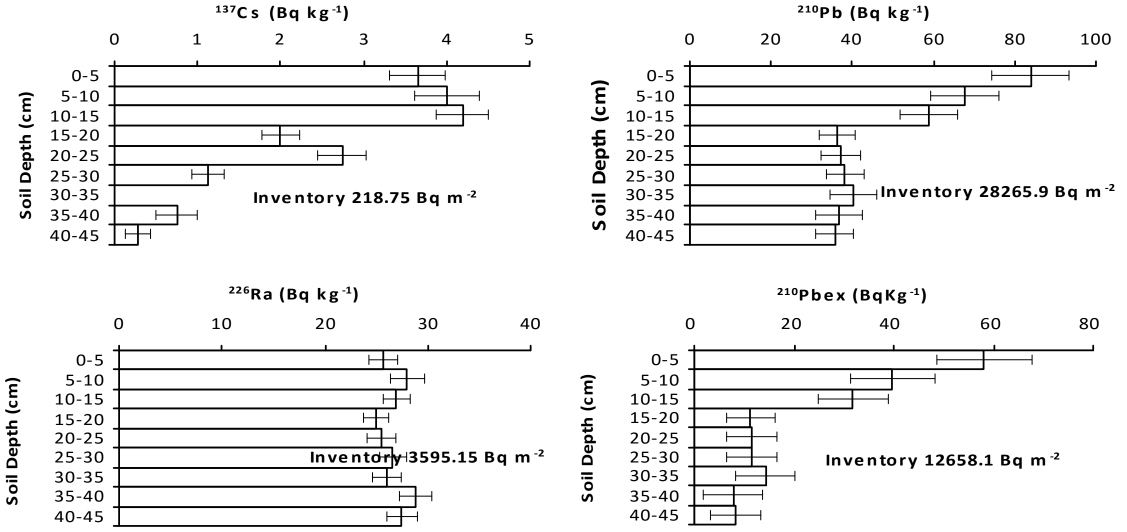


Fig. 16: Depth distribution of ^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$ activity in middle slope position

At bottom position, ^{137}Cs were found distributed in the top 0-70 cm and ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$ in the 0-100 cm (Fig. 18). ^{137}Cs activity varied from 4.82±0.42 to 0.37±0.17 Bq kg^{-1}, ^{210}Pb from 89.99±2.91 to 26.95±4.09 Bq kg^{-1}, ^{226}Ra from 28.87±1.48 to 20.37±1.21 Bq kg^{-1} and $^{210}Pb_{ex}$ from 61.12±3.26 to 2.19±4.29 Bq kg^{-1}.

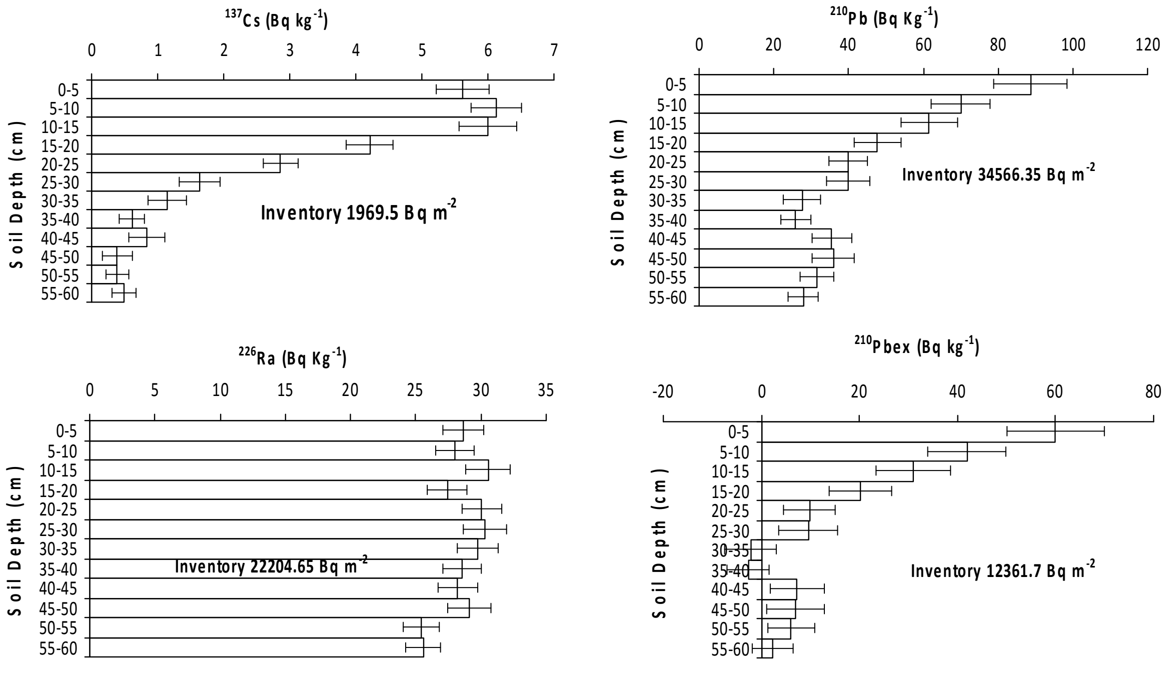


Fig. 17: Depth distribution of ^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$ activity in lower slope position

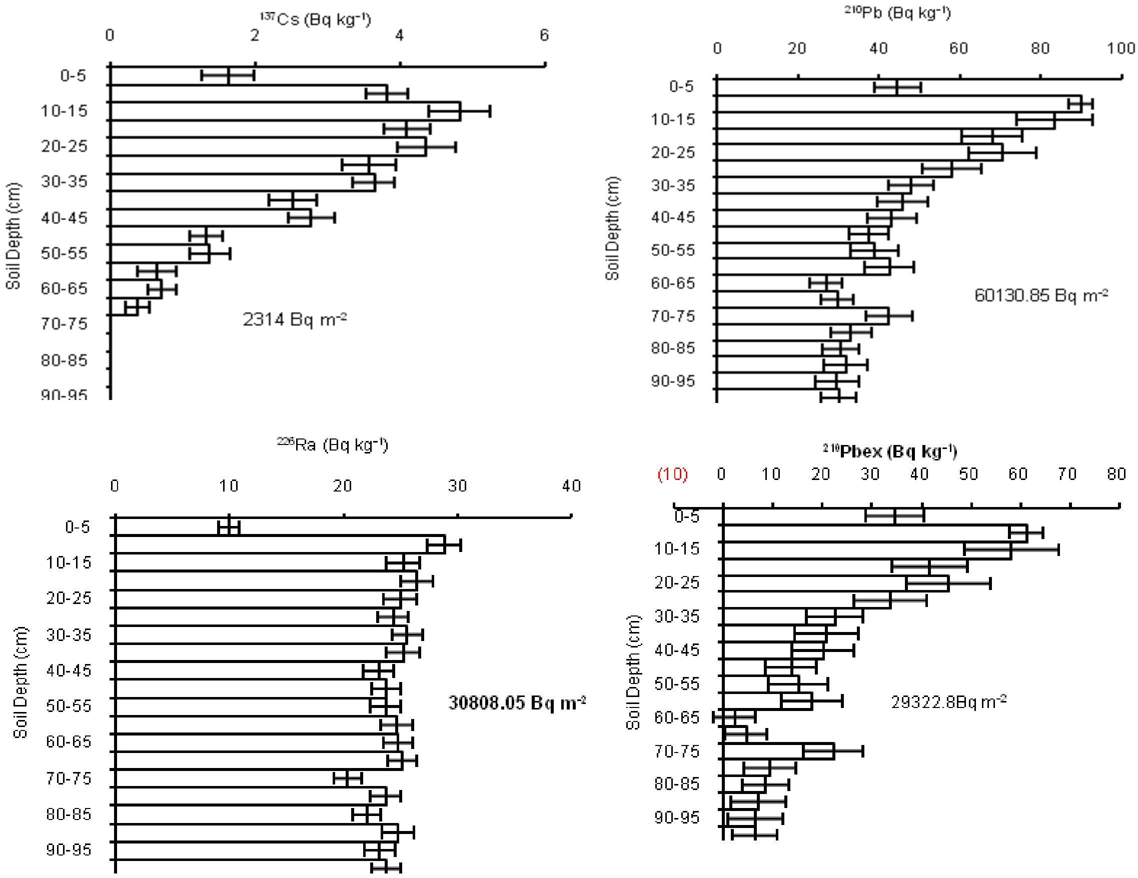


Fig. 18. Depth distribution of ^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$ activity in bottom position

Total inventory:

Total ^{137}Cs inventory of reference site and different slope positions is shown in Fig. 7. An average value of 946.4 Bq m^{-2}, 36607.4 Bq m^{-2}, 22190.4 Bq m^{-2} and 14417 Bq m^{-2} was obtained for the local reference ^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$ inventory, respectively.

The total inventory for the summit (344.5 Bq m^{-2}) and upper slope position (725.4 Bq m^{-2}) were 63.6% and 23.4% lower than the reference inventory, respectively. It indicated that these positions experienced soil erosion. In contrast, the inventory for the middle slope position (1218.8 Bq m^{-2}), lower slope position (1969.5 Bq m^{-2}), and bottom position (2314 Bq m^{-2}), was 28.8%, 108.1% and 144.5% higher than the reference inventory. It thus indicated that this position experienced soil sedimentation.

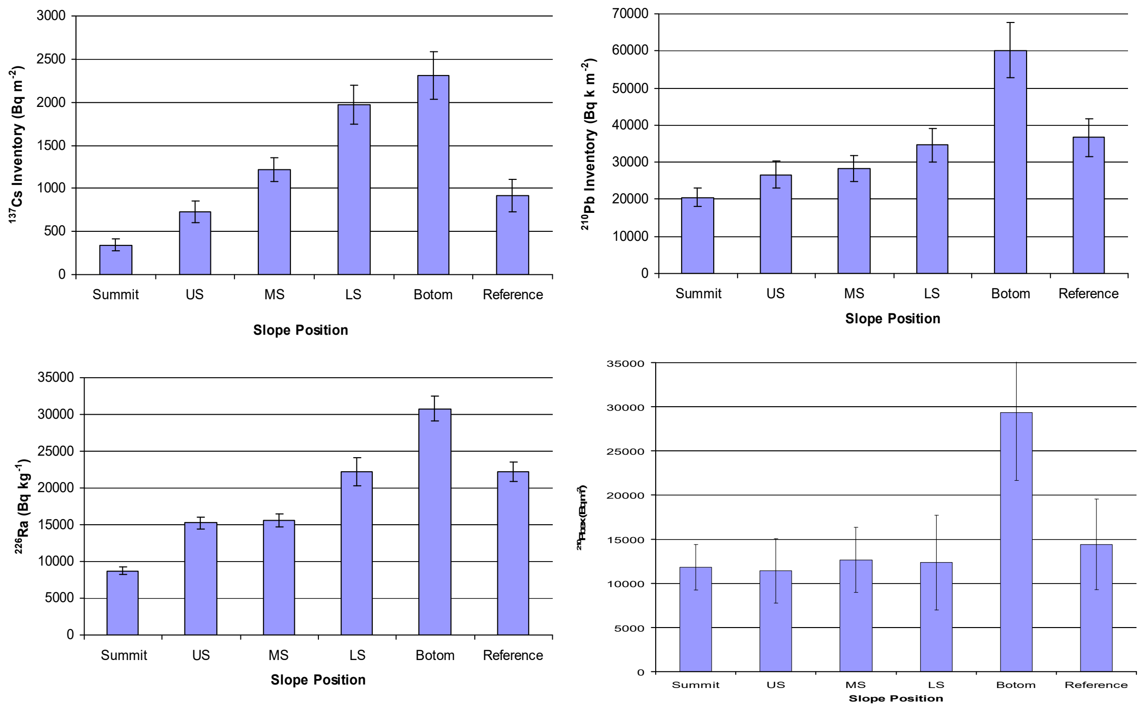


Fig. 19. Total FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and ^{210}Pb$_{ex}$) inventory (Bq m^{-2}) of reference site and different slope positions.

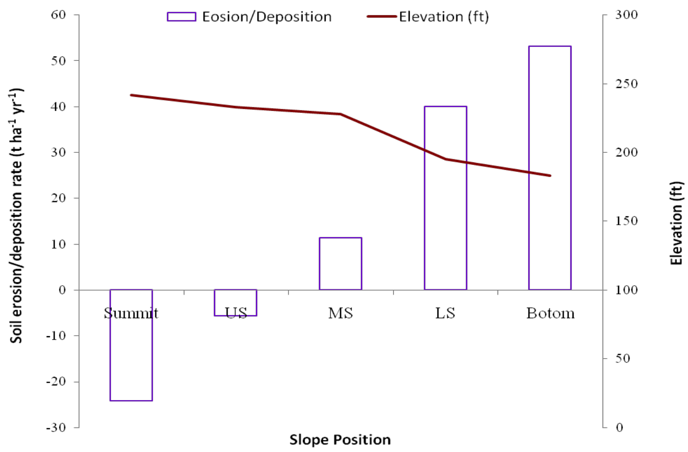


Fig. 20. Soil erosion (-ve) and deposition (+ve) rate on different slope positions related with elevation

Soil erosion/deposition:

The estimated erosion/deposition rates from Mass Balance Model 2 indicated that soil eroded from summit and upper slope positions by 24.93 and 6.33 t ha^{-1} yr^{-1}, respectively and deposited on middle slope position (10.21 t ha^{-1} yr^{-1}), lower slope position (38.34 t ha^{-1} yr^{-1}), and bottom position (51.26 t ha^{-1} yr^{-1}). The gross erosion rate was 5.2 t ha^{-1} yr^{-1}, net erosion rate was 11.4 t ha^{-1} yr^{-1} and sediment delivery ratio was -219%. Soil was eroded from the higher elevation and deposited on the lower elevation.

Conclusion:

FRN (^{137}Cs, ^{210}Pb, ^{226}Ra and $^{210}Pb_{ex}$) was distributed into different soil depth having decreasing trend with the increasing soil depth. Soil eroded from summit and upper slope positions by 24.93 and 6.33 $tha^{-1}yr^{-1}$, respectively and deposited on middle slope position (10.21 t ha^{-1} yr^{-1}), lower slope position (38.34 t ha^{-1} yr^{-1}), and bottom position (51.26 t ha^{-1} yr^{-1}). The gross erosion rate was 5.2 t ha^{-1} yr^{-1}, net erosion rate was 11.4 t ha^{-1} yr^{-1} and sediment delivery ratio was -219%. Soil was eroded from the higher elevation and deposited on the lower elevation.

Deep tube well irrigation water arsenic survey in some districts of Bangladesh

An initiative was taken to know the current Arsenic (As) contamination in deep tube well (DTW) irrigation water of Bangladesh. Water samples were taken from most As effected 10 districts. One DTW was chosen from every union of every upazilla of the selected districts (Table 94). Water samples were also collected from shallow tube well (STW) and hand tube well (HTW) nearest from the DTW to compare the depth distribution of As contamination. Total 128 DTW, 46 STW and 82 HTW water samples were collected from 131 unions, 34 upazillas.

Water sample was taken in a 125 ml plastic vial from DTW after 15 minutes running. 90 ml DTW water was collected with 10 ml 2 M HCl to protect from precipitation or any chemical change. GPS value was recorded from the sampling point. As was determined using atomic absorption spectrophotometer equipped with hydride generation system (HG-AAS) in soil science laboratory, BINA, Mymensingh.

The level of As contamination is shown in the map within the districts (Fig. 1). The results showed that 27.3% DTW water contain >200 ppb As, 47.7% contain >50 ppb As and 52.3% water contain As below risk limit (<50 ppb). 26.1% STW water contain >200 ppb As, 41.3% contain >50 ppb As and 32.6% water contain As below risk limit (<50 ppb). 28.0% HTW water contain >200 ppb As, 20.7% contain >50 ppb As and 51.2% water contain As below risk limit (<50 ppb). The highest DTW water As (474.4 ppb) was recorded from west aliabad, Faridpur sadar, Faridpur, the highest STW water As (619.5 ppb) was found in Vadulia, Ratail union, Kashiani upazilla, Gopalgonj district and the highest HTW water As (905.08 ppb) was found in Choto krisnopur, Bhangabazar union, Zajira upazilla, Shariatpur district.

Mymensingh: DTW water As contamination was found lower in Fulbaria upazilla, Mymensingh. Highest As (8.4 ppb) was found at Putijan union and the lowest (1.4 ppb) was from Sadar and Enayetpur. The average As concentration was 3.7 ppb.

Sherpur: 16.7% DTW water contain high level of As in Sherpur. Highest As (173.4) ppb was recorded from Nalitabari Pouroshova and the lowest (24.7 ppb) from rajnagar, Nalitabari. The average DTW As concentration was 60.6 ppb which was higher than risk limit. The depth of DTW was 220-270 ft.

Two STW water samples were collected and both contain lower As.
42.9% HTW water sample contain higher As than the risk limit. Highest HTW water As (117.9 ppb) was recorded from Nalitabari Pouroshova and the lowest (6.4 ppb) was recorded from Rajnagar, Nalitabari and the average value was 45.2 ppb.

Netrokona: Highest DTW water As (292.1 ppb) was found at Magan union, Mahangonj upazilla and the lowest (2.01 ppb) from Kaitail, Madan. The average DTW As concentration was 51.4 ppb which was above risk limit (50 ppb). The depth of DTW was 200-380 ft.

Five STW water sample was collected of which 60% water contain higher As than the risk limit. Highest STW water As (178.8 ppb) was recorded from Kalati, Kalmakanda and the average value was 75 ppb.

In HTW water highest As concentration (279 ppb) was found from Bat tali banirary, Mohongonj and the lowest (0) from Kaitai, Madan. The average As concentration was 94.87 ppb which was higher than the risk limit.

Faridpur: Water of this district is also most contaminated. 85% water of the collected samples contains higher As. Highest As (474.7 ppb) was found from Aliabad, Sadar upazilla and the lowest (5 ppb) from Chatol, Boyalmari upazilla. The average DTW As concentration was 234.7 ppb which was above risk limit (50 ppb). The depth of DTW was 210-285 ft.

Highest STW water As (357.5 ppb) was recorded from Gatti, Saltha, the lowest (18.5 ppb) from Bana, Alfadanga and the average value was 217.2 ppb.

Seven HTW water sample was collected of which six sample contain higher As than the risk limit. Highest STW water As (701.3 ppb) was recorded from Dangi, Nagarkanda and the lowest (27.3 ppb) from Atghor, Salta and the average value was 220.6 ppb.

Gopalgonj: Gopalgonj water was most contaminated water among the districts. In this district 100% water contain higher concentration of As. Highest As (389 ppb) was found from Ratail, Kashiani upazilla and the lowest (213.6 ppb) from Sajail, Kashiani upazilla. The average DTW As concentration was 296.1 ppb which was above risk limit (50 ppb). The depth of DTW was 243-288 ft.

Five STW water sample was collected of which 100% water contain higher As than the risk limit. Highest STW water As (619.5 ppb) was recorded from Ratail, Kashiani, the lowest (94.5 ppb) from Fukura, Kashiani and the average value was 263.22 ppb.

Two HTW water sample was collected of which 100% water contain higher As than the risk limit. Highest HTW water As (336.1 ppb) was recorded from Kandarpar, Muksudpur, the lowest (323.6 ppb) from Kandarpar, Muksudpur and the average value was 329.9 ppb.

Table 94. Selected unions and upazillas of the districts and number of sampling

Sl No.	Districts	Upazilla	Union	DTW	STW	HTW
1	Mymensingh	Fulbaria	Nawgoan, Putijana, Kushmail, Balian, Deokhola, Sadar, Bakta, Rangamati, Enaetpur, Kaladaha, Asim, Bhabanipur	12	0	0
2	Gopalgonj	Kashiani	Ratail, Fukra, Orakandi, Sajail	5	4	1
		Moksudpur	Khandarpar, Maharajpur, Batikamari	3	1	2
3	Faridpur	Sadar	Koizuri, Aliabad	2	0	2
		Bhanga	Municipality, Manikdah, Gharua, Chandra, Tujarpur, Hamerdi	6	2	0
		Boyalmari	Chandpur, Satoir, Chatol, Moyna	4	2	2
		Alphadanga	Buraich, Bana	3	2	1
		Nagarkanda	Loskordia,Talma, Dangi	3	2	1
		Shalta	Gatti, Atghor	2	1	1
4	Magura	Shalikha	Shotokhali, Arpara	5	5	0
		Sadar	Hazipur, Kosundi, Moghi, Atharo khada	4	4	0
		Muhammadpur	Nouhata	1	0	1
5	Rajbari	Sadar	Mizanpur, Chandani, Ramkanthapur, Baniabaha, Mulghar	5	1	4
		Pangsha	Pourashava, Kaliamohar, Machpara, Bahadurpur, Kosba Mazail	5	0	5
		Baliakandi	Islampur, Jamalpur, Jangal, Nababpur, Baliakandi	1	1	0
6	Shatkhira	Kolaroya	Helatala, Langolzara, Jalalabad, Sonabaria, Kerelkata	5	1	4
		Tala	Tetulia, Nagar ghata, Dhandia	4	2	2
		Sadar	Agardari,Poskhali, Bashdaha, Baikari, Zhaodanga	5	0	5
		Debhata	Kulia, Parulia, Nayapara	3	1	2
7	Netrokona	Sadar	Kailati, Thakurakona, Amtala, Rouha, BADC	5	2	2
		Barhatta	Shahota, Barhatta, Chiran, Asma, Raypur	5	0	5
		Mohongonj	Batally Banihary, Birampur, Suair, Magan, Somag Shildow	5	1	4
		Purbodhola	Purbadhala, Dalaomul goan, Gagra 1, Gagra 2, Jaria	5	0	5
		Durgapur	Bakoljora, Gaokandia	2	0	2
		Kalmakanda	Kailati, Pogla	3	2	1
		Kendua	Powrashava, Naopara, Mojaforpur, Paikura, Ashujia	5	0	5
		Madan	Kaitail	2	0	2
		Atpara	Baniajan, Surmushi, Taligati, Lunashar, Daut	5	0	5
8	Madaripur	Rajoir	Khalia, Kadambari, Amgram			
		Shibchar	Umidpur, Pouroshova			
9	Sariatpur	Naria	Kadarpur, Pouroshova, Muktarerchar			
		Zajira	Bhangabazar			
10	Sherpur	Nalitabari	Bagber, Rajnagar, Nalitabari UP, Pouroshova, Rupnarayankura, Kakorkandi			
		Nakla	Pouroshova, Gonopaddi, Baneshhordi			

Magura: 30% DTW water of the collected samples contains higher As. Highest As (74.2 ppb) was found from Arpara, Shalikha and the lowest (5.9 ppb) from Mogi, Sadar upazilla. The average DTW As concentration was 33.6 ppb which was lower than risk limit. The depth of DTW was 268-380 ft.

Highest STW water As (289.6 ppb) was recorded from Sotokhali, Shalikha and the lowest (2.4 ppb) from Mogi, Sadar and the average value was 58.4 ppb.

Only 1 HTW water sample was collected from Nouhata, Muhammadpur. As concentration (2.8 ppb) was lower than the risk limit.

Madaripur: Only 2 DTW was found active at Khalia, Rajoir in this district and both contains higher As. Highest As was 185.2 ppb and the lowest was 115.6 ppb from. The average DTW As concentration was 150.4 ppb which was higher than risk limit. The depth of DTW was 350 ft.

Highest STW water As (347.1 ppb) was recorded from Shibchar pouroshova and the lowest (5.5 ppb) from Amgram, Rajoir and the average value was 113.4 ppb. 50% STW water contain high As.

83.33% HTW water sample contain higher As than the risk limit. Highest HTW water As (869.5 ppb) was recorded from Shibchar pouroshova and the lowest (18.5 ppb) was recorded from Kadambari, Rajoir and the average value was 246.2 ppb.

Rajbari: 14.3% DTW water of the collected samples from this district contains higher As. Highest As (89.4 ppb) was found from Jamalpur, Baliakandi and the lowest (2.8 ppb) from Sadar upazilla. The average DTW As concentration was 18.6 ppb which was lower than risk limit. The depth of DTW was 168-443 ft.

Highest STW water As (211.3 ppb) was recorded from Jamalpur, Baliakandi and the lowest (1.4 ppb) from Baniabaha, Sadar and the average value was 92.9 ppb.

All HTW water sample contain lower As than the risk limit. Highest HTW water As (12.6 ppb) and the lowest (0 ppb) was recorded and the average value was 5.9 ppb.

Sariatpur: Only 1 DTW was found active at Kadarpur, Naria in this district which contains 7.4 ppb As.

Two STW water samples was collected in which the Highest STW water As (337.3 ppb) was recorded from Muktarerchar, Naria.

75% HTW water sample contain higher As than the risk limit. Highest HTW water As (905.1 ppb) was recorded from Bangabazar, Zajira and the lowest (34.6 ppb) was recorded from Kadarpur, Naria and the average value was 460.7 ppb.

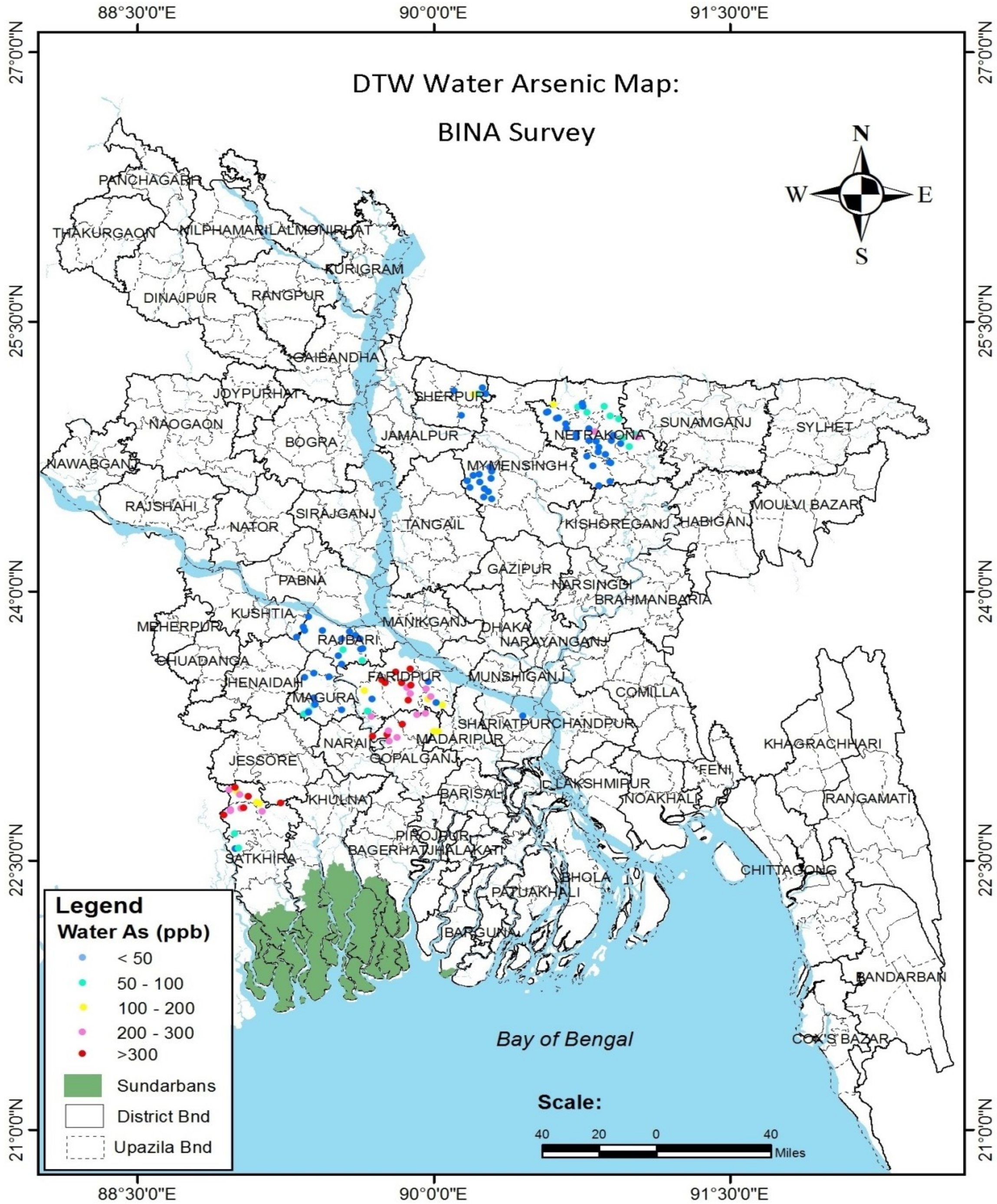


Fig. 20. DTW water As contamination in some districts of Bangladesh

Sathkhira: Sathkhira water was also most contaminated water among the districts. In this district 94% water contain higher concentration of As. Highest As (426 ppb) was found from Jalalabad, Kolaroya upazilla and the lowest (24.8 ppb) from Parulia, Debhata upazilla. The average DTW As concentration was 232.1 ppb which was above risk limit (50 ppb). The depth of DTW was 270-380 ft.

Four STW water sample was collected of which 100% water contain higher As than the risk limit. Highest STW water As (303.1 ppb) was recorded from Tetulia, Tala, the lowest (67.6 ppb) from Sonabaria, Kolaroya and the average value was 154.2 ppb.

58% HTW water contain higher As than the risk limit. Highest HTW water As (440.6 ppb) was recorded from Keralkata, Kolaroya and the lowest (5 ppb) from Poskhali, Sadar and the average value was 192.5 ppb.

Correlation: There was a weak correlation of As concentration and tube well depth. (Fig. 21). Water As concentration found lower with the increasing depth of tube wells.

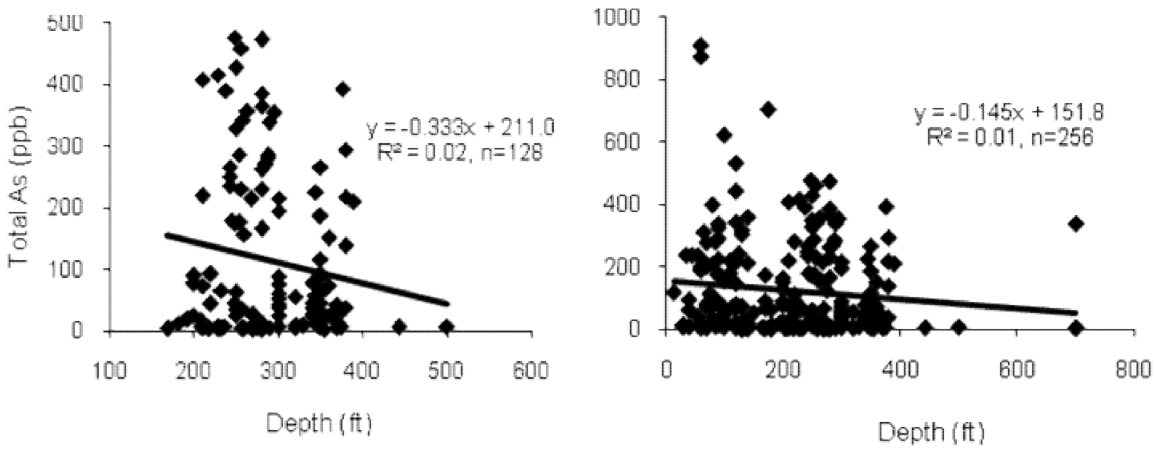


Fig 21. Correlation with water As and tube well depth

Table 95. Detail information of collected water samples from Mymensingh district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	Cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
24°36.632′	90°10.220′		Nawgoan	1986	2.8			270	-	35	Mustard/Rabi crops-Boro rice- T Aman
24°38.447′	90°11.991′		Putijana	1990	8.4			320	-	40	Mustard/Rabi crops-Boro rice- T Aman
24°38.832′	90°13.826′		Kushmail	1983	4.2			320	-	40	Mustard/Rabi crops-Boro rice- T Aman
24°41.310′	90°17.095′		Balian	1983	4.2			290	-	55	Mustard/Rabi crops-Boro rice- T Aman
24°39.958′	90°17.557′		Deokhola	1984	4.2			270	-	25	Mustard/Rabi crops-Boro rice- T Aman
24°37.458′	90°17.384′	Fulbaria	Sadar	1990	1.4			280	-	30	Mustard/Rabi crops-Boro rice- T Aman
24°36.249′	90°14.072′		Bakta	1990	2.8			270	-	30	Mustard/Rabi crops-Boro rice- T Aman
24°34.494′	90°11.002′		Rangamati	1984	2.8			280	-	35	Mustard/Rabi crops-Boro rice- T Aman
24°31.338′	90°15.150′		Enaetpur	1984	1.4			270	--	30	Mustard/Rabi crops-Boro rice- T Aman
24°34.080′	90°15.457′		Kaladaha	1984	4.2			275	-	30	Mustard/Rabi crops-Boro rice- T Aman
24°32.988′	90°16.631′		Asim	1990	4.2			280	-	35	Mustard/Rabi crops-Boro rice- T Aman
24°30.591′	90°17.563′		Bhabanipur	1990	2.8			260	-	30	Boro rice-T aman rice

Table 96. Detail information of collected water samples from Sherpur district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	Cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
25°06.917′	90°10.284′		Bagber	1982			19.786	270	60		Boro rice -T aman
25°06.728′	90°06.277′		Rajnagar	1975	24.7		6.379	250	60	30	Boro rice -T aman
25°05.850′	90°13.525′	Nalitabari	Nalitabari UP	1983	61.3		65.897	250	270	25	Boro rice -T aman
25°05.582′	90°12.195′		Pouroshova	1988	173.4		117.922	248	14	35	Boro rice -T aman
25°05.688′	90°15.914′		Rupnarayankura	1989	26.2			270		35	Boro rice -T aman
25°07.694′	90°14.881′		Kakorkandi	2008	34.3			250		30	Boro rice -T aman
24°58.314′	90°10.588′		Pouroshova	-	-	37.992	61.997	-	80, 40	-	-
24°58.617′	90°08.368′	Nakla	Gonopaddi	1989	44.0		9.688	220	40	55	Boro rice -T aman
24°57.843′	90°08.421′		Baneshhordi	2008		27.391	9.062		100, 40		

Table 97. Detail information of collected water samples from Netrokona district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	Cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
24˚54.205	90˚47.186		Thakurakona	1977	41.7	80.4		370	90	30	Boro rice-T aman rice
24˚50.103	90˚47.221	Sadar	Amtala	1977	6.2	10.3		375	85	35	Boro rice-T aman rice
24˚54.179	90˚40.384		Rouha	1977	14.7		41.7	350	55	40	Boro rice-T aman rice
24˚52.440	90˚43.335		BADC	1996	4.93			370	-	50	Boro rice-T aman rice
24˚53.068	90˚49.043		Shahota	1990	224.28		207.16	345	80	80	Boro rice-T aman rice
24˚51.958	90˚54.560	Barhatta	Barhatta	1990	23.2		199.6	345	70	50	Boro rice-T aman rice
24˚57.323	90˚56.104		Chiran	1991	60.6		14.75	350	93	110	Boro rice-T aman rice
24˚58.434	90˚53.539		Asma	1978	55.4		191.1	320	60	40	Boro rice-T aman rice
24˚59.577	90˚46.591		Raypur	1978	77.7		70.9	340	70	25	Boro rice-T aman rice
24˚52.188	91˚01.441		Batally Baniha	1991	67.9		279.0	350	85	30	Boro rice - Ograni Aman
24˚51.012	90˚57.384	Mohanganj	Birampur	1991	56.8		176.7	345	90	35	Boro rice - Ograni Aman
24˚48.085	90˚59.355		Suair	1991	85.7		171.7	350	90	35	Boro rice - Ograni Aman
24˚51.238	91˚02.082		Magan	1988	292.1	88.3		380	90	30	Boro rice - Ograni Aman
24˚49.202	90˚56.759		Somag Shido	1991	26.8		16.6	345	90	30	Boro rice - Ograni Aman
24˚59.663	90˚34.681		Gagra 1	1976	31.5		14.1	350	30	25	Boro rice-T aman rice
24˚59.470	90˚34.257	Purbadhala	Gagra 2	1976	26.2		7.4	340	30	30	Boro rice-T aman rice
24˚55.821	90˚40.185		Dalaomul goan	1976	29.8		234.9	365	55	40	Boro rice-T aman rice
24˚57.644	90˚37.322		Purbadhala	1976	30.6		225.3	375	60	25	Boro rice-T aman rice
24˚57.660	90˚37.867		Jaria	1975	45.5		6.3	350	70	35	Boro rice-T aman rice
25˚01.438	90˚43.840	Durgapur	Bakoljora	1990	76.2		90.6	200	170	30	Boro rice - Ograni Aman
25˚02.126	90˚36.522		Gaokandia	1988	194.0		5.6	300	280	35	Boro rice - Ograni Aman
25˚02.584	90˚45.142		Kailati	1990-91	41.6		18.7	300	195	35	Boro rice - fellow
25˚01.640	90˚51.784	Kalmakanda	Pogla	91-92	51.5	21.6		300	100	30	Boro rice - fellow
25˚01.621	90˚45.435		Kailati	90-91	37.5	178.8		300	110	30	Boro rice - fellow
24˚41.598	90˚48.373		Naopara	-	24.1		12.9		180	30	Boro rice-T Aman- Rabi crops
24˚36.512	90˚53.662		Mojaforpur	1976	23.6		9.6	340	218	35	Boro rice-T Aman- Rabi crops
24˚35.073	90˚50.167	Kendua	Paikura	1976	12.6		62.6	345	180	32	Boro rice-T Aman- Rabi crops
24˚44.979	90˚46.490		Ashujia	1976	43.8		2.34	340	170	30	Boro rice-T Aman- Rabi crops
24˚440.694	90˚49.815		Powrashava	1976	8.51		6	330	100	35	Boro rice-T Aman- Rabi crops
24˚42.777	90˚53.780	Madan	Kaitail	1976	28.79		1.84	345	180	30	Boro rice - T aman/ fellow
24˚42.964	90˚53.439		Kaitail	1976	2.01		0	355	200	30	Boro rice - T aman/ fellow
24˚47.956	90˚50.240		Baniajan	1976	20.36		236.5	350	35	25	Boro rice - T aman- Rabi crop/fellow
24˚49.913	90˚49.3		Surmushi	1976	21.47		236.5	345	45	25	Boro rice - T aman- Rabi crop/fellow
24˚46.284	90˚49.984	Atpara	Taligati	1990	6.59		214.36	350	120	40	Boro rice - T aman- Rabi crop/fellow
24˚50.173	90˚53.921		Lunashar	1987	35.93		80.27	340	70	45	Boro rice - T aman- Rabi crop/fellow
24˚45.498	90˚52.277		Daut	1991	19.76		11.03	365	130	30	Boro rice - T aman- Rabi crop/fellow

Table 98. Detail information of collected water samples from Faridpur district

GPS N	GPS E	Upazilla	Union	Year of Installation	DTW depth (ft)	Total As (ppb) DTW	Total As (ppb) STW	Total As (ppb) HTW	STW/HTW depth (ft)	Command area (ac)	Cropping pattern
23°32.908′	89°48.556′	Sadar	Koizuri	2012	228	413.8		241.0	125	30	Rabi crops-Boro/jute- T aman
23°33.840′	89°52.852′		Aliabad	2001	248	474.7		219.9	120	35	Rabi crops-Boro/jute- T aman
23°30.154′	89°44.371′	Boalmari	Chandpur	2011	210	406.1	341.5		120	60	Lentill-Jute-T Aman
23°29.508′	89°58.416′		Satoir	1974	258	34.2		123.9	275	100	Lentill-Jute-T Aman
23°23.820′	89°41.386′		Chatol	2005	210	5.0	220.1		120	40	Potato-Jute-Aman
23°26.566′	89°39.110′		Moyna	2006	260	156.6		76.1	70	50	Wheat-Rice-Jute
23°19.543′	89°40.107′	Alfadanga	Buraich	2004	220	91.8		154.4	100	40	Rabi crop-Rice -Rice
23°18.054′	89°41.083′		Buraich	1988	210	218.7	72.3		115	50	Rabi crop-Rice -Rice
23°19.833′	89°39.966′		Bana	2008	211	72.4	18.5		120	40	Rice-Rice
23°25.571′	89°53.025′	Nagarkanda	Loskordia	2006	285	268.6	74.6		80	35	Rabi crop-Rice -Rice
23°27.673′	89°51.960′		Talma	2005	243	235.0	60.5		100	30	Rabi crop-Rice -Rice
23°28.313′	89°53.159′		Dangi	2004	280	364.2		**701.3**	175	30	Rabi crop-Rice -Rice
23°29.239′	89°50.431′	Saltha	Gatti	2004	280	471.5	357.5		140	40	Rabi crop-Rice -Rice
23°29.185′	89°45.350′		Atghor	2005	256	457.6		27.3	80	40	Rabi crop-Rice -Rice
23°23.750′	89°58.410′	Bhanga	Municipality	2000	244	178.7	112.8		75	35	Rice- Wheat
23°27.217′	89°57.814′		Manikdah	2007	243	248.3	309.6		65	30	Boro rice - T Aman
23°22.602′	90°00.827′		Gharua	2007	248	43.9			-	35	Wheat- Jute, Boro rice - T Aman
23°21.731′	90°02.857′		Chandra	2005	254	175.1			-	25	Boro rice - T Aman
23°24.608′	89°59.160′		Tujarpur	2005	256	229.9	218.5		110	22	Boro rice - T Aman
23°23.288′	89°52.375′		Hamerdi	1998	250	326.7			-		Boro rice - T Aman

Table 99. Detail information of collected water samples from Gopalgonj district

GPS N	GPS E	Upazilla	Union	Year of Installation	Total As (ppb) DTW	Total As (ppb) STW	Total As (ppb) HTW	Depth (ft) DTW	Depth (ft) STW/HTW	Command area (ac)	cropping pattern
23°11.353′	89°41.566′	Kashiani	Ratail	2002	340.7			258	70	35	Boro rice - T Aman
23°11.925′	89°46.007′		Ratail	2002	389.0	619.5		238	100	30	Boro rice - T Aman
23°09.696′	89°46.583′		Fukra	2002	284.1	94.5		288	40	75	Boro rice - T Aman
23°10.851′	89°48.908′		Orakandi	2005	285.6	279.4		253	220	55	Boro rice - T Aman
23°13.155′	89°46.370′		Sajail	2009	213.6	145.4		268	120	40	Boro rice - T Aman
23°15.331′	89°50.533′	Muksudpur	Khandarpar	2002	355.9		323.6	263	90	30	Wheat-Rice- Rabi crops
23°18.567′	89°55.000′		Maharajpur	2002	279.4		336.1	288	90	30	Wheat-Rice- Rabi crops
23°18.941′	89°57.645′		Batikamari	2012	265.3	177.3		243	90	25	Wheat-Rice- Rabi crops

Table 100. Detail information of collected water samples from Magura district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	Cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
23°31.068′	89°20.747′	Sadar	Hazipur	1968	25.2	9.2		360	120	35	Boro rice-T. Aman-Mustard/rabi crops,
23°31.192′	89°28.307′		Kosundi	1973	10.3	4.5		280	120	25	Boro rice-T. Aman-Mustard/rabi crops,
23°24.270′	89°23.549′		Moghi	1981	5.9	2.4		300	130	30	Boro rice-T. Aman-Mustard/rabi crops,
23°32.325′	89°23.654′		Atharo khada	1977	23.9	79.0		300	120	35	Boro rice-T. Aman-Khesahari
23°19.792′	89°21.942′	Shalikha	Shotokhali	1983	72.2	52.0		360	150	30	Boro rice-Jute-Mustard/T Aus
23°18.750′	89°20.636′		Shotokhali	1973	60.6	289.6		300	90	45	Boro rice-T Aus-Mustard
23°21.799′	89°23.609′		Arpara	1973	74.2	66.3		300	170	60	Boro-T Aman
23°21.910′	89°24.053′		Arpara	1983	6.7	3.7		268	180	50	Boro-T Aman
23°19.314′	89°21.982′		Shotokhali	1992	37.9	19.0		380	140	35	Boro-T Aman
23°20.082′	89°32.004′	Muhammadpur	Nouhata	1975	8.5		2.8	280	180	40	Wheat-Jute-T Aman

Table 101. Detail information of collected water samples from Madaripur district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
23°12.933′	90°00.266′	Rajoir	Khalia	1989	115.6	150.615		350	200	60	Boro rice-T Aman rice-fellow
23°12.877′	90°01.572′		Khalia	1989	185.2		127.244	350	200	55	Boro rice-T Aman rice-fellow
23°10.769′	89°58.910′		Kadambari	2008		156.23	163.16		265, 200		Boro rice-T Aman rice-fellow
23°10.673′	89°58.849′		Kadambari			47.439	18.458		250, 200		Boro rice-T Aman rice-fellow
23°10.992′	90°03.103′		Amgram	1990		5.499	110.693		700, 220		Boro rice-T Aman rice-fellow
23°20.116′	90°11.851′	Shibchar	Umidpur			10.922	188.406		250, 60		Boro rice -fellow
23°21.997′	90°09.158′		Pouroshova	2004		347.119	869.522		250, 60		Boro rice -fellow

Table 102. Detail information of collected water samples from Rajbari district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
23°44.973′	89°36.277′		Mizanpur	2001	2.8		2.8	258	205	30	T Aman Rice - Boro Rice - Mustard
23°46.294′	89°34.561′		Chandani	2005	2.8		0.0	233	130	30	T Aman Rice - Boro Rice - Mustard
23°43.909′	89°37.629′	Sadar	Ramkanthapur	2005	2.8		12.6	228	30	45	T Aman Rice - Boro Rice - Lentil/Mustard
23°40.388′	89°37.949′		Baniabaha	2009	5.6	1.4		208	140	40	T Aman Rice - Boro Rice - Lentil/Mustard
23°40.613′	89°38.442′		Mulghar	2009	2.8		2.8	168	180	50	Boro rice - T Aman rice
23°46.741′	89°26.141′		Pourashava	2001	2.8		4.2	218	130	30	Boro rice - T Aman rice/Onion, Wheat
23°46.580′	89°20.753′		Kaliamohar	2002	17.8		4.2	193	132	30	Boro rice - T Aman rice/Onion, Wheat
23°47.824′	89°20.503′	Pangsha	Machpara	2002	12.0		5.6	182	135	35	Boro rice/Wheat - Onion - T Aman rice
23°51.346′	89°21.942′		Bahadurpur	2009	25.1		7.0	200	140	35	Boro rice - T Aman rice-Rabi crops
23°44.406′	89°18.428′		Kosba Mazail	2005	5.6		7.0	228	140	30	Boro rice - T Aman rice-Rabi crops
23°43.790′	89°31.988′		Islampur	2001	5.6		8.4	443	130	45	Boro rice - T Aman
23°36.569′	89°38.242′		Jamalpur	2009	89.4	211.3		200	140	40	Boro rice - T Aman
23°35.431′	89°32.113′	Baliakandi	Jangal	2001	16.4		5.6	208	140	30	Wheat-Jute/Rice
23°40.268′	89°32.484′		Nababpur	2001	65.2	66.0		233	100	30	Rabi crop - Boro rice - T aman rice
23°38.143′	89°30.974′		Baliakandi	2001	7.0		7.0	236	165	35	Rabi crop- Boro rice - T aman rice

Table 103. Detail information of collected water samples from Sariatpur district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	Cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
23°18.102′	90°27.107′		Kadarpur	2013	7.4		34.564	500	135	45	Boro rice - T aman
23°17.787′	90°25.891′	Naria	Pouroshova	2005		3.352	199.945		700, 60	45	Boro rice - T aman
23°18.836′	90°23.711′		Muktarerchar			337.255	277.145		700, 70		Boro rice - T aman
23°19.948′	90°15.490′	Zajira	Bhangabazar	2009			905.077		60	40	Boro rice - T aman

Table 104. Detail information of collected water samples from Sathkhira district

GPS		Upazilla	Union	Year of Installation	Total As (ppb)			Depth (ft)		Command area (ac)	Cropping pattern
N	E				DTW	STW	HTW	DTW	STW/HTW		
22°47.172′	89°01.617′		Agardari	1978	229.7		71.2	280	130	75	Maize/Rabi crop - Jute - Aus
22°46.464′	88°58.352′		Poskhali	1976	214.4		5.0	300	60	40	Maize/Rabi crop - Jute - Aus
22°46.891′	88°58.342′	Sadar	Bashdaha	1977	261.3		104.3	280	80	35	Boro rice - T Aman
22°45.050′	88°56.337′		Baikari	1976	384.0		397.1	280	80	35	Boro rice - T Aman
22°47.342′	89°02.430′		Zhaodanga	1979	337.2		316.1	290	130	35	Boro - Jute - T Aman
22°52.834′	89°00.296′		Helatala	2001	137.4		19.0	380	100	30	Mustard - Boro - Jute
22°51.768′	89°01.117′		Langolzara	1992	216.2		46.9	380	100	50	Mustard - Boro - T Aman
22°51.321′	89°03.819′	Kolaroya	Jalalabad	1987	426.0		529.5	250	120	40	Mustard - Boro - T Aman
22°53.360′	88°57.964′		Sonabaria	1980	209.0	67.6		390	120	30	Mustard - Boro - T Aman
22°54.272′	88°59.692′		Kerelkata	1988	352.6		440.6	295	120	35	Boro - Fellow
22°48.984′	89°13.627′		Tetulia	1982	390.9	303.1		376	130	30	Mustard - Boro - T Aman
22°46.209′	89°07.885′	Tala	Nagar ghata	1987	264.8		223.5	350	90	40	Boro Rice - fellow
22°49.300′	89°06.432′		Dhandia	2001	164.9		22.2	280	120	35	Boro Rice - fish
22°48.822′	89°07.180′		Dhandia	2000	149.8	73.4		360	130	35	Mustard - Boro - T Aman
22°38.746′	88°59.605′		Kulia	1985	91.7		12.8	350	120	25	Mustard - Boro - T Aman
22°33.848′	88°59.652′	Debhata	Parulia	1982	24.8			270	-	25	Mustard - Boro - T Aman
22°34.079′	89°00.667′		Nayapara	1989	88.3	172.6		300	170	30	Mustard - Boro - T Aman

Agricultural Land Management for Improving Soil Fertility and Irrigation Efficiency

Methodology

Both laboratory and field studies were conducted to achieve the purpose of the project. However, the following approaches and methodologies were followed to attain the objectives of the proposed research project.

Table 105. Physical and chemical characteristics of initial soil of Sutiakhali, Mymensingh

Soil characters	Mymensingh	Critical level*
Soil texture	Silt loam (Sand 27.06%, Silt 63.4% Clay 9.54%)	-
pH	6.53	-
Organic carbon (%)	1.35	-
Total N (%)	0.097	0.12
Available P (µg g^{-1})	6.0	7.0
Exchangeable K (meq $100g^{-1}$)	0.097	0.12
Available S (µg g^{-1})	9.3	10.0
Available Zn (µg g^{-1})	0.41	0.60
Available B (µg g^{-1})	0.17	0.20

*Fertilizer Recommendation Guide (FRG)-2012, BARC

Cropping Patern-1: Vegetable-T. Aus rice-T. Aman rice

Effect of integrated nutrient management on soil fertility and productivity of Cabbage in Vegetable-T. Aus rice-T. Aman rice cropping pattern

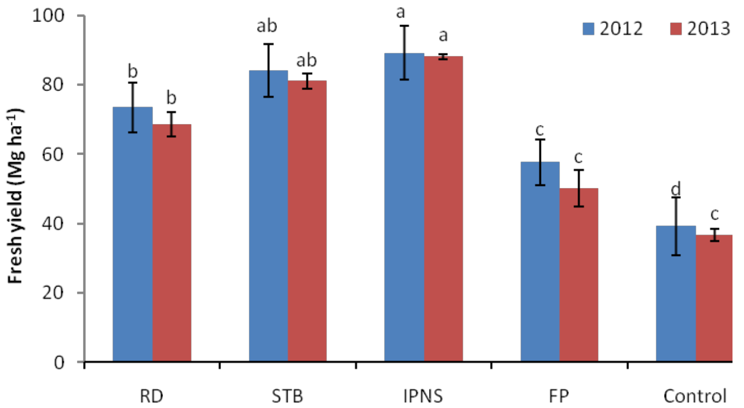
Treatments:

T_1: Recommended Dose (RD) ($N_{150}P_{53}K_{50}S_{30}Zn_{1.5}B_{0.7}Mo_{0.5}$)
T_2: Soil Test Base (STB) ($N_{178}P_{65}K_{51}S_{27}Zn_{1.5}B_{0.7}Mo_{0.5}$)
T_3: Integrated Plant Nutrition Sytem (IPNS) ($N_{158}P_{59}K_{42}S_{24}Zn_{1.5}B_{0.7}Mo_{0.5}$)+Cow Dung (CD) @ 5.0 t ha^{-1}
T_4: Farmer's Practice (FP) ($N_{65}P_{42}K_{71}S_6$)
T_5: Control (no fertilizer)

Crop	:	Cabbage (Atlas 70)
Replication	:	4
Plot Size	:	4.5×3.15 m^2
No of raw	:	6
Raw to raw distance	:	60 cm
No. of plant/raw	:	7
Plant to plant distance	:	45 cm
Total plant/plot	:	42 nos.
Location	:	Sutiakhali, Mymensingh (Agro- Ecological Zone (AEZ) - 9)

Results:

Fresh yield of Cabbage was significantly influenced by the applied treatments. The highest yield of 89.2 t ha^{-1} in 2012 and 88.1 t ha^{-1} recorded in 2013 with the combined application of chemical fertilizer and Cowdung by IPNS (Fig.22). The second highest fresh yield of 84.1 and 81.1 t ha^{-1} was recorded in 2012 and 2013, respectively from STB chemical fertilizer treatment which was statistically identical with IPNS. The fresh yield of cabbage increased 56% over control and 35% over farmer's practice in 2012, and 58% over control and 43% over farmer's practice in 2013.



Note: Means followed by the same letters are not significantly different at 5% level by DMRT

Fig. 22. Fresh yield (t ha^{-1}) of Cabbage influenced by different nutrient management

After completion of first cycle of cropping pattern, the soil characters such as soil pH, temperature, moisture and Soil organic carbon (SOC) were determined. The parameters influenced by the applied treatments (Table 106). Soil pH and temperature were lowest in IPNS treatment and highest in control. SOC was significantly affected by the application of nutrients. SOC decreased compare to initial value. On the other hand for applying CD in the IPNS treatment the SOC concentration got highest value while the RD and STB treatment recorded the lowest SOC (Fig. 23). The SOC decreased (0.22-0.56%) compare to initial SOC, but increased 0.16% in IPNS treatments over control.

Table 106. Effect of integrated nutrient management on soil temperature, moisture and pH

Treatments	Soil Temp. (^{0}C)	Soil Moisture (vol. %)	pH
RD	23.2ab	12.9b	6.4bc
STB	23.3a	12.3b	6.3c
IPNS	22.6b	13.2ab	6.2c
FP	23.4a	14.3a	6.5ab
Control	23.9a	13.5ab	6.5a
CV (%)	2.00	5.82	1.70
SE (±)	0.23	0.39	0.05
P <	0.05	0.05	0.05

In a column, means followed by common letter (s) do not differ significantly at 5% level by DMRT.

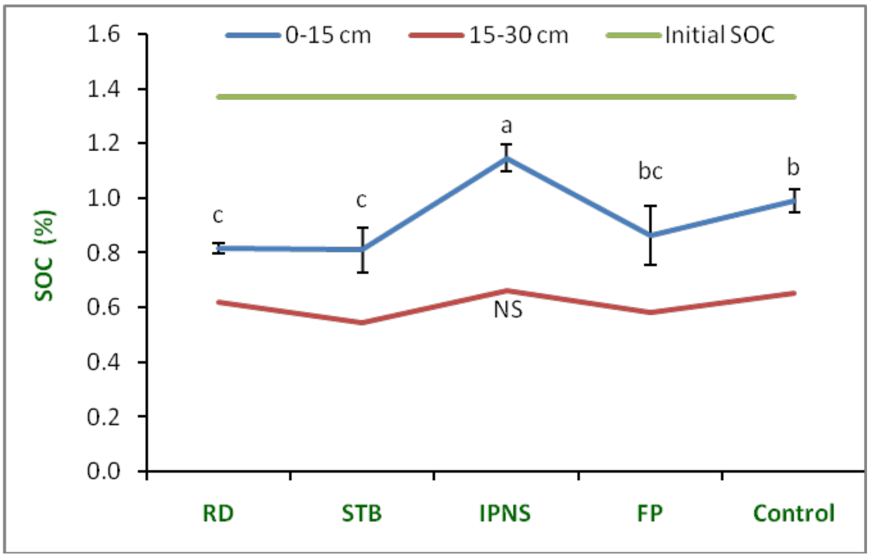


Fig 23. Change in SOC (%) after completing of the cropping pattern 1 at 0-30 cm depth

Effect of integrated nutrient management on soil fertility and productivity of T. Aus rice in Vegetable-T. Aus rice-T. Aman rice cropping pattern

Crop : T. Aus rice (BRRI dhan 48)
Design : RCB
Replication : 4

Treatments:

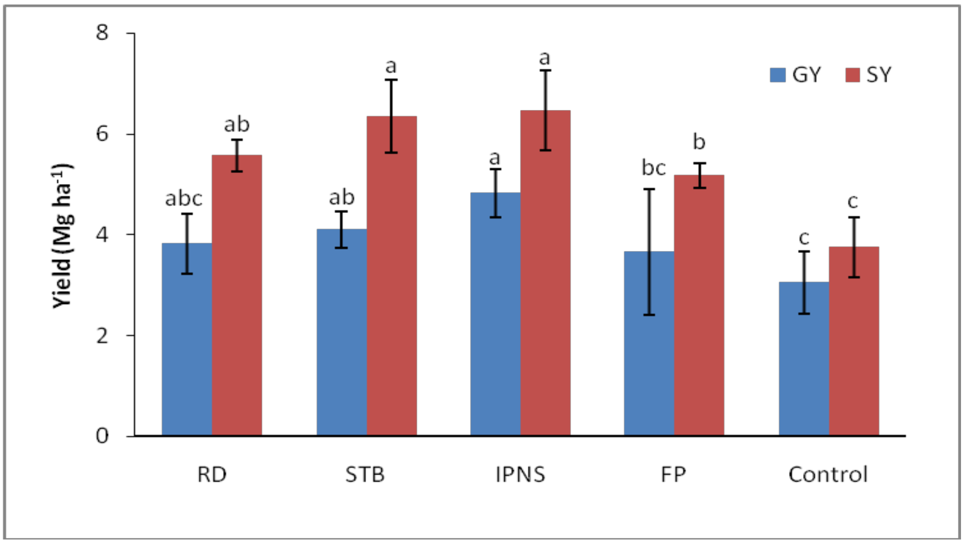
T_1 : RD ($N_{75}P_{12}K_{45}S_9Zn_{1.5}$)
T_2 : STB ($N_{74}P_{11}K_{36}S_7Zn_{1.5}$)
T_3 : $N_{54}P_5K_{27}S_5Zn_{1.5}$ (IPNS) + CD @ 5.0 t ha^{-1}
T_4 : FP ($N_{69}P_{30}K_{37}$)
T_5 : Control (no fertilizer)

Plot Size : 4.5 x 3.15 m^2
Spacing : 20 x 20 cm^2
Location : Sutiakhali, Mymensingh (AEZ 9)

T. Aus rice

Grain yield responded significantly with the application of fertilizer treatments (Fig. 24). The treatment of chemical fertilizer with cowdung (IPNS) produced the highest grain yield (4.8 t ha^{-1}) which was statistically at par with STB treatment. The IPNS treatment applied in T. Aus rice produced 36.6% higher grain yield over control and 24.1% higher yield over farmer's practice. On the other hand, the lowest yield (3.1 t ha^{-1}) was recorded in the control treatment. It was statistically identical with the treatment FP.

Like grain yield, straw yield also affected significantly by the fertilizer management (Fig. 24). The yield of straw varied from 5.8 t ha^{-1} to 8.5 t ha^{-1} due to the application of fertilizer treatments. The highest yield reported by the IPNS treatment which is not significantly different with STB treatment. Similar to grain yield, the lowest straw yield (5.8 t ha^{-1}) was obtained by control treatment which received no fertilizer.



Note: Means followed by the same letters are not significantly different at 5% level by DMRT.

Fig. 24. Grain and Straw yield (t ha^{-1}) of T.aus rice influenced by different nutrient.

Plant height responded significantly to the fertilizer treatments (Table 107). The plant height of rice varied from 70.9 cm to 97.4 cm depending on various treatments. The highest plant height (97.4 cm) was observed in IPNS treatment and the lowest (70.9 cm) recorded in control treatment which received no fertilizer.

Tillers $hill^{-1}$ and panicle length also responded significantly due to the nutrient addition. The tillers $hill^{-1}$ ranged from 15 to 20 and panicle length ranged from 21.9 to 23.5 cm. For both the parameter, highest value recorded from IPNS treatment and the lowest from control treatment.

Grains $panicle^{-1}$ also showed a significant effect by the applied nutrients ranging from 93 to 124 (Table 107). The highest grains $panicle^{-1}$ (124) was observed in IPNS treatment and the lowest (93) in control treatment.

Like other yield components, 1000 grains weight also showed significant influenced by the use of different treatments (Table 107). The 1000-grains weight varied from 19.6 g to 25.4 g. The highest 1000-grains weight was recorded in IPNS treatment which was statistically not different with STB and RD.

Table 107. Effect of integrated nutrient management on yield and yield contributing parameters of T. Aus rice.

Treatments	Plant Height (cm)	Tillers hill^{-1} (nos.)	Panicle Length (cm)	Grain Panicle^{-1} (nos.)	1000 seed weight (g)
RD	96.9a	16b	23.0abc	110.5ab	23.8ab
STB	94.3a	17.5ab	23.2ab	112.3a	23.6ab
IPNS	97.4a	19.5a	23.5a	123.6a	25.4a
FP	84.1b	15.9b	22.2bc	98.6bc	22.7b
Control	70.9c	15.1c	21.9c	92.9c	19.6c
CV (%)	6.8	11.6	3.3	8.1	5.4
SE (±)	3.02	0.97	0.35	4.3	0.62
P <	0.01	0.05	0.05	0.01	0.001

In a column, means followed by common letter (s) do not differ significantly at 5% level by DMRT.

Effect of integrated nutrient management on soil fertility and productivity of T. Aman rice in Vegetable-T. Aus rice-T. Aman rice cropping pattern

Treatments:

T_1 : RD ($N_{76}P_8K_{43}S_{11}$)
T_2 : STB ($N_{89}P_9K_{44}S_{11}$)
T_3 : $N_{69}P_3K_{35}S_8$ (IPNS)
T_4 : FP ($N_{69}P_{30}K_{37}S_{10}$)
T_5 : Control (no fertilizer)

Crop : T. Aman (BINA dhan 7)
Replication : 4
Plot Size : 4.5 X 3.15 m^2
Spacing : 20 cm × 20 cm
Location : Sutiakhali, Mymensingh (AEZ 9)

T. Aman

Grain yield responded significantly with the application of fertilizer treatment (Fig. 25). The treatment of chemical fertilizer with cowdung (IPNS) produced the highest grain yield (6.7 t ha^{-1}) which was statistically at par with STB treatment. Due to application of IPNS, the grain yield of T. aman increased 36.7% higher than control and 14.2% higher than farmer's practice. On the other hand, the lowest yield (4.3 t ha^{-1}) was recorded in the control treatment. It was statistically identical with the treatment FP.

Like grain yield, straw yield was also significantly affected by the fertilizer management (Fig. 25). The yield of straw varied from 5.2 t ha^{-1} to 8.6 t ha^{-1} due to the application various treatments. The highest yield (8.6 t ha^{-1}) reported by the IPNS treatment which is not significantly different with STB treatment. As like as grain yield, the lowest straw yield (5.2 t ha^{-1}) was obtained by control treatment which received no chemical fertilizer.

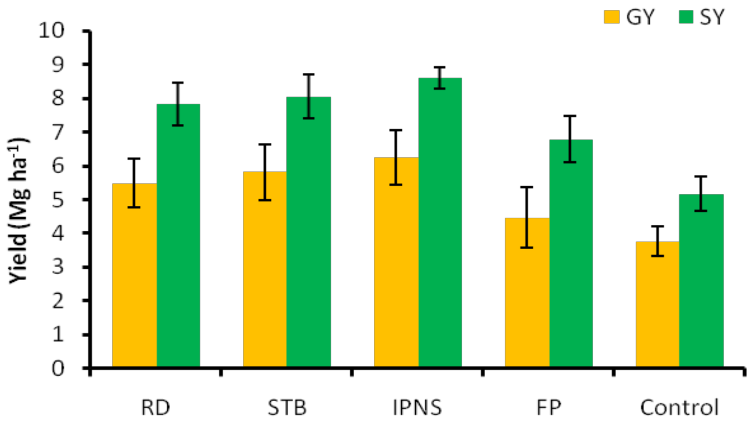


Fig. 25. Grain and Straw yield (t ha^{-1}) of T. Aman rice by different treatments.

Plant height responded significantly to the fertilizer treatments (Table 108). The height of the rice plant depending on the treatment varied from 89.3 cm to 96.6 cm. The highest plant height (96.6 cm) was observed in IPNS treatment and the lowest (89.3 cm) in control which received no fertilizers.

Tillers hill^{-1} and panicle length also responded significantly due to the nutrient addition. The tillers hill^{-1} ranged from 15.8 to 19.3 and panicle length ranged from 20.7 to 25.2 cm. For both the parameter, highest value recorded from IPNS treatment and the lowest value from control treatment.

There was also a significant effect of the applied nutrients on the grains panicle^{-1}, showing a variation from 87 to 97 (Table 108). The highest grains panicle^{-1} (97) was observed in IPNS treatment and the lowest (87) in control.

Like other yield components, 1000 grains weight also showed significant influence of different treatments (Table 108). The 1000-grains weight varied from 21.09 g to 25.88 g. The highest 1000-grains weight was recorded in IPNS treatment which was statistically at par with STB and RD treatments.

Table 108. Effect of integrated nutrient management on yield and yield contributing parameters of T. Aman rice.

Treatments	Plant Height (cm)	Tillers hill^{-1} (nos.)	Panicle Length (cm)	Grain Panicle^{-1} (nos.)	1000 seed weight
RD	93.4ab	17.1bc	24.1ab	93.8 ab	24.31a
STB	96.0a	18.0ab	24.0ab	95.1ab	24.81a
IPNS	96.6a	19.3a	25.2a	97.4a	25.88a
FP	95.9a	16.7bc	23.7b	91.4bc	23.21ab
Control	89.3b	15.8c	20.7c	87.3c	21.09b
CV (%)	5.13	5.4	4.01	6.53	5.4
SE (±)	1.5	0.5	0.5	1.6	0.82
P <	0.05	0.01	0.01	0.05	0.05

In a column, means followed by common letter (s) do not differ significantly at 5% level by DMRT.

CP 2: Boro rice-Fallow-T. Aman

Effect of integrated nutrient management and water management on the productivity and water use efficiency of Boro rice in Boro-Fallow-T. Aman cropping pattern

Crop : Boro Rice (BRRI dhan28)
Design : Split plot
Replication : 3

Treatments:
Main plot: Water management
i) T_{CF} (Continuous flooding)
ii) T_{AWD} (Alternate wetting and drying)
Sub-plot: Fertilizer management
T_1 : RD ($N_{88}P_8K_{50}S_{13}Zn_{1.5}$)
T_2 : STB ($N_{104}P_9K_{51}S_{13}Zn_{1.5}$)
T_3 : $N_{84}P_3K_{42}S_{11}Zn_{1.5}$ (IPNS) + CD @ 5.0 t ha^{-1}
T_4 : FP ($N_{69}P_{60}K_{37}$)
T_5 : Control (no fertilizer)

Grain yield responded significantly with the fertilizer application (Table 109) in both continuous flooding (CF) and alternate wetting and drying (AWD) in 2012 and 2013. The treatment of chemical fertilizer with cowdung (IPNS) produced the highest grain yield (5.6 and 6.4 t ha^{-1} in 2012 and that of 5.2 and 6.7 t ha^{-1} in 2013 by CF and AWD treatments, respectively) which is 35.2% and 32.4% higher in CF and 39.3% and 32.6% in AWD over control. On the other hand, the lowest yield (3.6 and 4.09 t ha^{-1} by CF and 3.1 and 4.2 t ha^{-1} by AWD in 2012 and 2013, respectively was recorded in the control treatment.

Table 109. Effect of integrated nutrient management and water management on Grain yield and Straw yield (Mg ha^{-1}) contributing parameters of Boro rice.

	2012		2013	
	Grain yield	Straw yield	Grain yield	Straw yield
Continuous flooding (CF)				
RD	4.7b	6.97bc	5.34b	6.61b
STB	5.3b	8.02ab	5.46b	7.26ab
IPNS	5.6a	8.60a	6.42a	8.46a
FP	4.7c	6.43c	5.04b	6.66b
Control	3.6d	4.52d	4.09c	5.72c
CV (%)	9.0	7.3	9.14	12.17
SE (±)	0.25	0.42	0.28	0.49
P<	0.01	0.01	0.01	0.05
Alternate wetting and drying (AWD)				
RD	4.3b	6.51b	5.82ab	6.28bc
STB	4.7ab	7.11ab	5.84ab	6.93ab
IPNS	5.2a	8.25a	6.69a	7.99a
FP	4.1b	6.70b	4.94bc	6.0bc
Control	3.1c	4.79c	4.15c	5.39c
CV (%)	8.9	8.9	14.66	8.75
SE (±)	0.50	0.50	0.49	0.39
P<	0.05	0.05	0.05	0.01

In a column, means followed by common letter (s) do not differ significantly at 5% level by DMRT.

Like grain yield, straw yield was also significantly affected by fertilizer management (Fig. 26). The straw yield varied from 4.5 to 8.6 Mg ha^{-1} in 2012 and 5.7 to 8.5 t ha^{-1} in 2013 by CF and 4.8 to 8.3 t ha^{-1} in 2012 and that of 5.3 to 7.99 t ha^{-1} in 2013 by AWD due to the application of different fertilizer treatment. The highest straw yield 8.6 and 8.5 t ha^{-1} recorded in 2012 and 2013, respectively by CF. While the straw yield 8.3 and 7.99 t ha^{-1} reported in 2012 and 2013, respectively by AWD by the application of IPNS treatment which is at par with STB treatment. Similar to grain yield, the lowest straw yield was obtained by control treatment which received no chemical fertilizer.

Effect of integrated nutrient management on the productivity and water use efficiency of T. aman rice in Boro-Fallow-T. Aman cropping pattern

Treatments:

Main plot: Water management

- i) T_{CF} (Continuous flooding)
- ii) T_{AWD} (Alternate wetting and drying)

Sub-plot : Fertilizer management

- T_1 : RD ($N_{76}P_8K_{43}S_{11}$)
- T_2 : STB ($N_{89}P_9K_{44}S_{11}$)
- T_3 : $N_{69}P_3K_{35}S_8$(IPNS) + CD @ 5.0 t ha^{-1}
- T_4 : FP ($N_{69}P_{30}K_{37}$ S_{10})
- T_5 : Control (no fertilizer)

Crop	:	T. Aman (Binadhan-7)
Replication	:	3
Plot Size	:	6 × 3 m^2
Spacing	:	20 cm × 20 cm
Location	:	Sutiakhali, Mymensingh (AEZ 9)

Grain yield responded significantly with the application of fertilizer treatment (Fig. 26) in 2012. The treatment of chemical fertilizer (IPNS) with cowdung produced the highest grain yield (6.97 t ha^{-1}) which is 30% higher over control. On the other hand, the lowest yield (4.88 t ha^{-1}) was recorded in the control treatment.

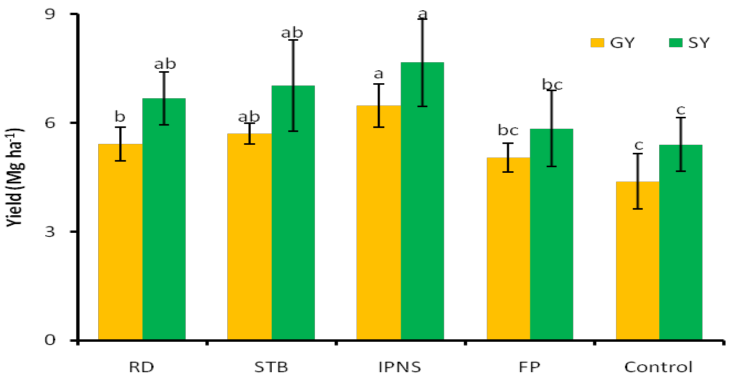


Fig. 26. Grain yield (t ha^{-1}) of T Aman rice influenced by different nutrient and water management

Like grain yield, straw yield was also significantly affected by fertilizer managements (Fig. 26). The highest straw yield (9.86 t ha^{-1}) reported by the STB treatment which is not significantly different with RD and IPNS treatment. Similar to grain yield, the lowest straw yield was obtained by control treatment which received no chemical fertilizer.

Plant height responded significantly to the fertilizer treatments (Table 110). The height of the rice plant depending on the treatment varied from 88.2 cm to 94.7 cm. The highest plant height (94.7 cm) was observed in IPNS treatment and the lowest (88.2 cm) in control which received no fertilizer.

Tillers $hill^{-1}$ and panicle length also responded significantly due to the nutrient addition. The tillers $hill^{-1}$ ranged from 16 to 19 and panicle length ranged from 23.3 to 24.9 cm. For both the parameter, highest value recorded from IPNS treatment and the lowest from control treatment.

There was also a significant effect of the applied nutrients on the grains $panicle^{-1}$, showing a variation from 88 to 97 (Table 110). The highest grains $panicle^{-1}$ (97) was observed in IPNS treatment and the lowest (88) in control.

Table 110. Effect of integrated nutrient management on yield and yield contributing parameters of T. Aman rice.

Treatments	Plant Height (cm)	Tillers $hill^{-1}$ (nos.)	Panicle Length (cm)	Grain $Panicle^{-1}$ (nos.)
RD	91.43b	17.63a	24.63ab	96.97ab
STB	90.17bc	17.13a	24.77bc	97.43ab
IPNS	94.73a	18.63a	24.89a	99.3a
FP	89.83bc	16.47ab	23.83cd	91.13bc
Control	88.20c	15.77c	23.32d	87.93c
CV (%)	6.16	5.38	3.91	5.63
SE (±)	0.80	0.38	0.39	2.17
P <	0.05	0.01	0.05	0.05

In a column, means followed by common letter (s) do not differ significantly at 5% level by DMRT.

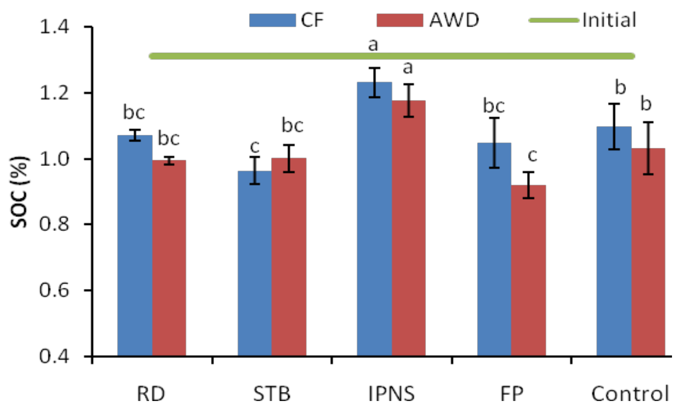


Fig. 27. Change in SOC (%) after completing the cropping pattern 2 at 0-15 cm depth

Soil organic carbon (SOC) was significantly affected by the application of fertilizer treatments. SOC decreased compare to initial value but increased in IPNS treatment due to application of CD. The SOC concentration in IPNS treatment got highest value and the STB and FP treatment recorded the lowest value by CF and AWD, respectively (Fig. 27). Soil organic carbon decreased (0.13 – 0.44%) compare to initial value (1.38%), but increased to some extent (0.01-0.26%) compare to control by IPNS treatment in both CF and AWD plots.

Conclusion

From the experimental result of one complete cycle of two cropping patterns it appeared that application of chemical fertilizer with cowdung seems to be better for crop production as well as maintaining good soil health. For making comprehensive conclusion of the project another cycle of both the cropping pattern needs to be completed.

Effect of PGPR biofertilizer incombination with chemical nitrogen and phosphorus on growth and yield of Binadhan-14

To see the effect of PGPR biofertilizer incombination with chemical nitrogen fertilizer on growth, yield and yield attributes of Binadhan-14 in late Boro season a pot experiment was conducted in glass house of BINA, Mymensingh in 2013-2014. There were six treatments viz. Control (N_0P_0+PG_0) (T1), PGPR inoculation without N&P application (T2), ¼ N+1/4P+PGPR (T3), 1/2N+1/2P (T4), 3/4N+3/4 P+PGPR (T5) and Full dose of N+P (T6). Soil used in the study was silty clay loam with pH 6.6, organic carbon 1.05%, Nitrogen 0.073% , P 14 ppm, K 0.02 meq /100g and S 15 ppm. The pots were 60cm x 50cm in size and contained 28 kg soil in each. The experiment was laid out in a completely randomized design with three replications. Binadhan-14 was used as test crop variety in the study. A number of nine hills were transplanted in each pot. K, S, Zn and B (980, 280, 28 and 14 mg/pot, respectively) were applied as basal dose as MoP, Gypsum, Zinc oxide and Boric acid, respectively at final pot preparation. Full dose of N and P were applied as 120 kg N and 25 kg P/ha (1.68mg N and 0.35mg P/pot, respectively) as urea and triple supper phosphate, respectively. Data on growth, yield and yield contributing parameters were recorded in time.

Results (Table 111-113) revealed that PGPR inoculant incombination with nitrogen and phosphorus gave significantly higher values of growth, yield and yield contributing parameters of Binadhan-14 over uninoculated control. PGPR along with nitrogen and phosphorus showed near about equal yield of grain and straw of rice to $^{1}/_{4}$ N and P application. Application of PGPR inoculant and ½ NP showed more or less similar grain and straw yield with ½ NP applications. ¾ N and P + PGPR applied treatment exhibited similar grain and straw yield with full dose of nitrogen + phosphorus applied treatment. Straw and root yield of rice showed similar results with that of grain yield. Yield contributing parameters like number of panicle per pot, grains/panicle, grain weight/panicle and 1000 grain weights were also influenced by PGPR application over uninoculated control treatment.

Table 111. Effect of PGPR biofertilizer incombination with nitrogen and phosphorus on growth of Binadhan-14 in Boro season

Treatment	Plant height (cm)	Shoot dry weight (g/hill)	Root length (cm)	Root dry weight (g/Hill)	Tiller per hill (no.)
T_1: N_0P_0+PG_0	99.40 c	14.63 c	18.60 b	4.24 e	5.54 b
T_2 : N_0P_0+PG_m	103.60 bc	16.28 bc	21.07 ab	5.17 de	6.79 ab
T_3: 1/4NP+PG_m	107.80 ab	18.99 ab	24.14 a	5.80 cd	7.40 ab
T_4: 1/2NP+PG_0	107.80 ab	19..30 ab	23.78 a	6.82 bc	7.69 a
T_5: 3/4NP+PG_m	110.10 a	21.41 a	24.74 a	7.87 ab	8.78 a
T_6: Full NP+PG_0	109.20 a	21.96 a	24.47 a	8.04 a	8.34 a
Sig. level	*	**	**	**	**
%CV	3.05	6.23	5.76	7.01	9.83

In a column, having same letter(s) do not differ significantly at 1% and 5% level of probability as per DMRT.
** = Significant at 1% level, * = Significant at 5% level

Table 112. Effect of PGPR biofertilizer incombination of nitrogen and phosphorus on yield of grain, straw and root of Binadhan-14 in Boro season

Treatments	Grain wt. per hill (g)	Grain yield (g/pot)	Straw yield (g/pot)	Root yield (g/pot)
T_1: N_0P_0+PG_0	15.06 c	135.50 d	131.70 c	38.16 e
T_2 : N_0P_0+PG_m	17.82 bc	160.70 cd	146.50 b	46.53 de
T_3: 1/4NP+PG_m	20.05 abc	180.40 bc	170.90 ab	52.20 cd
T_4: 1/2NP+PG_0	21.65 ab	194.90 ab	173.70 ab	61.38 bc
T_5: 3/4NP+PG_m	23.86 a	214.70 a	192.70 a	70.50 ab
T_6: Full NP+PG_0	24. 59a	221.30 a	197.60 a	72.36 a
Sig. level	**	**	**	**
%CV	9.90	6.23	7.52	6.48

In a column, having same letter(s) do not differ significantly at 1% and 5% level of probability as per DMRT.
** = Significant at 1% level

Table 113. Effect of PGPR biofertilizer incombination with nitrogen and phosphorus on yield attributes of Binadhan-14 in Boro season

Treatment	Panicle length (cm)	Panicle per pot (no.)	Grains per panicle (no.)	Grain wt. per Panicle (g)	1000 grain wt. (g)
T_1: N_0P_0+PG_0	21.13 c	49.86 b	89.07 b	1.99 d	22.27
T_2 : N_0P_0+PG_m	22.17 bc	61.14 ab	94.77 b	2.20 c	23.30
T_3: 1/4NP+PG_m	23.79 ab	66.57 ab	109.60 a	2.57 b	23.67
T_4: 1/2NP+PG_0	23.21 ab	69.13 a	109.50 a	2.61 b	24.04
T_5: 3/4NP+PG_m	24.14 a	75.60 a	118.40 a	2.86 a	24.31
T_6: Full NP+PG_0	24.30 a	77.16 a	119.20 a	2.77 ab	24.61
Sig. level	**	**	**	**	NS
%CV	3.79	9.45	4.93	3.80	3.50

In a column, having same letter(s) do not differ significantly at 1% and 5% level of probability as per DMRT.
** = Significant at 1% level, NS = Non-significant

Conclusion

From this experiment it can be concluded that PGPR biofertilizer could save 17-21% N and P fertilizer. However, further trial is necessary in pot as well as in field in different seasons for confirmation of this finding.

Effects of phosphatic biofertilizer with inorganic and organic P on Mustard–Summer Mungbean-T. aman cropping sequence

Field experiments were conducted to evaluate the phosphatic biofertilizer (PB) with inorganic or organic sources of P on Mustard–Summer mungbean–T. aman cropping sequence at BINA substation, Ishurdi and Magura during 2013-14. The experiment was laid out in a Randomized Complete Block Design using seven treatments with three replications. The treatments were as follows: T_1: Control, T_2: 100% P from TSP, T_3: 50% P from TSP, T_4: 50% P from TSP + Phosphatic biofertilizer (PB), T_5: 50% P from cowdung (CD), T_6: 50% P from CD + PB and T_7: Phosphatic biofertilizer (PB). Mustard (var. Binasarisha-4) was sown on 7 Nov. 2013 and harvested on 22 Feb. 2014 at Ishurdi while at Magura it was sown on 8 Nov. 2013 and harvested on 15 May 2014. Then summer mungbean (var. Binamoog-8) was sown on 7 March 2014 and harvested on 15 May 2014 at Ishurdi whereas it was sown on 5 March 2014 and harvested on 18 May 2014 at Magura following same layout.

Characteristics of initial soils for both the locations have been given in Table 114. Recommended fertilizer rates (Table 115) were used as per Fertilizer Recommendation Guide (BARC 2012). In case of cowdung treatments, IPNS was followed. Phosphatic biofertilizer (as liquid inoculant) was applied with the seeds of mustard and mungbean before the sowing.

Table 114. Physical, chemical and microbiological characteristics of initial soils of experimental fields at Ishurdi and Magura

Characteristics	Ishurdi	Magura
Textural class	Loam	Clay Loam
Cation exchange capacity (cmol kg^{-1})	13.0	12.2
Soil pH	7.7	7.6
Organic carbon (%)	0.62	0.67
Total N (%)	0.055	0.060
Available P (mg kg^{-1})	13.20	14.0
Total P (mg kg^{-1})	1475.8	1490.4
Exchangeable K (cmol kg^{-1})	0.264	0.223
Available S (mg kg^{-1})	10.6	11.40
PSB population (cfu g^{-1} dry soil)	1.7×10^4	1.5×10^4

The Table 116 shows that the treatment T_4 (50% P from TSP + PB) gave significantly maximum seed yield of mustard (2.03 and 1.91 t ha^{-1}) followed by the treatment T_6 (1.92 and 1.87 t ha^{-1}**)** at Ishurdi and Magura, respectively. The treatments T_2 (100% P from TSP), T_4 (100% P from TSP + PB) and T_6 (50% P from cowdung + PB) gave identical seed yields at both the locations. Without P treatment gave significantly the lowest seed yield of mustard at both the locations. Straw yields of mustard (Table 116) were not significantly affected with the different treatments at both the locations. The treatment T_6 (50% P from CD) gave statistically highest straw yield (4.35 and 4.28 t ha^{-1} at Ishurdi and Magura, respectively) of mustard followed by the treatment T_4 (50% P from TSP + PB) at Ishurdi and T_2 (100% P from TSP) at Magura. The treatment T_1 gave the lowest straw yield at both the locations. The results indicated that phosphatic biofertilizer with reduced rate of P i.e. 50% P from TSP + Phosphatic biofertilizer gave comparable seed yields of mustard to the 100% P from TSP alone.

Table 115. Full rates (100%) of nutrients (kg ha^{-1}) and 50% P equivalent CD (t ha^{-1}) for mustard and mungbean as per fertilizer recommendation guide (2012).

Crops	N	P	K	S	Zn	B	CD
Mustard	90	27	32	15	1.0	1.0	1.9
Summer mungbean	18	18	20	10	-	-	1.3

Table 116. Effects of phosphatic biofertilizer with inorganic and organic P fertilizer on seed and straw yields of mustard (var. Binasarisha- 4) during 2013-14

Treatments	Ishurdi		Magura	
	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1: Control	1.37e	3.82	1.33 c	3.90
T_2: 100% P from TSP	1.89 abc	3.91	1.83 a	4.22
T_3: 50%P from TSP	1.67cd	3.96	1.54 b	4.04
T_4: 50%P from TSP+Phosphatic biofertilizer (PB)	2.03 a	4.17	1.91 a	4.13
T_5: 50%P from cowdung	1.73 bcd	3.85	1.49 bc	4.01
T_6: 50%P from cowdung+PB	1.92 ab	4.35	1.87 a	4.28
T_7: PB	1.52 de	3.92	1.42 bc	4.00
CV (%)	7.15	NS	5.89	NS

In a column means having common letter(s) do not differ significantly at 5% level by DMRT.

Phosphatic biofertilizer with inorganic and organic sources of P significantly influenced the yields of subsequent mungbean at Ishurdi and Magura (Table 117). The treatment T_4 (50% P from TSP + PB) produced significantly maximum seed yields at Ishurdi (1.27 t ha^{-1}) and Magura (1.45 t ha^{-1}) followed by the treatment T_2 (100% P from TSP) at both the locations. The treatment T_1 gave significantly the lowest seed yield at both the locations. The treatment T_6 gave the highest stover yield (1.73 t ha^{-1}) of summer mungbean at Ishurdi whereas the treatment T_4 gave the highest stover yield (1.72 t ha^{-1}) at Magura. But all the treatments except T_1 showed identical stover yields of summer mungbean at both the locations with few exceptions. The results revealed that phosphatic biofertilizer with 50% P from TSP could be used for cultivation of summer mungbean as an alternate of 100% P from TSP alone.

Table 117. Effects of phosphatic biofertilizer with inorganic and organic P fertilizer on seed and stover yields of summer mungbean (Binamoog-8) 2013-14

Treatments	Ishurdi		Magura	
	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)
T_1: Control	0.82 b	1.25 c	0.88 d	1.00 b
T_2: 100% P from TSP	1.24 a	1.46 b	1.37 ab	1.56 a
T_3: 50%P from TSP	1.18 a	1.37 bc	1.08 bcd	1.35 a
T_4: 50%P from TSP+Phosphatic biofertilizer (PB)	1.27a	1.53 b	1.45 a	1.72 a
T_5: 50%P from cowdung	1.04 ab	1.50 b	1.12 abcd	1.59 a
T_6: 50%P from cowdung+PB	1.16 a	1.73 a	1.28 abc	1.63 a
T_7: PB	1.01 ab	1.48 b	1.02 cd	1.42 a
CV (%)	13.43	6.80	15.33	10.43

In a column means having common letter(s) do not differ significantly at 5% level by DMRT.

Effect of rhizobial strains and their mixed culture on growth and yield of lentil

An experiment was conducted at Magura substation to evaluate the performance of rhizobial strains on growth and yield of lentil those were isolated from different part of Bangladesh and collected from nifTAL, USA. Three BLR strains, two nifTAL strains, two mixed cultures, recommended dose of urea and one nitrogenous control were used as different treatments for this experiment. The experiment was conducted in randomized complete block design (RCBD) with three replications. The plot sizewas 6 m^2 and plant to plant distance was 8-10 cm and line to line distance was 30 cm. As per fertilizer recommendation guide, fertilizers like P, K, S, and Zinc were applied at the rate of 16, 20, 12 and 1 Kg/ha, respectively in all plots as basal dose and nitrogen (16 kg $ha-^1$) was applied as a treatment. Parameters like nodule weight and plant weight were recorded at flowering stage. At harvest, pod numbers, 100 seed weight and yield were recorded from randomly selected ten plants of each plot.

Results showed (Table 118) that significant variations were present in all recorded parameter except hundred seed weight. Nodule weight ranged from 13.20 to 19.93 mg/ plant. The highest nodule weight (199.93 mg) was found in the strain nifTAL640 and minimum nodules weight was found in urea treatment. Strain BLR26 produced the highest plant weight (2.96g $plant-^1$) which was followed by the strain nifTAL640 and the lowest plant weight was produced by the strain nifTAL638.

Significant variations were present in pod number/plant produced by different treatments. The highest numbers of pods (110g $plant-^1$) were observed in the treatment BLR26 while minimum was present in the treatment strain nifTAL638. There was no significant variation among different treatment in case of hundred seed weight produced by different treatments.

Seed yield from different treatments showed significant variations among them. Urea treatment produced the highest yield (1679 Kg $ha-^1$) which was statistically similar to the strain BLR26. Seed yield produced by recommended dose of urea and the strain BLR26 were statistically similar but significantly higher than any other treatments. Although the strains BLR175, nifTAL640 and mixed culture-II produced significantly higher yield over the strain nifTAL638 but they were statistically similar. Minimum yield was observed in the strain nifTAL638. Among rhizobial strains, strain BLR26 seems to be the best for lentil inoculation since it produced the highest yield than other used inoculated strain.

Table 118. Effect of rhizobial strains on growth and yield of lentil

Treatment	At flowering stage		At harvest		
	Nodule weight (mg)	Plant weight (g)	Pod plant-^{1} (Nos)	Hundred seed weight (g)	Seed yield (Kg ha-^{1})
T_1 (Control, no nitrogen)	17.43 bc	2.06 ef	90.77 fg	2.11	1338 c
T_2 (Rl nifTAL638)	16.90 bc	2.00 f	87.14 g	2.18	1199 d
T_3 (RlnifTAL640)	19.93 a	2.57 b	101.50 cd	2.25	1544 ab
T_4 (R.sp. BLR26)	18.83 ab	2.96 a	110.00 a	2.20	1670 a
T_5 (R.sp. BLR175)	16.16 c	2.37 cd	103.80 bc	2.15	1636 ab
T_6 (R.sp. BLR235)	16.43 c	2.27 d	94.29 ef	2.13	1512 b
Mixed-I (638 & 640)	17.37 bc	2.27 d	88.64 fg	2.18	1284 cd
Mixed-II (26,75 & 235)	16.63 c	2.23 de	97.22 de	2.17	1567 ab
Urea (33 kg ha^{-1})	13.20 d	2.48 bc	108.00 ab	2.21	1679 a
CV	5.86	4.33	3.01	4.44	4.58

In a column, means followed common letter (s) do not differ significantly at 5% level by DMRT.

Abbreviations : Rl = *Rhizobium leguminosarum*, R = *Rhizobium*, BLR = Bangladeshi lentil rhizobia nifTAL = Nitrogen Fixation by Tropical Agricultural Legumes

Conclusions

This experiment showed that effective rhizobial strains could be used for lentil cultivation at field conditions to increase lentil yield even in the presence of indigenous rhizobial population. From this experiment it is also clear that rhizobial strains differ significantly in their effectiveness to make symbiosis with their host and therefore it is necessary to collect new strains from different localities and evaluate their performance to have better strains for inoculant production. Further evaluations are needed to confirm the performance of these strains at field conditions.

Molecular characterization of rhizobia from lentil root nodules

Background

Rhizobial strains were isolated from field-grown lentil root nodules from different parts of Bangladesh in 2009. Detailed descriptions of the strains (isolation localities, isolation procedure, phylogenetic and population analysis, DNA fingerprint analysis and phenotypic characterization) are available in Rashid *et al.* [2012 & 2014]. Phenotypic characteristics, DNA fingerprint, and the phylogenetic and population analysis of eight gene sequences showed that these strains belong to three new rhizobial clades/ lineages within the genus *Rhizobium*

Materials and methods

Bacterial strains

In this study, three strains from previously described three lineages (BLR27^{T}, BLR175^{T} and BLR195^{T} from lineages I, II and III, respectively) were further analyzed by whole cell fatty acid content, DNA-DNA hybridization and whole genome sequence analysis to confirm their species status. These experiments were conducted at Ghent University, Belgium; University of York, England and at DSMZ, Germany during 2013-2014.

Phylogentic analyses

We described three new lineages in the genus *Rhizobium* from effective root nodules of lentils from Bangladesh in 2012. Since then several additional new species and strains have been described in this genus. Therefore, in present study the 16S-rRNA, *recA* and *atpD* gene sequences from 15 strains from our previous study were compared with representatives of these novel groups to assess their taxonomic status. The sequences were obtained from NCBI and aligned with the Clustal X in BioEdit. Phylogenetic trees were reconstructed using the neighbour-joining and maximum likelihood method in MEGA version 5. For sequence evolution, general time reversible (GTR) model with gamma distribution was used in ML analysis. Bootstrap support for each node was evaluated with 1000 replicates. Trees were rooted using *Mesorhizobium* as out group.

DNA-DNA hybridization and GC content analysis

High-quality DNA was prepared using the method of Wilson (1983) with minor modifications. DNA-DNA hybridizations were performed using a microplate method at 47.8 °C with photobiotin-labelled probes as described before using an HTS7000 Bio Assay Reader (PE Applied Biosystems) for fluorescence measurements. The DNA G+C content was determined by HPLC following standard protocol.

Genome sequencing and Average Nucleotide Identity

Genomic DNA was extracted from strains grown in TY medium using PowerSoil DNA isolation kits (MoBio, Carlsbad, CA), and then fragmented, barcoded, quantitated and run as part of a batch of eight genomes on a 318 chip on an Ion Torrent PGM using the manufacturer's recommended protocols (Thermo Fisher, Waltham, MA). Each genome was assembled using the Newbler GS De Novo assembler version 2.8 (Roche diagnostics) with default parameter values. ANI was calculated within the JSpecies software. The Nucleotide MUMmer algorithm (NUCmer) was used, with default parameter settings, to calculate the ANI by subtracting the similarity errors from the alignment length. Genomes were compared with each other, with genome assemblies obtained using the same methods for *Rhizobiumpisi* DSM30132^T and *Rhizobiumfabae* CCBAU33202^T (unpublished), and with complete genome assemblies downloaded from NCBI for the following strains: *Rhizobiumetli* CFN42^T (GCA_000092045), *Rhizobiumphaseoli* CIAT652 (GCA_000020265), *Rhizobium leguminosarum*3841 (GCA_000009265), *Rhizobiumleguminosarum* WSM1325 (GCA_000023185), *Rhizobium* sp. WSM2304 (GCA_000021345).Sequence reads used for ANI calculations are available in the European Nucleotide Archive as study PRJEB7125 (http://www.ebi.ac.uk/ena/data/view/PRJEB7125).

Phenotypic characterization

Different phenotypic characteristics i.e. colony size, tolerance to NaCl, temperature and pH, and antibiotic sensitivity were determined following the protocols described in Rashid *et al*. (2012).

Fatty acid analysis

The cellular fatty acid compositions of type strain of proposed species were analyzed after growing on YEMA plates at 28°C for 3 days. Cells were saponified and transmethylated as described by Kuykendal *et al*. (1988) and were separated by using the Sherlock microbial identification system (RTSBA6; MIDI) and an Agilent (model 680N) gas chromatograph. Fatty acid compositions were determined at DSMZ, Germany.

Results

Phylogenetic analyses

The 16S rRNA gene sequences from the strains from proposed new species (*R.lentis*, *R.bangladeshense* and *R.binae*) were very similar and clustered with type strains of *R.etli*CFN42^T, *R.phaseoli*CIAT652, *R.fabae*CCBAU33202^T, *R.pisi*DSM30132^T, *R.leguminosarum* USDA2370^T, *R.laguerreae* FB206^T (Fig. 28). The analysis of the concatenated sequences of *recA* and *atpD* genes (Fig. 29 and MLSA are available in supplementary materials 2 – 4) revealed that the proposed species formed three separate clades/lineages and the closest relatives were *R. etli* and *R. phaseoli*. Moreover, *Rhizobium* sp. strain ESC1110, isolated from *Phaseolus vulgaris* from Hispaniola Island, Spain was closely related to the *R. lentis*. (Fig. 29).

DNA - DNA relatedness

DDH experiments were conducted with the type strains of *R.etli* and *R.phaseoli*, since these two species were very close to the novel strains in phylogenetic analyses. The results of the DDH experiments are shown in the table 119.

Strain BLR27^T (proposed type strain of clade I) showed 50 % and 56 % DNA relatedness to the type strains of *R.etli* and to *R. phaseoli,* respectively. It showed 60 % relatedness to strain BLR175^T (proposed type strain of clade II) and 50 % DNA relatedness to strain BLR195^T (proposed type strain of clade III). The strain BLR175^T showed 53 % relatedness to BLR195^T. Overall, the proposed type strains (BLR27^T, BLR175^T and BLR195^T) showed 50 - 62 % relatedness to their most closely related species and 50 - 60 % relatedness to each other. The DNA G+C content of the novel strains were 61.1 %, 60.9 % and 61.4 % for BLR27^T, BLR175^T and BLR195^T, respectively. These values are within the range of the genus *Rhizobium*.

Genome sequence and average nucleotide identity analysis

Ion Torrent sequencing yielded 155Mbp, 264Mbp, 237Mbp of sequence from BLR27^T, BLR175^T and BLR195^T, respectively, corresponds to 27- to 49-fold coverage, so it can be expected that virtually all the genomic sequence is included. Assembly resulted in 140, 89 and 187 contigs (>100 bp) with N50 sizes of 229 kb, 286 kb and 173 kb, respectively.

Pairwise ANI was calculated between these genomic sequences, and with other strains in the *R. leguminosarum* species complex for which genome data were available (Table 120). Each ANI was calculated in both directions, but the results never differed by more than 0.03%. ANI values ranged from 87.27% to 92.39%, with this highest value being between BLR195^T and *R. phaseoli*CIAT652. All these values are well below 96%, which is accepted as the species boundary, equivalent to a DDH of 70%. Hence, each of the three BLR strains belongs to a distinct species, and these are different from all the closely related species described previously.

Phenotypic characteristics

Phenotypic characteristics of strains belonging to the three proposed species and their close relatives are given in Table 121. *R. binae* and most *R. bangladeshense* strains were able to grow at pH 10, and also in 0.5 % NaCl, unlike most strains of *R. lentis*. On the other hand, all *R. lentis* and some *R. bangladeshense* strains showed resistance to amplicillin.

Fatty acid analysis

The cellular fatty acids compositions of type strains of proposed species are mentioned in the Table 122. The type strains of proposed species and their close relatives contain some common fatty acids: 16:0; 18:0; 16:0 3 OH; 19:0cyclo ω8c; summed featured 2 and summed featured 8. Moreover, fatty acid like 15:0 iso 2 OH and summed feature 3 are found only in proposed species.

Conclusions

We have selected one representative strain from each clade that was identified in the housekeeping gene phylogeny, and demonstrate through the use of DDH and ANI analysis that they do indeed meet the standard criteria for distinct species, since all DDH values are below 70% and ANI values below 96%. DDH has been the standard method for bacterial species demarcation for the last 50 years (McCarthy & Bolton, 1963; Tindall *et al*., 2010; Wayne *et al*., 1987), but it has major limitations. It is time-consuming, laborious, and hard to standardize between laboratories. An increasingly significant limitation, as more species are described, is that DDH requires a laboratory comparison with all possible close relatives. DDH was developed before genome sequencing became feasible, but sequence-based methods have the potential to provide more reliable information more easily. The calculation of average nucleotide identity (ANI) from genome sequence data has been shown to give comparable results to DDH, with a species boundary at around 96% (Goris *et al*., 2007; Konstantindis & Tiedje, 2005). Our study does not test the accuracy of this boundary, since all ANI values were much lower than this, but it does provide further evidence that low ANI values can be used as an effective substitute for DDH when establishing that strains do not belong to the same species. We expect that, in future, proposals for new bacterial species will increasingly use ANI evidence in place of DDH. In this study, the two methods provide consistent evidence that three new species are involved in lentil nodulation in Bangladesh, for which we proposed the names *Rhizobium lentis*, *Rhizobium bangladeshense* and *Rhizobium binae*.

Table 119. Genetic relatedness measured by DDH between strains representing the novel clades and type strains of the most closely related species

Species	Strain	*DNA G+C content (% mol)*	DNA-DNA relatedness (%)				
			Rhizobiumlentis (BLR27^T)	*Rhizobium bangladeshense* (BLR175^T)	*Rhizobium binae* (BLR195^T)	*Rhizobium etli* (LMG 17827^T)	*Rhizobium phaseoli* (LMG 8819^T)
Rhizobiumlentis	BLR 27^T	61.1	100.00	60.90	50.40	50.60	56.30
Rhizobium bangladeshense	BLR175^T	60.9	60.90	100.00	53.20	49.20	62.20
Rhizobium binae	BLR195^T	61.4	50.40	53.20	100.00	54.90	55.80

Table 120. Average nucleotide identity (ANI) between strains representing the novel clades and the most closely related sequenced members of the *Rhizobium leguminosarum* complex

Species	Strain	Average Nucleotide Identity (%)		
		R. lentis BLR27^T	*R. bangladeshense* BLR175^T	*R. binae* BLR195^T
R. lentis	BLR27^T	100	89.70	88.64
R. bangladeshense	BLR175^T	89.72	100	88.51
R. binae	BLR195^T	88.62	88.51	100
R. etli	CFN42^T	89.04	88.64	89.28
R. phaseoli	CIAT 652	88.56	88.25	92.39
R. fabae	CCBAU 33202^T	88.90	88.64	88.81
R. pisi	DSM 30132^T	88.82	88.18	88.46
R. leguminosarum	3841	88.33	87.27	88.28
R. leguminosarum	WSM1325	88.01	87.59	88.06
Rhizobium sp.	WSM 2304	88.09	87.76	88.55

Abbreviation: R= Rhizobium

Table 121. Phenotypic characteristics of proposed three new species and their close relatives

Species	NaCl tolerance (%)			Temperature tolerance (^{0}C)	pH tolerance		Antibiotic sensitivity (µg/mL)										
							Ampicillin					Kanamycin		Nalidixic acid			
	0.5	1.0	2.0	37	8.2	10	50	75	100	125	150	10	20	10	20	30	40
Rhizobium lentis (21 strains)	—	—	—	+	+	v	+	+	+	v	v	+	+	+	+	+	+
Rhizobium bangladeshense (6 strains)	+	—	—	+	+	+	+	v	v	v	v	+	+	+	+	+	+
Rhizobium binae (3 strains)	+	v	—	+	+	+	+	—	—	—	—	+	v	+	+	+	+
*Rhizobium etli**	ND	ND	ND	+	ND	ND	ND	ND	ND	ND	ND	ND	ND	+	+	+	+
*Rhizobium phaseoli**	+	—	—	v	—	—	+	+	+	+	+	ND	ND	ND	ND	ND	ND
*Rhizobium pisi**	+	+	—	+	+	—	—	—	—	—	—	ND	ND	ND	ND	ND	ND
*Rhizobium fabae**	+	+	+	+	+	—	+	+	+	+	+	+	+	ND	ND	ND	ND
*Rhizobium leguminosarum**	+	—	—	—	+	ND	v	v	v	v	v	ND	ND	ND	ND	ND	ND
*Rhizobium laguerreae**	+	—	—	+	ND	ND	v	v	v	v	v	ND	ND	ND			

Abbreviations:+ =growth positive for >80% of strains, — = growth negative for >80% of strains, and v=strains varied in response. ND=not determined/data not available.

*Data taken from Rashid et al. [2012] and published species descriptions.

N.B.: All strains grew at 32^{0}C and showed acidic reaction on BTB medium, but none grew at 40^{0}C temperature, in tetracycline (5 µg /mL) or on LB medium.

Table 122. Fatty acid pattern in type strain of proposed species and their closely related species. Values are percentage of total fatty acids. Data for reference strains are taken from Tighe, *et al.* (1999) and Tian, *et al.* (2008) and are means for the numbers of strains. Name/number of strains are mentioned in parenthesis.

Fatty acid	*R.lentis* (BLR27^{T})	*R.bangladeshense* (BLR175^{T})	*R.binae* (BLR195^{T})	*R.fabae* (CCBAU33202^{T})	*R.etli* (n=30)	*R.leguminosarum* (n=28)
15:0 iso 2OH	0.55%	absent	0.79	absent	absent	absent
16:0	2.03 %	2.67%	2.12%	2.37	2.53	4.08
16:0 3-OH	0.91%	2.16%	0.80%	0.96	1.20	1.32
18:0	3.23%	6.88%	4.63%	6.75	8.71	7.83
18:1ω9c	absent	absent	2.36%	0.92	0.12	absent
18:0 3OH	absent	absent	0.97%	1.41	absent	absent
18:1ω7c 11methyl	absent	absent	0.63%	0.89	1.48	4.70
19:0 cycloω8c	11.37%	6.66%	21.76%	4.89	10.19	13.91
*Summed featured 2	5.80%	7.00%	5.62%	6.75	5.95	6.46
+Summed featured 3	0.43%	absent	absent	absent	absent	absent
±Summed featured 8	75.35%	74.62%	60.32%	72.55	66.17	57.22

Abbreviation*: R= Rhizobium*

Summed featured indicate two or more fatty acids that could not be separated by MIDI system.

*Summed featured 2 consist one or more of 12:0 (aldehyde), unknown ECL 15.489, 14:0 3OH/ 16:1 iso I.

+ Summed featured 3 consists 16:1ω7c/16:1ω6c.; ± Summed featured 8 consist 18:1ω7c/18:1ω6c

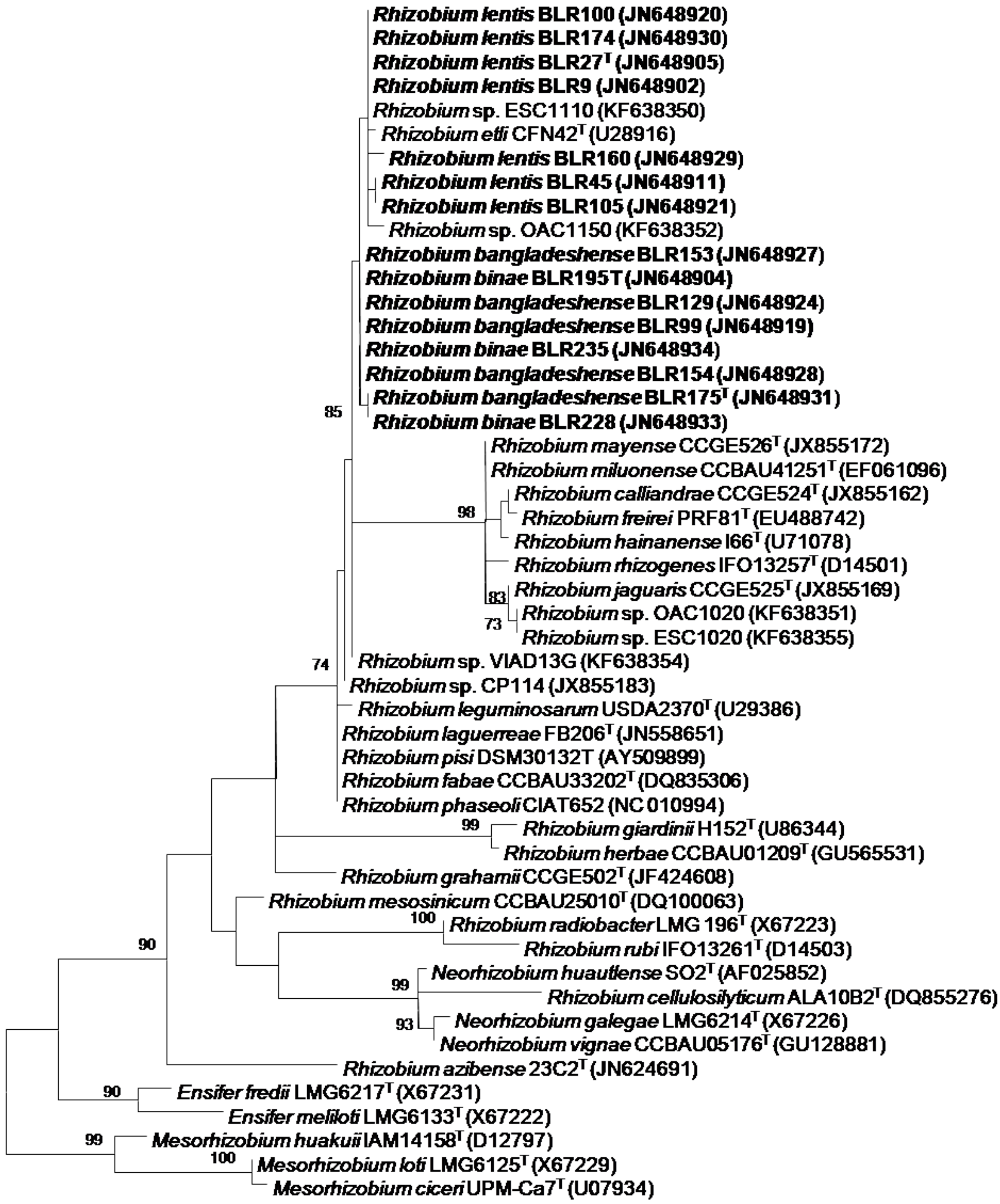


Fig. 28. ML tree from 16S rRNA gene partial sequences. Bootstrap values ≥70 are indicated for each node (1000 replicates).

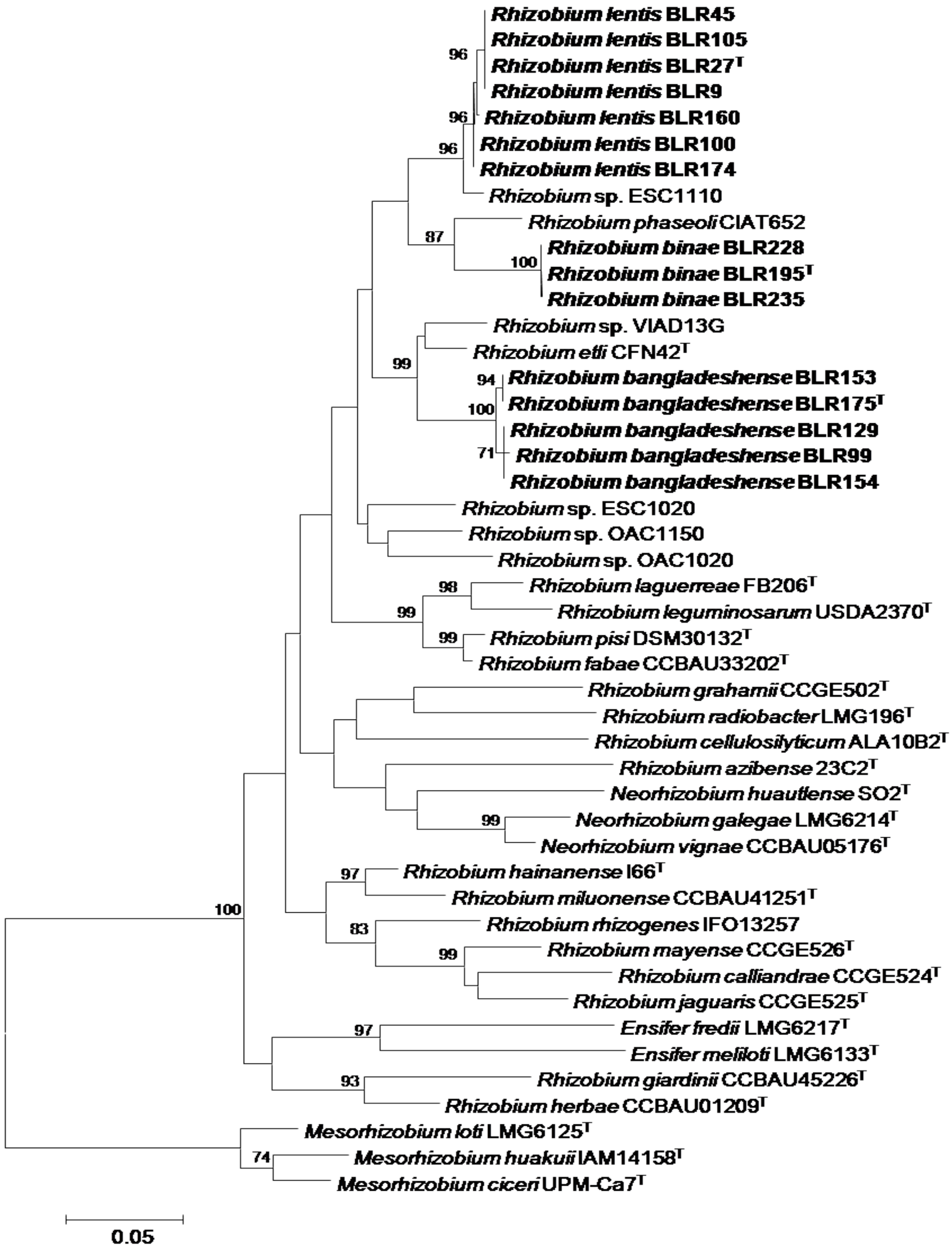


Fig. 29. ML tree from concatenated sequence of atpD-recA genes. Bootstrap values ≥70 are indicated for each node (1000 replicates)

ENTOMOLOGY DIVISION

RESEARCH HIGHLIGHT

Among the six short duration mutants of rice the overall infestation by stem borer throughout the cropping season was below the economic injury level (5-10%)

In artificial infested condition the lowest leaf area consumed by rice hispa was observed in the mutant NERICA-10 (3.9 cm^2)

Among the two submergence tolerant varieties of rice the overall infestation by stem borer throughout the cropping season was below the economic injury level (5-10%)

Significant difference were observed among the six mutants/varieties of summer mungbean with respect to jassid, white fly and pod borer infestation. Pod borer, jassid and white fly infestation was lower at Rangpur than that of Ishurdi.

No significant difference were oberved among the chickpea mutants/varieties against the cutworm and pod borer infestation. But the infestations was higher at Jamalpur than that of Rajshahi

Pulse beetle became highly sterile at 50, 70, 90, 110 Gy and not sterile at 5, 10, 15, 20, 25 Gy radiation and 20%, 30%, 40%, sterile at 30, 35, and 40Gy radiation doses.

Three hundred seventy brinjal shoot and fruit borer were caught using ten pheromone traps in seven days.

Among the tested mutants and varieties of groundnut the mutants Gc(1)-24-1-1-1 and Gc(1)-32-3-1-1-1 showed significantly lowest infestation against all the insects (cutworm, jassid, leaf roller and hairy caterpillar). So these mutants may be less susceptible against tested insects.

All the tested mutants of soybean were less infested by the cabbage looper, hairy caterpillar and pod borer than the check varieties (Binasoybean -1 and Binasoybean -5).

Among the tested mutants of mustard two mutants RC-9 and RC-10 were found to be less susceptible/tolerant to aphid and sawfly at four locations (Mymensingh, Comilla, Magura and Rangpur).

Considering all the concentration and the effectiveness of four plant extracts the order of efficacy against pulse beetle were pithraj leaf > riot lata leaf (Mikania) > mahogany seed > raintree leaf.

Evaluation of short duration mutants of rice for to tolerance to major insect pest under field condition

Six short duration mutants of rice, Viz. RM(2)-40(C)-1-1-10, RM(2)-40(C)-3-1-7, RM(2)-40(C)-4-2-8, RM(2)-40(C)-1-1-1, RM(2)-40(C)-4-2-7 and RM(2)-40(C) -1-1-5 were tested along with two resistant check, T27A & TKM 6 and a susceptible check, TN1 against rice stem borer under field condition. The experiment was laid out in a randomized complete block design with three replications during aman season, 2013 at BINA farm, Mymensingh. No protective measure was taken to control the insect pests. Data were recorded during maximum tillering and heading stage and analyzed statistically.

Among the six short duration mutants of rice the overall infestation by stem borer throughout the cropping season was below the economic injury level (5-10%)

Table 1. Mean infestation of short duration mutants of rice for tolerance to stem borer under field condition

Mutants	% Dead Heart	% White Head
RM(2)-40(c)-1-1-10	0.27 c	0.51 b
RM(2)-40(c)-3-1-7	0.63 b	0.26 c
RM(2)-40(c)-4-2-8	0.39 b	0.58 b
RM(2)-40(c)-1-1-1	0.89 a	0.47 b
RM(2)-40(c)-4-2-7	0.11 c	0.00
RM(2)-40(c)-1-1-5	0.05 c	0.35 c
TNI (Susceptible check)	0.95 a	0.99 a
T27A (Resistant check)	0.00	0.00
TKM 6 (Resistant check)	0.23 c	0.00

Means in a column followed by same letter(s) are not differ significantly at 5% level by DMRT.

Evaluation of drought tolerant lines of rice against rice hispa under artificial infested condition

Two drought tolerant lines of rice, NERICA-1 and NERICA-10 were tested along with two resistant check, T27A & TKM6 and a susceptible check, TN1 against rice hispa under artificial infested condition. The experiment was laid out in a completely randomized design with 4 replications in the laboratory of Entomology Division of BINA. Data were recorded timely and analyzed statistically.

In artificial infested condition the lowest leaf area consumed by rice hispa was observed in the mutant NERICA-10 (3.9 cm^2)

Table 2. Mean infestation of drought tolerant lines of rice for tolerance to rice hispa under artificial infested condition

Lines	Leaf area consumed by rice hispa (cm^2)
NERICA-1	5.0 b
NERICA-10	3.9 ab
T27A (Resistant check)	3.2 ab
TKM6 (Resistant check)	4.2 ab
TN1 (Susceptible check)	7.1 a

Means in a column followed by same letter(s) are not differ significantly at 5% level by DMRT.

Evaluation of submergence tolerant varieties of rice for tolerance to major insect pest under field condition

Two submergence tolerant varieties of rice, Viz. Binadhan-11 and Binadhan-12 were tested along with two resistant check, TKM 6 & T27A and a susceptible check, TN1 against rice stem borer under field condition. The experiment was laid out in a randomized complete block design with three replications during aman season, 2013 at BINA farm, Mymensingh. No protective measure was taken to control the insect pests. Data were recorded during maximum tillering and heading stage and analyzed statistically.

Among the two submergence tolerant varieties of rice, the overall infestation by stem borer throughout the cropping season was below the economic injury level (5-10%).

Table 3. Mean infestation of submergence tolerant varieties of rice for tolerance to stem borer under field condition

Mutants	% Dead Heart	% White Head
Binadhan-11	0.53 b	0.42 b
Binadhan-12	0.49 b	0.36 b
TNI (Susceptible check)	0.93 a	0.97 a
T27A (Resistant check)	0.17 c	0.00
TKM6 (Resistant check)	0.19 c	0.00

Means in a column followed by same letter(s) are not differ significantly at 5% level by DMRT.

Evaluation of summer mungbean mutants/strains for tolerance to their major insect pest under field condition

Four advance mutants of summer mungbean and two check varieties were evaluated for resistance to jassid, whitefly and pod borer under field condition during summer season of 2013. The experiments were conducted in a randomized complete block design with three replications at BINA substation farm, Ishurdi and Rangpur. Unit plot size was 3 m × 4 m. Seeds were sown on 6 March, 2013 at Ishurdi and 14 March at Rangpur, respectively. The field was exposed to natural attack of insects and no control measure was taken. To assess the percentage of presence of jassid and whitefly data were taken by using cage (1 case = 40 cm × 45 cm = 6 plants) at the vegetative stage. Ten plants per plot were selected randomly for assessing percentage of pod borer infestation before harvest. The data were analyzed statistically.

Significant difference were observed among the six mutants/varieties with respect to jassid, white fly and pod borer infestation. Pod borer, jassid and white fly infestations were lower at Rangpur than that of Ishurdi.

Table 4. Mean infestation of summer mungbean mutants to whitefly, jassid and pod borer at two locations

Variety/lines	% Infestation					
	Pod borer		Jassid		Whitfly	
	Ishurdi	Rangpur	Ishurdi	Rangpur	Ishurdi	Rangpur
BARI MOOG-6	15.38 a	5.78 ab	11.92 a	4.81 a	8.12 a	2.94 a
MBM477-60	10.12 b	6.22 ab	8.17 b	2.97 b	5.33 b	1.73 b
MBM-88	9.27 b	7.31 a	7.54 b	3.61 b	4.85 b	0.95 b
MBM-07-892	11.95 b	5.27 ab	9.05 b	5.50 a	6.07 ab	1.65 b
MBM-07-Y-1	12.23 b	4.18 b	3.94 c	2.33 b	9.06 a	2.08 a
Binamoog-5	8.74 c	4.98 ab	10.56 a	4.05 a	7.93 ab	2.01 a

Means in a column followed by same letter(s) are not differ significantly at 5% level by DMRT.

Evaluation of chickpea mutants/varieties for tolerance to cutworm and pod borer under field condition

Five mutants/strains of chickpea along with 3 check varieties were tested for their resistance to cutworm and pod borer (*Helicoverpa armigera*) during the rabi season of 2013-14 at BINA annex farm, Jamalpur and at farmers field, Godagari, Rajshahi. Randomized cmplete block design with three replication were followed for setting the experiments. No protective measure was taken and the plants were kept for natural infestation. Data on the pod borer infestation was recorded from 10 randomly selected plants/plot at harvest. Recorded data were statistically analyzed and presented in Table 5 and Table 6.

Table 5. % Plant Infested by Cutworm

Mutant/varieties	Rajshahi	Jamalpur	Irrespective to Location
CPM-BR-4-400	0.88	7.99	4.43
CPM-BR-7-300	0.00	4.43	2.22
CPM-860-200	0.95	6.04	3.49
CPM-860-300	2.67	6.13	4.39
CPM-860-400	1.90	8.54	5.22
Binasola-4	0.00	5.33	2.66
Binasola-5	2.23	6.77	4.50
Binasola-7	3.55	8.82	6.18

Means in a column followed by same letter(s) are not differ significantly at 5% level by DMRT.

Table 6. % Pod Infested by Pod Borer

Mutant/varieties	Rajshahi	Jamalpur	Irrespective to Location
CPM-BR-4-400	1.68	23.97	12.82
CPM-BR-7-300	3.15	49.12	26.13
CPM-860-200	2.71	36.22	19.47
CPM-860-300	3.39	24.78	14.09
CPM-860-400	3.77	23.04	13.41
Binasola-4	2.04	17.59	9.82
Binasola-5	1.46	33.46	17.46
Binasola-7	2.13	26.45	14.29

No significant difference was observed among the mutants/varieties against the cutworm and pod borer while the infestation was higher at Jamalpur than that of Rajshahi.

Evaluation of groundnut mutant/lines to major insect pests under field condition

Three mutant lines of groundnut with two check varieties, PK-1 and Dacca-1 were evaluated against jassid, cutworm, leaf roller and hairy caterpillar at BINA substation farm, Ishurdi. The experiment was laid out in a randomized complete block design with three replications. Data on number of jassids/cage were counted. Data on percentage of plant infested by cutworm, leaf roller were also collected and leaf area consumed by each larva of hairy caterpillar by transparent checker scale. All the data were analyzed statistically.

Table 7. Mean Infestation of groundnut mutants to cut-warm, jassid, leaf roller and hairy caterpillar

Variety/Mutant	Number of jassid/cage	% Plant infested by cutworm	% Leaf infested by leaf roller	Leaf area (mm2) consumed by hairy caterpillar
Gc(1)-24-1-1-1	4.46 c	5.89 c	1.86 c	14.21 c*
Gc(1)-32-3-1-1-1	3.23 c	4.94 c	1.66 c	13.18 c
Gc(1)-3-2-2-1	6.94 b	8.09 b	2.93 a	14.84 c
PK-1	13.24 a	11.78 a	2.46 ab	30.11 b
Dacca-1	12.57 a	11.03 a	2.60 ab	36.77 a

*Means in a column followed by same letter(s) are not different significantly at 5% level by DMRT.

Among the tested mutants and varieties of groundnut the mutants Gc (1)-24-1-1-1 and Gc (1)-32-3-1-1-1 showed significantly lowest infestation against all the insects (cutworm, jassid, leaf roller and hairy caterpillar) and the another mutant Gc (1)-3-2-2-1 was also lower infested by hairy caterpillar only than other varieties (Table 7). So, above mentioned two mutants may be moderately tolerant against tested insects.

Evaluation of advanced lines of soybean to cabbage looper, hairy caterpillar and pod borer under field condition

Four advanced mutant lines and two check varieties of soybean were evaluated against cabbage looper, hairy caterpillar and pod borer in the field at BINA H/Q farm Mymensingh. The experiment was laid out in a randomized block design with three replications. Data on percent plant infested by cabbage looper was taken. Data on leaf area consumed by hairy caterpillar were also measured by transparent checker scale and percentage of pod infested by pod borer was recorded from 10 randomly selected plants per plot after harvest.

All the tested mutants of soybean were found to be less infested by cabbage lopper, hairy caterpillar and pod borer than their check varieties (Binasoybean-1 and Binasoybean-5). On the other hand the lowest infested by cabbage lopper was observed in the mutants SBM-22. Though no significant difference were observed among the mutants/varietyes against cabbage lopper (Table 8).

Table 8. Mean infestation of soybean lines to cabbage lopper, hairy caterpillar and pod borer

Variety/mutants	Plant infested by cabbage lopper	Leaf area consumed by hairy caterpillar	Pod borer
SBM-9	3.34	21.54 b*	1.14 b
SBM-15	3.76	22.53 b	1.09 b
SBM-18	3.03	23.32 b	1.12 b
SBM-22	2.91	21.02 b	1.35 b
Binasoybean-1	4.28	29.52 a	2.96 a
Binasoybean-5	4.71	29.92 a	2.62 a

*Means in a column followed by same letter(s) are not different significantly at 5% level by DMRT.

Evaluation of advance sesame mutants for their resistance to major insect pests

Four mutants of sesame along with one check variety Binatil-2 were evaluated against hairy caterpillar, aphid and pod borer at BINA H/Q farm, Mymensingh. The experiments was laid out in a randomized block design with three replications. The unit plot size was 5m x 3m. Spacing between plant to plant and row to row were 5 cm and 25cm, respectively. The plants were exposed to natural infestation and no protective measures were taken. Data on no. of aphids/plant were collected from ten randomly selected plants per plot. Data on leaf area consumed by hairy caterpillar by transparent checker scale and that on percentage of pod infested by pod borer was taken from 10 randomly selected plants per plot after harvest. All the data were analyzed statistically.

The average attack by sesame pod borer was very low throughout the cropping season. However, all the mutants showed higher infested against all the tested insects (hairy caterpillar and pod borer) than the check variety Binatil-2 (Table 9). So this experiment will be repeated next year.

Table 9. Mean infestation of sesame mutants to hairy caterpillar, aphid and pod borer

Variety/mutants	Leaf area consumed by hairy caterpillar	No. of aphid/plant	Pod borer
SM-8	32.09 a	30.60 b	1.51 b
SM-9	31.47 a	25.60 c	1.78 b
SM-058	31.42 a	32.17 ab	3.38 a
SM-067	33.22 a	36.07 a	2.88 a
Binatil-2	24.90 b	21.67 c	0.47 c

*Means in a column followed by same letter(s) are not different significantly at 5% level by DMRT.

Evaluation of advanced mustard/rapseed mutants for their resistance to major insect pests under field condition

Four mutants of mustard along with two check varieties Binasharisha-4 and Tori-7 were evaluated against aphid and sawfly in the field at four locations (1) BINA H/Q farm, Mymensingh, BINA substation farm (2) Rangpur (3) Magura and (4) Comilla. The experiments were laid out in a randomized block design with three replications. The unit plot 4 m × 5 m. Spacing between plant to plant and row to row were 5 cm and 20 cm, respectively. The plants were exposed to natural infestation. No protective measures were taken against these pests. Data on no. of aphids/plant were recorded. Data on percentage of plant infested by aphid and sawfly were collected from 5 randomly selected lines per plot. All the data were analyzed statistically.

Significant differences were observed among the mustard mutants/varieties with respect to percent plant infested by aphids, No. of aphids per plant and percent plant infested by sawfly. The lowest infestation was observed in the mustard RC-9 followed by the mutants Rc-10 and the variety Binasharisha-4 against aphids and sawfly (Table 10, 11, 12) So the above mentioned two mutants and one variety may be regarded as less susceptible tolerant to aphid and sawfly.

Table 10. Mean infestation of mustards to aphid at Mymensingh, Comilla, Rangpur and Mugara

Varieties/Mutants	% Plant infested by aphid				
	Mymensingh	Comilla	Rangpur	Magura	Mean of locations
RC-9	2.06 a	1.46 c	2.50 d*	1.8 b	1.988
RC-10	1.60 b	2.16 c	2.70 d	1.8 b	2.067
MM-63	1.53 b	4.80 b	14.56 a	2.27 a	5.792
MM-64	2.20 a	6.13 a	15.23 a	2.87 a	6.608
Binasharisha-4	1.47 b	3.40 b	4.90 cd	2.07 a	2.967
Tori-7	1.53 b	4.36 b	7.96 b	2.20 a	4.017

*Means in a column followed by same letter(s) are not different significantly at 5% level by DMRT.

Table 11. Mean infestation of mustards mutants to sawfly at Mymensingh, Comilla, Rangpur and Mugara

Variety/Mutants	% Plant infested by sawfly				
	Mymensingh	Comilla	Rangpur	Magura	Mean of locations
RC-9	26.80	21.98	9.86	14.49	18.03 c*
RC-10	26.99	23.58	10.46	16.85	19.47 bc
MM-63	28.43	30.35	19.48	22.75	25.24 a
MM-64	31.01	31.59	21.04	23.46	26.78 a
Binasharisha-4	27.13	23.60	12.38	18.03	20.31 bc
Tori-7	28.34	28.94	17.21	20.30	23.70 ab

*Means in a column followed by same letter(s) are not different significantly at 5% level by DMRT.

Feeding responses of mustard aphid *Lipaphis crysimi (*Kalt) on mustard mutants

Three mutants of mustard along with one check variety Binasharisha-4 on the feeding responses of mustard aphid. For this purpose honey dew, droplets excreated by the aphid were collected in a feeding chamber consisted of an inverted transparent plastic cup. Para film was stretched over the base of inverted cup. Three 5th instar nymphs previously starved for 2 hours was released into the excised twinge of mustard plant. After the nymphs settled on, the twig was placed into the feeding chamber through a hole at the top of the cup. A cotton pad was then placed in the hole to prevent escape of the insect. The nymphs were allowed to feed for 24 hours. After 24 hours. The honey dew droplets were counted from the stretched Para film under binocular microscope at 6 x magnification. Thirty (30) feeding chamber were used for maintenance five replications for each treatment.

The mutant/variety showed significant differences in respect of excreted honeydew by aphid when feeding on mustard plant. The insect fed on the mutant 'RC-9' excreted lowest No. of honeydew droplets followed by the mutants RC-10, than other mutants/varieties (Table 13). So, these mutants may be less susceptible tolerant to aphid.

Table 12. Honey dew droplets of mustard aphid deposited in 24 hours

Mutants/varieties	No. of honey dew droplets
RC-9	5.67 d
RC-10	6.67 cd
MM-63	7.33 bc
MM-64	10.00 a
Binasharisha-4	7.33 bc
Tori-7	7.67 b

*Means in a column followed by same letter(s) are not different significantly at 5% level by DMRT.

Determination of effective radiation dose(s) for controlling pulse beetle (*Callosobruchus chinenesis*)

Eleven radiation doses (5, 10, 15, 20, 25, 30, 40, 50, 70, 90 and 110 Gy) were tested against pulse beetle (*Callosobruchus chinenesis*). The experiment was laid out in a completely randomized design with replications. Data were recorded timely on radiated pulse beetle and analyzed statistically.

Pulse beetle became highly sterile at 50, 70, 90, 110 Gy and not sterile at 5, 10, 15, 20, 25 Gy radiation and 20%, 30%, 40%, sterile at 30, 35, and 40Gy radiation doses.

The results showed that extracts of all the plant parts had very close efficacy in relation to direct toxicity effect and repellency. Table 14 and 15.

Table 13(a). Different radiation dose (s) for controlling pulse beetle

	Different radiation dose (s) Gy						
	5	10	15	20	25	30	35
Level of sterility	0%	0%	0%	0%	0%	20%	30%

Table 13(b). Different radiation dose (s) for controlling pulse beetle

	40	50	70	90	110
Level of sterility	40%	80%	80%	100%	100%

Management of brinjal shoot and fruit borer by using IPM packages

Brinjal shoot and fruit borer were managed in the farmer field using four method (a) Sanitation: weekly removal and destruction of pest damaged shoots and fruits from the field (b) Use of sex-pheromone (c) Application of bio-rational pesticide, Spinosad (Tracer 45 SC) and (d) Artificial release of bio-control agents (Bracon & Tricogramma). Data were recorded timely on brinjal shoot and fruit borer and analyzed statistically.

Three hundred seventy brinjal shoot and fruit borer were caught using ten pheromone traps in seven days.

Table 14. Brinjal shoot and fruit borer were caught using ten pheromone traps in seven days

Trap No.	Fruit fly catch/trap (No.) in different dates							
	1-7-14	4-7-14	8-7-14	12-7-14	16-7-14	20-7-14	24-7-14	Total
1	5	7	3	9	4	6	10	44
2	3	4	7	4	9	5	2	34
3	2	7	5	9	7	6	4	40
4	0	5	9	3	0	8	6	31
5	9	7	5	4	8	6	0	39
6	6	8	7	5	0	3	5	34
7	7	5	4	9	11	8	7	51
8	5	4	3	8	4	3	0	27
9	0	6	5	8	6	7	2	34
10	5	4	8	6	5	4	4	36
								Grand Total = 370

Toxicant and repellent effects of four plant extracts on pulse beetle (*Callosobruchus chinensis* (L)

Experiments were conducted in the laboratory of the Division of Entomology, Bangladesh Institute of Nuclear Agriculture, (BINA), Mymensingh to evaluate the efficacy of four indigenous plants parts such as leaves of raintree (*Albizia saman*), riot lata (*Mikania micrantha*). Pithraj (*Aphanamixis polystachya*) and seeds of mahogany (*Swietenia macrophlla)* with methanol extracts at the rates of 10.0, 7.5, 5.0 and 2.5% for their (1) direct toxicity and (2) Repellent action against the pulse beetle, *Callosobruchus chinensis* (L). The experiments were set up following Completely Randomized Design (CRD).

Table 15. Mean mortality percentages of pulse beetle by different plant extracts at different concentrations at different DAT

Plant Extract	Dose (%)	Mortality (%)		
		5 DAT	7 DAT	9 DAT
Riot lata (Mikania) leaf	10.0	93.33 ab	76.66 bc	66.66 ab
	7.5	86.66 cd	73.33 cd	63.33 bc
	5.0	76.66 ef	63.33 ef	50.00 de
	2.5	73.33 fg	60.00 ef	43.33 fg
	Control	0.00	0.00	0.00
Mahogani seed	10.0	86.66 cd	73.33 cd	63.33 bc
	7.5	80.00 de	66.66 de	56.33 cd
	5.0	70.00 fg	56.66 gh	46.66 ef
	2.5	60.00 hi	50.00 hi	36.66 gh
	Control	0.00	0.00	0.00
Pithraj leaf	10.0	96.66 a	83.33 a	70.00 a
	7.5	90.00 bc	76.66 bc	63.33 bc
	5.0	83.33 de	63.33 ef	53.33 de
	2.5	76.66 ef	60.00 ef	43.33 fg
	Control	0.00	0.00	0.00
Raintree leaf	10.0	80.33 de	70.00 cd	56.33 cd
	7.5	73.33 fg	54.44 hi	46.66 ef
	5.0	63.33 hi	50.00 hi	36.66 gh
	2.5	53.33 jk	43.33 jk	30.00 hi
	Control	0.00	0.00	0.00
Sx		2.02	1.80	1.60
Probability		0.05	0.05	0.01

DAT = Day's After Treatment.
Within column, values followed by different letter(s) are significantly different by DMRT.

Direct toxic effect

Significantly the highest mortality (96.66%) was observed in 10% concentration of pitraj leaf at 5DAT and the lowest mortality (30.00%) was observed in 2.5% concentration of raintree leaf extract at 9DAT (Table 14). The toxicity of different plant extracts were infested by different concentrations at different DAT.

Table 16. Repellent effects of different plant extracts at different concentrations at different HAT

Plant Extract	Dose (%)	Repellency rate (%)					Mean Repellency (%)
		1 HAT	2 HAT	3 HAT	4 HAT	5 HAT	
Riot lata leaf	10.0	58.00a	51.13b	51.13b	58.00b	58.00	45.02b
	7.5	44.46b	50.31b	44.66bc	51.23c	51.33	48.34c
	5.0	44.40b	38.00d	44.44bc	38.00d	44.44	41.85d
	2.5	31.13d	38.00d	31.31d	38.00d	38.00	35.28e
Mahogani seed	10.0	44.66d	51.13b	44.44b	51.13c	51.13	48.50c
	7.5	44.66b	38.00d	38.66b	38.00d	44.66	40.80d
	5.0	31.13d	38.00d	31.13d	38.00d	38.00	38.00e
	2.5	24.66e	31.13e	24.66de	31.13e	31.13	28.54f
Pithraj leaf	10.0	58.00a	64.66a	58.00a	64.66a	64.66	61.99
	7.5	56.00a	39.33b	49.33b	56.00	56.00	51.33b
	5.0	44.46b	51.13b	41.46bc	51.13e	51.13	47.86c
	2.5	38.00c	44.46c	44.46bc	38.00d	44.46	41.87d
Raintree leaf	10.0	31.13d	38.00d	31.13d	38.00d	38.00	35.25e
	7.5	24.66e	31.13e	24.66de	31.13e	31.13	28.54f
	5.0	18.00f	24.66f	18.00e	24.66f	24.66	21.99g
	2.5	16.00f	1034g	16.00c	10.32g	17.00	15.73h
Sx		1.85	1.96	2.18	1.74	1.76	1.52
Level of Significance		0.01	0.01	0.05	0.01	NS	0.01

HA T = Hours After Treatment.
Within column, values followed by different letter(s) are significantly different by DMRT.

Effect of plant extracts as repellent

The mean repellency rate of different plant extracts was found significant statistically except 5HAT. The highest mean repellency rate was found with 10% pitraj leaf extract (61.99%) followed by riot lata (Mikania) leaf extract, mahogany seed extract and raintree leaf extract (Table 15).

The effectiveness of all the plant extracts were found to increase with the increase of doses and decreased proportionately with the increase of time. Considering all the concentration and the effectiveness, the order of efficacy against pulse beetle was pitraj leaf > riot lata leaf (Mikania) > mahogany seed > raintree leaf. Research on the insecticidal activities of riot lata leaf (Mikania) and raintree leaf were not found before but on the basis of efficacy, riot lata leaf (Mikania) ranked 2nd and raintree leaf ranked 4th in the efficacy order.

PLANT PATHOLOGY DIVISION

RESEARCH HIGHLIGHTS

In rice five mutants/advanced lines RM (2)-40-3-1-3, RM (2)-40-3-1-7, RM (2)-40-4-2-4, RM (2)-50-2-1-1 and BINA GSR-3 were found to be moderately resistant to bacterial leaf blight during Aman season. However, 6 mutants/advanced lines and 7 advanced lines showed moderately resistant reaction to bacterial leaf blight during Boro season. BINA GSR-3 produced the highest grain yield in both the seasons.

For the experiment of eco-friendly management of bacterial leaf blight of rice the lowest disease severity and the highest grain yield (4.68 t ha^{-1}) were recorded in the treatments T_1 [Bleaching powder (2mg L^{-1}) + $ZnSO_4$ (2%)] and T_6 [Tetracycline (1g L^{-1})], respectively.

Three mutants (MM-63, MM-64 and MM-15) of mustard and the check variety Binasarisha-4 showed moderately resistant reaction to alternaria blight.

For integrated management of collar rot of soybean, combined application of bavistin, mustard oil cake and *Trichoderma* sp. was superior as it possessed the least disease incidence (6.7%).

Addition of Trichoderma suspension with household waste compost and municipal waste compost reduced the disease incidence of collar rot of tomato 40.0% and 46.7%, respectively. Therefore addition of Trichoderma suspension with waste compost could enhance the disease suppression ability of the compost.

Three onion mutants (BP_2/100/1, BP_2/100/2 and BP_2/100/12) and the check variety (BARI Piaj-2) showed tolerant reaction to purple blotch disease.

In the evaluation of the efficacy of different fungicides in controlling purple blotch disease of onion, the least disease incidence was found in Bavistin (78%) followed by Entracol (85%). Reduction of disease incidence over control was 22% by Bavistin and 13% by Entracol.

Eight mutants were evaluated against root rot and stemphylium blight at Magura. The mutants LM-28-2, LM-75-4, LM-123-7, LM-132, LM-156-1, LM-185-2, LGL-206 and LGL-803 were found moderately resistant to root rot. The mutants LM-28-2, LM-75-4, LM-123-7, LM-132, LM-156-1 and LGL-803 were found moderately resistant to stemphylium blight.

Eight different techniques of the application *Trichoderma* were tested for controlling sheath blight of rice. Reduction of disease over control was the highest (66.67%) in the treatment T_7 (Soil treatment with *Trichoderma* and its spray after 30, 50 and 70 days of transplanting).

RICE

Evaluation of some promising germplasm of rice for bacterial leaf blight and sheath blight resistance during aman season

Six mutants and seven advanced lines of rice along with four check varieties and one susceptible check variety were assessed for bacterial leaf blight (BLB) (*Xanthomonas oryzae* pv. *oryzae*) and sheath blight (ShB) (*Rhizoctonia solani*) resistance during aman season of 2013 under inoculated field condition. The experiment was conducted in a randomized block design with three replications at BINA farm, Mymensingh. The unit plot size was 2 m x 2 m. The spacing between lines and hills were 25 cm and 15 cm, respectively. The seedlings were transplanted on 2 August 2013. The fertilizers were applied as recommended doses. Ten hills in each plot were inoculated at the booting stage with *X. oryae* pv. *oryzae* by clipping method. For sheath blight, ten hills were inoculated in each plot with 7-days old *R. solani* previously grown on PDA at booting stage of plant growth. Plants were assessed for BLB and ShB severity after two and three weeks of inoculation, respectively following the scale developed at IRRI.

Mean BLB incidence and severity ranged from 60.0-100.0% and 2.2-7.7, respectively (Table 1). Four mutants and one advanced line were found to be moderately resistant and others were moderately susceptible to susceptible against BLB. Mean sheath blight incidence and severity ranged from 73.3-100.0% and 2.5 to 8.1 (Table 1). All the mutants and three advanced lines were found to be moderately susceptible to sheath blight. Grain yield ranged from 405.5 to 670.3 g m^{-2} and the highest grain yield was obtained from BINA GSR-3.

Table 1. Mean incidences and severities of bacterial leaf blight and sheath blight and grain yield of some mutants and advanced lines of rice during aman season of 2013 at Mymensingh

Mutant/variety	Bacterial leaf blight			Sheath blight			Grain yield (g m^{-2})
	Incidence (%)	Severity	DR	Incidence (%)	Severity	DR	
RM (2)-40-3-1-3	80.0	2.4	MR	100.0	5.5	MS	510.5
RM (2)-40-3-1-5	100.0	4.6	MS	76.7	4.4	MS	531.8
RM (2)-40-3-1-7	60.0	3.3	MR	83.3	4.4	MS	429.8
RM (2)-40-4-2-4	100.0	2.8	MR	100.0	3.9	MS	494.8
RM (2)-40-4-2-7	93.3	4.8	MS	86.7	4.7	MS	553.8
RM (2)-50-2-1-1	73.3	3.0	MR	100.0	4.8	MS	502.3
BINA Arom-8	100.0	7.0	S	100.0	7.9	HS	469.2
BINA Arom-9	80.0	4.5	MS	96.7	4.1	MS	517.0
BINA Arom-10	100.0	4.9	MS	100.0	4.7	MS	592.2
BINA E-1	86.7	6.6	S	100.0	6.7	S	490.8
BINA E-3	100.0	4.4	MS	100.0	5.0	MS	561.5
BINA GSR-1	100.0	5.7	MS	100.0	6.7	S	585.0
BINA GSR-3	93.3	2.6	MR	93.3	6.1	S	670.3
Binadhan-7	83.3	3.3	MR	86.7	4.4	MS	540.5
Binadhan-11	80.0	2.3	MR	100.0	4.4	MS	579.2
BRRI dhan38	76.7	4.3	MS	73.3	2.5	MR	638.7
BRRI dhan49	83.3	2.2	MR	96.7	3.9	MS	520.2
TN-1	100.0	7.7	HS	100.0	8.1	HS	405.5

DR = Disease reaction, MR = Moderately resistant, MS = Moderately susceptible, S = Susceptible and HS = Highly susceptible.

Evaluation of some promising germplasm of rice for bacterial leaf blight and sheath blight resistance during boro season

Fourteen advanced lines and one promising mutant of rice along with 4 check varieties were assessed for bacterial leaf blight (BLB) and sheath blight (ShB) resistance during boro season of 2013-14 under inoculated field condition. The experiments were conducted in a randomized block design with three replications at BINA farm, Mymensingh. The unit plot size was 3 m x 2 m. The spacing between lines and hills were 25 cm and 15 cm, respectively. The seedlings were transplanted on 9 February 2014. The fertilizers were applied at recommended doses. The method of inoculation and assessment of the disease were similar to the previous experiment of aman rice.

Mean bacterial leaf blight severity ranged from 2.5 to 5.8 (Table 2). The mutant RM (2)-40-1-1-10 and four advanced lines were found to be moderately resistant to BLB. All the germplasms in the inoculated condition produced sheath blight incidence more than 50%. Mean sheath blight severity ranged from 1.1 to 7.0. Seven advanced lines showed moderately resistant reaction to sheath blight. Mean grain yield ranged from 430.0 to 726.7 g m^{-2} and the highest grain yield obtained from BINA GSR-3 (Table 2).

Table 2. Mean incidences and severities of bacterial leaf blight and sheath blight and grain yield of some mutants and advanced line of rice during boro season of 2013-14 at Mymensingh

Mutant/variety	BLB		ShB			Grain yield
	Severity (0-9)	Disease Reaction	Disease Incidence (%)	Severity (0-9)	Disease Reaction	(g m^{-2})
RM (2)-40-1-1-10	3.4	MR	100.0	5.4	MS	695.0
RC (2)-2-4-1-2	3.1	MR	100.0	3.2	MR	550.0
RC (2)-2-4-1-4	2.5	MR	70.0	2.9	MR	640.0
RC (2)-2-4-3-1	3.4	MR	75.0	3.3	MR	603.3
BINA E-1	4.8	MS	83.3	6.3	S	630.0
BINA E-3	4.1	MS	100.0	6.6	S	650.0
BINA Arom-8	5.2	MS	80.0	4.6	MS	586.7
BINA Arom-9	3.6	MS	73.3	2.4	MR	610.0
BINA Arom-10	3.7	MS	63.3	3.0	MR	626.7
BINA GSR-1	3.8	MS	86.7	4.8	MS	650.0
BINA GSR-3	3.8	MS	90.0	4.3	MS	726.7
Nerica-1	3.0	MR	75.0	3.6	MS	536.7
BPP-10	4.3	MS	63.3	2.3	MR	683.3
BPP-20	5.4	MS	56.7	2.1	MR	456.7
BPP-40	3.1	MR	100.0	5.0	MS	481.7
BPP-50	3.7	MS	65.0	5.0	MS	670.0
Binadhan-5	4.1	MS	80.0	1.1	MR	650.0
Binadhan-10	4.2	MS	76.7	1.6	MR	586.7
BRRI dhan28	5.1	MS	100.0	6.7	S	613.3
BRRI dhan29	4.6	MS	83.3	5.1	MS	716.7
TN-1	5.8	S	100.0	7.0	S	430.0

MR = Moderately resistant, MS = Moderately susceptible and S = Susceptible

Eco-friendly management of bacterial leaf blight of rice

Bleaching powder, *Trichoderma* and antibiotics were used to assess the effects against bacterial leaf blight of rice during Aman season of 2013 at BINA farm Mymensingh. The treatments were: T_1 = Bleaching powder (2 mg L^{-1}) + $ZnSO_4$ (2%), T_2 = Cupravit (3 g L^{-1}), T_3 = Amoxyciline (1g L^{-1}) + Copper oxychloride, T_4 = *Trichoderma* suspension (10^7 cfu ml^{-1}), T_5 = Bleaching powder with irrigation water (2"), T_6 = Tetracycline (1g L^{-1}) and T_7 = Control. The experiment was conducted in RCBD with three replications. The unit plot size was 3 m x 2m and the spacing between lines and plants within lines were 25 cm and 15 cm, respectively. The recommended doses of fertilizers were applied and cultural practices were followed. The inoculation was done following clipping method at panicle initiation stage. All the treatments were sprayed at three split at 10 days interval starting from 3 days before inoculation. Plants were assessed for severity at 10 days after third spray following the scale developed at IRRI. The grain yield and agronomic parameters were recorded after harvest.

The mean disease incidence, per cent disease index (PDI) and grain yield significantly varied among the treatments (Table 3). The highest disease development was recorded in control plots where inoculation of pathogen was done and the lowest was recorded in the T_1 [Bleaching powder (2 mg L^{-1}) + $ZnSO_4$ (2%)] and T_6 [Tetracycline (1g L^{-1})] plots. The grain yield varied from 3.48 to 4.68 t ha^{-1}.

Table 3. Effects of antibiotics, bleaching powder and *Trichoderma* on bacterial leaf blight in aman rice (cv. Binadhan-7) during 2013 at Mymensingh

Treatments	Incidence (%)	PDI	Plant height (cm)	Number of tillar	Grain yield (t ha^{-1})	Yield increased over control (%)
T_1 = Bleaching powder + $ZnSO_4$ (2%)	53.2	28.1	93.5	7.6	4.53	30.27
T_2 = Cupravit	48.4	30.7	95.7	7.3	4.48	28.83
T_3 = Amoxyciline+ Copper oxychloride	48.4	32.4	93.9	7.3	4.12	18.30
T_4 = *Trichoderma* suspension	61.9	31.9	95.2	7.5	3.90	12.07
T_5 = Bleaching powder with irrigation water	47.6	34.1	97.2	8.3	4.53	30.27
T_6 = Tetracycline	37.3	28.9	94.2	7.8	4.68	34.58
T_7 = Control	90.5	52.6	92.9	7.3	3.48	--
LSD $_{(P \geq 0.05)}$	11.2	5.6	2.5	0.8	0.62	--

PDI = per cent disease index

GROUNDNUT

Field evaluation of advanced mutants of groundnut against foot and root rot and cercospora leaf spot

Five mutants along with two check varieties (Dacca-1 and Zhingabadam) of groundnut were evaluated for their resistance to foot and root rot (*Aspergillus niger*) and cercospora leaf spot (*Cercospora arachidicola*) diseases under artificial inoculated condition at Mymensingh and Jhinaidha during 2013-14. The experiments were conducted in a randomized complete block design with three replications.

The unit plot size was 2 m × 1.7 m at Mymensingh and 2m x 1m at Jhinaidah. Spacing between rows and plants within rows were 40 cm and 15 cm, respectively. Seeds were sown on 8 February, 2014 and 11 February, 2014 at Mymensingh and Jhinaidha, respectively. The disease severity was assessed following the scale 0-5 for foot and root rot and 0-9 for cercospora leaf spot.

For foot and root rot disease all the mutants and the check varieties were moderately susceptible at Mymensingh (Table 4). All the mutants along with the check varieties were susceptible to highly susceptible to the disease at Jhinaidha

In case of cercospora leaf spot disease the mutant D_1/20/17-1 and the check variety Zhingabadam were tolerant and the rest mutants/varieties were susceptible at Mymensingh (Table 5). At Jhinaidha only the mutant PK-1 was tolerant while the other mutants showed moderately resistant reaction to cercospora leaf spot disease.

Table 4. Disease reaction of mutants/varieties of groundnut to foot and root rot disease during 2013-14

Mutants/varieties	Mymensingh		Jhinaidha	
	Disease severity (0-5)	Disease reaction	Disease severity (0-5)	Disease reaction
PK-1	2.7	MS	4.3	S
RS/25/3-1	3.3	MS	5.0	HS
Zhingabadam	3.0	MS	4.8	HS
GC(1)-32-1-1-1	2.8	MS	5.0	HS
Dacca-1	3.2	MS	4.7	HS
GC(1)-24-1-1-2	3.1	MS	5.0	HS
D_1/20/17-1	2.7	MS	4.4	S

MS = Moderately susceptible, S = Susceptible, HS = Highly susceptible

Table 5. Disease reaction of mutants/varieties of groundnut to cercospora leaf spot disease during 2013-14

Mutants/varieties	Mymensingh		Jhinaidah	
	Disease severity (0-9)	Disease reaction	Disease Severity (0-9)	Disease reaction
Zhingabadam	4.4	T	3.2	MR
D_1/20/17-1	5.5	T	2.4	MR
RS/25/3-1	5.9	S	2.2	MR
GC(1)-24-1-1-2	5.9	S	2.3	MR
GC(1)-32-1-1-1	5.9	S	2.1	MR
Dacca-1	6.3	S	2.3	MR
PK-1	6.5	S	3.6	T

MR = Moderately resistant, T = Tolerant S = Susceptible

RAPESEED

Field evaluation of rapeseed mutants against alternaria blight

Eight rapeseed mutants along with two check varieties viz. Binasarisha-4 and Tori-7 were tested against alternaria blight (*Alternaria brassicae*) under natural condition at BINA sub-station farm, Magura and Rangpur during the winter season of 2013-14. The experiment was conducted in a randomized complete block design with three replications. The unit plot size was 2m × 2m. Seeds were sown on 16 November, 2013. The severity scale 0-5 was followed for assessing the disease at early pod maturity stage.

Among the mutants/varieties four (MM-63, MM-64, MM-15 and Binasarisha-4) showed moderately resistant reaction at both the location excluding Binasarisha-4 at Rangpur (Table 6). The variety Binasarisha-4 was graded as resistant at Rangpur. The mutant RC-5 was moderately susceptible in both locations while MM-51 and RC-8 were moderately resistant in Magura but moderately susceptible in Rangpur.

Table 6. Response of mutants/varieties of rapeseed to alternaria blight at Magura and Rangpur

Mutants/variety	Magura			Rangpur		
	Leaf area diseased (%)	Disease severity (0-5)	Disease reaction	Leaf area diseased (%)	Disease severity (0-5)	Disease reaction
Binasarisha-4	6.9	2.3	MR	5.6	1.7	R
MM-64	10.4	2.7	MR	7.3	2.3	MR
MM-63	11.0	2.3	MR	6.9	2.0	MR
RC-10	12.5	2.3	MR	15.7	1.7	R
MM-15	13.0	2.7	MR	7.5	2.5	MR
RC-8	13.0	2.3	MR	18.7	3.5	T
MM-51	13.3	2.7	MR	11.3	3.5	T
RC-9	14.6	2.7	MR	23.0	2.0	MR
RC-5	14.8	3.0	T	9.7	3.0	T
Tori-7	17.3	4.3	S	19.6	4.7	HS

R = Resistant, MR = Moderately resistant, T = Tolerant

TOMATO

Evaluation of municipal solid waste cum-*Trichoderma* against collar rot of tomato

An experiment was conducted to find out the effect of different waste composts along with Trichoderma against collar rot disease (*Sclerotium rolfsii*) of tomato at BINA substation farm, Magura during the winter season of 2013-14. The treatments as follows: T_1 = 4 Ton Municipal solid waste compost (MSWC), T_2 = 4 Ton House hold solid waste compost (HSWC), T_3 = 4 Ton MSWC + 50% NPK, T_4 = 4 Ton HSWC + 50% NPK, T_5 = MSWC + *Trichoderma* (150 ml), T_6 = HSCW + *Trichoderma* (150 ml), T_7 = 100% NPK and T_8 = Control. The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 4m × 3m. The seedlings of Binatomato-5 were transplanted on 15 November. Disease severity was measured following (1-9) scale.

Table 7. Disease incidence and severity of collar rot of tomato in response to different treatments at Magura during winter season of 2013-14

Treatments	Disease incidence (%)	Disease severity (1-9)	Disease reaction	Fruit yield (g/m^2)
T_1 = 4 Ton MSWC	53.3 bcd	2.9	MR	100 a
T_2 = 4 Ton HSWC	57.8 abc	3.7	T	81 d
T_3 = 4 Ton MSWC + 50% NPK	66.7 ab	5.0	T	99 ab
T_4 = 4 Ton HSWC + 50% NPK	71.1 a	4.4	T	79 d
T_5 = MSWC + *Trichoderma* (150 ml)	46.7 cd	2.6	MR	92 bc
T_6 = HSCW + *Trichoderma* (150 ml)	40.0 d	2.5	MR	79 d
T_7 = 100% NPK	64.4 ab	5.2	MS	89 c
T_8 = Control	73.3 a	6.0	MS	47 e

The highest disease incidence (73.3%) was recorded in control plots (Table 7). The least disease incidence (40.0%) was observed in the treatment of HSWC and *T. harzianum* (150 ml) following the treatment of MSWC and *T. harzianum* (150 ml) where disease incidence was recorded as 46.7%. When HSWC and MSWC was singly applied then the disease incidence was 57.8% and 53.3%, respectively. In combination of *Trichoderma* suspension with HSWC and MSWC the disease incidence reduced to 40.0% and 46.7%. Therefore, addition of *Trichoderma* suspension with waste compost could enhance the suppression ability of the compost. The highest fruit yield ($100g/m^2$) was obtained in the treatment T_1 (4 ton MSWC) followed by T_3 (4 ton MSWC + 50% NPK) ($99g/m^2$).

SOYBEAN

Integrated management of collar rot of soybean

Single and combined application of three integrated disease management components viz. cultural [(Mustard oil cake (MOC), chemical (Entracol, Dithane M-45 and Bavistin) and bio-agent (*Trichoderma* sp.)] along with control were assessed to find out a suitable strategy for the management of collar rot of soybean caused by *Sclerotium rolfsii*. The seeds of Binasoybean-2 were directly sown in rows on 20 December of 2013. The experiment was conducted in a randomized complete block design with three replications at farmer's field of Noakhali. The experiment contained eight treatments viz. (T_1) Entracol ($2g\ L^{-1}$), (T_2) Dithane M-45 ($4g\ L^{-1}$), (T_3) Bavistin ($2g\ L^{-1}$), (T_4) Mustard oil cake ($150g\ m^2$), (T_5) *Trichoderma* sp. ($65g\ m^2$) (T_6) Integration of Entracol + MOC+ *Trichoderma* sp. (T_7) Integration of Bavistin + MOC+ *Trichoderma* sp. and (T_8) Control (without treatment). Bio-agent was applied in rows before sowing. Entracol, Dithane M-45 and Bavistin were applied to the collar region of the soybean plants as fungicidal solution three days before inoculation. MOC powder was applied in the soil 3 days before sowing. The plants were inoculated with five day-old culture of *S. rolfsii* at the collar region. Weeding and irrigation were done as and when necessary. Data were taken at harvesting stage.

All of the treatments receiving one or more components of integrated control measure reduced disease incidence and severity of collar rot over control (Table 8). Combined application of bavistin, mustard oil cake and *Trichoderma* sp. (T_7) was considerably superior to the treatments in controlling the disease. The effectiveness of T_7 treatment possessed significantly the least disease incidence (6.7%). Combined application of Entracol + *Trichoderma* sp. + MOC ranked next to the former treatment.

Table 8. Effects of different treatments on collar rot of soybean during 2013-14 at Noakhali

Treatments	Disease incidence (%)	Disease severity (1-9)	Disease reaction
T_1= Entracol (2g L^{-1})	13.3 bcd	1.2	R
T_2= Dithane M-45 (4g L^{-1})	13.3 bcd	1.2	R
T_3= Bavistin (2g L^{-1})	20.0 b	1.8	MR
T_4= Mustard oil cake (MOC) (150 kg ha^{-1})	20.0 b	1.8	MR
T_5= *Trichoderma* sp. (65g m^2)	15.5 bc	1.4	R
T_6= Integration of Entracol + MOC+ *Trichoderma* sp.	11.1 cd	1.0	R
T_7= Integration of Bavistin + MOC+ *Trichoderma* sp.	6.7 d	0.6	R
T_8= Control	55.5 a	5.0	T

R = Resistant, MR = Moderately resistant, T = Tolerant

The untreated control treatment developed considerably the highest disease incidence (55.5 %) and severity (5.0). All the treatments excluding single application of Bavistin, MOC and control showed resistant reaction whereas Bavistin and MOC showed moderately resistant and control exhibited tolerant reaction to the disease.

SESAME

Evaluation of some advanced mutants of sesame against root rot

Six mutants of sesame were assessed against root rot (*Sclerotium rolfsii*) at Mymensingh and Rangpur during the summer season of 2014 under natural field condition. The experiments were conducted in a randomized complete block design with three replications. The incidence and severity of root rot were recorded at maximum pod maturity stage following (0-5) scale.

Table 9. Disease reaction of six mutants and two check varieties of sesame to root rot in Mymensingh and Rangpur during 2013-14

Mutants/varieties	Mymensingh			Rangpur		
	Disease incidence (%)	Disease severity (0-5)	Disease reaction	Disease incidence (%)	Disease severity (0-5)	Disease reaction
Binatil-2	6.5	3.2	MS	48.4	4.5	HS
SM-Black	17.7	3.7	S	20.3	4.4	HS
SM-067	13.2	3.7	S	40.2	4.4	S
SM-White	13.1	3.8	S	24.0	4.4	S
SM-058	17.6	3.9	S	50.1	4.9	S
Binatil-1	22.4	3.7	S	26.6	4.4	HS
SM-8	24.3	4.9	S	38.3	4.4	S
SM-9	28.6	4.1	S	41.3	4.4	S

S = Susceptible, MS = Moderately susceptible, HS = Highly susceptible

The mean disease incidence of root rot ranged from 6.5-28.6% and 20.3-50.1% at Mymensingh and Rangpur, respectively (Table 9). All the mutants and varieties showed susceptible to highly susceptible reaction to root rot at Mymensingh and Rangpur excluding Binatil-2 at Mymensingh. The variety Binatil-2 showed moderately susceptible reaction to the disease.

ONION

Evaluation of onion mutants against purple blotch disease

Four mutants (BP_2/75/2, BP_2/100/1, BP_2/100/2, and BP_2/100/12) along with two check varieties (Baripiaj-2 and Baripiaj-3) were evaluated against purple blotch disease (*Alternaria porri*) under natural field condition during winter season of 2013-14. The experiment was conducted at BINA farm, Mymensingh. The experiment was laid out in randomized complete block design with three replications. Unit plot size was 1.0 m × 1.0 m. Spacing was line to line 20 cm and plant to plant 15 cm. Transplanting was done on 12 December 2013. Fertilizers were applied @ Cowdung: 10 $tonha^{-1}$, Urea: 260 $kgha^{-1}$, TSP: 200 $kgha^{-1}$, MP: 150 $kgha^{-1}$, Gypsum: 110 $kgha^{-1}$ .The disease incidence and severity was assessed following (0-5) scale (Sharma, 1986). Three mutants (BP_2/100/1, BP_2/100/2 and BP_2/100/12) and the check variety (Baripiaj-2) showed tolerant reaction to purple blotch disease (Table 10). The mutant (BP_2/75/3) and the check variety (Baripiaj-3) were susceptible to the disease.

Table 10. Disease reaction of four mutants and two check varieties of onion to purple blotch in Mymensingh during winter season of 2013-14

Mutants/varieties	Disease incidence (%)	Disease severity (0-5)	Disease reaction
BP_2/75/2	100	3	S
BP_2/100/1	100	4	T
BP_2/100/2	100	3	T
BP_2/100/12	100	3	T
Baripiaj-2	100	4	T
Baripiaj-3	100	4	S

T = Tolerant, S = Susceptible

Efficacy of different fungicides in controlling purple blotch of onion

An experiment was conducted in the field of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during winter season of 2013-14. The experiment was conducted in RCBD (Randomized Complete Block Design) having three replications. The individual size of the plot was 1m × 1m. Spacing was line to line 20 cm and plant to plant 15 cm. The treatments were as follows: (1) Rovral (@ $2g/L^{-1}$), (2) Nativo (@ $0.4g/L^{-1}$), (3) Mancosil (@ $2g/L^{-1}$), (4) Entracol (@ $2g/L^{-1}$), (5) Bavistin (@ $2g/L^{-1}$), Biofungicide (*Trichoderma* based) and (7) Control. Transplanting was done on 22 December 2013. Fertilizers were applied @ Cowdung: 10 ton ha^{-1}, Urea: 260 kg ha^{-1}, TSP: 200 kg ha^{-1}, MP: 150 kg ha^{-1}, Gypsum: 110 kg ha^{-1}. Suspension of *Trichoderma harzianum* (10^{-6} spore/ml) was used as biofungicide. Spray of each fungicide was done for three times at 10 days interval starting from thirty DAT. The disease incidence and severity was assessed following (0-5) scale (Sharma, 1986) at 30DAT, 60DAT and 80 DAT.

Table 11. Effect of different fungicides on disease incidence and severity of purple blotch of onion

Treatments	30 DAT		60 DAT		80 DAT	
	Disease Incidence (%)	Disease severity	Disease Incidence (%)	Disease severity	Disease Incidence (%)	Disease severity
Rovral	27	1	79	2	87	3
Nativo	47	1	84	2	100	4
Mancosil	64	1	83	2	100	4
Entracol	45	1	74	2	85	3
Bavistin	17	1	71	2	78	3
Biofungicide	31	1	76	2	87	4
Control	64	2	94	3	100	5
LSD (P≥0.05)	10.8	-	11.5	-	12.6	-

The least disease incidence (78%) at 80 DAT was found in the application of Bavistin followed by Entracol (85%). Reduction of disease incidence by Bavistin was 22% followed by Entracol (13%) over control (Table 11). The same trend was followed at 60 DAT i.e. the least disease incidence (71%) was found in Bavistin followed by Entracol (76%). At 60 DAT the disease reduction was 24% for Bavistin and for Entracol the disease reduction was (21%) over control. The biofungicide had (19%) and (13%) disease reduction over control at 60 DAT and 80 DAT. The fungicide Rovral showed (16%) and (13%) disease reduction over control at 60 DAT and 80 DAT.

LENTIL

Evaluation of lentil mutants against root rot and stemphylium blight

Eight advanced mutants along with three check varieties of lentil were evaluated against root rot (*Fusarium* sp.) and stemphylium blight (*Stemphylium sarciniformis*) at Magura during the winter season of 2013-14 under inoculated condition. The experiments were conducted in randomized complete block design with three replications. The seeds were sown in rows on 30 November, 2013. Distances between rows and seed were 30 cm and 5-6 cm, respectively.

Table 12. Diseases reaction of root rot and incidence and severity of stemphylium blight on some mutants of lentil at Magura

Mutants/varieties	Root rot		Stemphylium blight			
	DI (%)	DR	DI (%)	DS (0-5 scale)	DR	Grain wt. (g/m^2)
LM-28-2	8.4		37.4	2	MR	103.5
LM-75-4	8.6		38.3	2	MR	115.2
LM-123-7	8.8		27.5	2	MR	107.1
LM-132	22.3		25.9	2	MR	95.3
LM-156-1	9.6		30.7	2	MR	90.1
LM-185-2	18.3	MR	44.38	3	MS	111.1
LGL-206	20.3		35.1	3	MS	74.9
LGL-803	11.9		27.2	2	MR	91.0
Binamashur-2	16.4		47.3	3	MS	77.8
Binamashur-5	7.9		19.9	2	MR	59.8
Binamashur-6	9.1		30.3	2	MR	126.2
LSD $_{(P\geq0.05)}$	10.7	-	12.3	0.8	-	25.5

MR = Moderately Resistance, MS = Moderately Susceptible, DR= Disease reaction
DI =Disease Incidence, DS = Disease severity

The mean incidence of root rot and stemphylium blight ranged from 7.9-22.3% and 19.9-47.3%, respectively. All the mutants were found moderately resistant to root rot (Table 12). The mean severity of stemphylium blight ranged from 2-3. The mutants LM-28-2, LM-75-4, LM-123-7, LM-132, LM-156-1 and LGL-803 were found moderately resistant to stemphylium blight and the rest were moderately susceptible. Grain weight 115.2 (g/m^2) was the highest in LM-75-4.

Biological control of sheath blight of rice

Effect of different application techniques of *Trichoderma* sp. for controlling sheath blight of rice

An experiment was done at three locations of Magura, Rangpur and Mymensingh to evaluate application techniques of *Trichoderma* for controlling sheath blight (*Rhizoctonia solani*) of rice during Aman season, 2013-14. The experiment contained eight treatments viz.

T_1 = Seed treatment with *Trichoderma*
T_2 = Seedling treatment with *Trichoderma*
T_3 = Soil treatment with *Trichoderma*
T_4 = Seedling treatment with *Trichoderma* and its spray after 30 days of transplanting
T_5 = Seedling treatment with *Trichoderma* and its spray after 30 and 50 days of transplanting
T_6 = Seedling treatment with *Trichoderma* and its spray after 30, 50 and 70 days of transplanting
T_7 = Soil treatment with *Trichoderma* and its spray after 30, 50 and 70 days of transplanting
T_8 = Control (without *Trichoderma*)

The experiment was conducted in a randomized block design with three replications. Replication to replication distance was 1m. The unit plots size, row to row and plant to plant distance were 2m × 1m, 30cm and 15cm, respectively. The seedlings were transplanted on 17 August, 25 August and 19 August 2013 at Magura, Rangpur and Mymensingh, respectively.

The incidence of sheath blight among the treatments at different locations were significantly different. The incidence ranged from 23.47-87.61%, 17.61-98.09% and 44.75-97.62% at Magura, Rangpur and Mymensingh, respectively. The mean incidence ranged from 26.19-94.27%. The lowest incidence was found in the treatment T_7 (26.19%) and the highest was in control (94.27%). The mean incidence was decreased (72.21%) in the treatment T_7 over control (Table 13).

The severity of sheath blight among the treatments at different locations were significantly different. The severity ranged from 3-7, 3-9 and 1-7 at Magura, Rangpur and Mymensingh, respectively (Table 14). The mean severity ranged from 3-9. The lowest mean severity was found in the treatment T_7 and the highest was in control. Mean severity decreased 66.67% in the treatment T_7 over control. The highest grain weight (662.3 g/m^2) and the lowest grain weight (519.4 g/m^2) were found in the treatment T_7 and control, respectively. The maximum increased of grain weight (27.51%) was found in the treatment T_7.

Table 13. Effect of different application techniques of *Trichoderma* on sheath blight incidence

Treatments	Disease Incidence (%)				
	Magura	Rangpur	Mymensingh	Mean	Incidence decreased over control (%)
T_1	64.18	27.13	70.95	54.09	42.62
T_2	68.08	32.85	73.79	58.24	38.22
T_3	63.59	22.85	57.14	47.86	49.23
T_4	67.86	46.67	59.04	57.86	38.62
T_5	29.62	27.14	62.37	39.71	33.94
T_6	31.9	25.71	70.47	42.69	54.47
T_7	23.47	17.61	44.75	26.19	72.21
T_8	87.61	98.09	97.62	94.27	-
$LSD_{0.05}$	5.91	5.15	12.12	12.50	-

T_1 = Seed treatment with *Trichoderma*
T_2 = Seedling treatment with *Trichoderma*
T_3 = Soil treatment with *Trichoderma*
T_4 = Seedling treatment with *Trichoderma* and its spray after 30 days of transplanting
T_5 = Seedling treatment with *Trichoderma* and its spray after 30 and 50 days of transplanting
T_6 = Seedling treatment with *Trichoderma* and its spray after 30, 50 and 70 days of transplanting
T_7 = Soil treatment with *Trichoderma* and its spray after 30, 50 and 70 days of transplanting
T_8 = Control (without *Trichoderma*)

Table 14. Effect of different application techniques of *Trichoderma* on sheath blight severity and yield of rice

Treatments	Disease Severity (0-9)					
	Magura	Rangpur	Mymensingh	Mean	Severity decreased over control (%)	Yield g/m^2
T_1	5	5	5	5	44.44	606.7
T_2	3	5	3	5	44.44	552.7
T_3	5	3	3	5	44.44	630.5
T_4	5	5	3	5	44.44	523.2
T_5	3	5	3	5	44.44	552.8
T_6	3	5	3	5	44.44	632.2
T_7	3	3	1	3	66.67	662.3
T_8	7	9	7	9	-	519.4
$LSD_{0.05}$	1.5	1.7	-	1.9	-	25.5

T_1 = Seed treatment with *Trichoderma*
T_2 = Seedling treatment with *Trichoderma*
T_3 = Soil treatment with *Trichoderma*
T_4 = Seedling treatment with *Trichoderma* and spray its after 30 days of transplanting
T_5 = Seedling treatment with *Trichoderma* and spray its after 30 and 50 days of transplanting
T_6 = Seedling treatment with *Trichoderma* and spray its after 30, 50 and 70 days of transplanting
T_7 = Soil treatment with *Trichoderma* and spray its after 30, 50 and 70 days of transplanting
T_8 = Control (without *Trichoderma*)

AGRICULTURAL ENGINEERING DIVISION

RESEARCH HIGHLIGHTS

It is revealed that irrigation at pre-vegetative, vegetative, bulb formation and flowering stages (up to field capacity) are required for optimum seed yield of Onion mutants. The onion mutants Bp2/75/2 produced the highest seed yield.

The sensitiveness of Binatil-3 to water-logging is: vegetative stage>flowering stage>pod formation stage.

Under the prevailing climatic condition of Magura, the highest seed yield and water productivity of Mungbean can be obtained with one irrigation at flowering stage, in addition to pre-sowing irrigation.

The groundwater of BINA Head Quarter and sub-stations are found within the permissible limit for irrigation.

Block farming were carried out for Karif-2 (Binadhan-7), Rabi and Kharif-1 crops in Nachole and Gomostapur upazilla of Chapai Nawabganj district. Binadhan-7 produced average grain yield of 4.01 t ha^{-1} and maturity duration was 122 days. Farmers were very much interested for Binadhan-7 due to its short duration, which facilitated water saving and profitable Rabi crop cultivation in proper time.

In Rabi, average yield of wheat, mustard and chickpea were 3.23 t ha^{-1}, 1.41 t ha^{-1} and 1.15 t ha^{-1} respectively. It was also found that wheat and mustard needed two irrigations while chickpea needed one light supplemental irrigation. Moreover, it was observed that these 3 Rabi crops were harvested by the end of March and easily allowing time for the next successive Kharif-1 crops mungbean and sesame.

Based on water resources, a year round cropping sequence was developed for Magura and Mymensingh.

In Mymensingh, the best cropping pattern was selected as T. aman-Mustard-Boro in terms of rice equivalent yield (REY, 15.35 t ha^{-1}). This pattern along with the best water management practice saved 5% water compared to farmers existing pattern (T. aman-Fallow-Boro) which produced REY of 10.91 t ha^{-1}.

In Magura, the best cropping pattern was selected as T. aman-Lentil-Sesame in terms of rice equivalent yield (22.49 t ha^{-1}). This pattern along with the best water management practice saved 44% water compared to farmers existing pattern (T. aman-Fallow-Boro) which produced REY of 11.67 t ha^{-1}.

WATER REQUIREMENT AND IRRIGATION SCHEDULING OF DIFFERENT CROPS IN DIFFERENT CROPPING SYSTEMS

This is an on-going project. The objectives are to determine the irrigation requirement, water requirement and water productivity of different crop mutants/varieties developed by BINA in different AEZ, to find out the suitable cropping pattern depending on available water resource under abundant or deficit water supply, and to study the effect of water-logging for crops to be grown in low-lying areas or of sensitive in nature.
This year, irrigation management for Onion, Sesame and Mungbean were investigated.

Irrigation management for optimizing onion seed production

Objective

The experiment was aimed to determine the optimum water requirement for maximum seed production of onion mutants developed by BINA.

Methods

Fifty days old seedling of four mutants Bp2/100/1, Bp2/100/2, Bp2/75/2, Bp2/100/12 and one cheek variety Baripiaj2 were transplanted at Lysimeter of BINA farm, Mymensingh on 4th December 2013. The experimental design was RCBD having irrigation treatments in the main plots and onion mutants/ varieties in sub-plots. The irrigation treatment were: T_1 = Irrigation at pre-vegetative stage (15-20 DAT) up to field capacity, T_2 = Irrigation at pre-vegetative and vegetative stage (45-50 DAT), T_3 = Irrigation at pre-vegetative, vegetative stage, and bulb formation stage (65 DAT), T_4 = Irrigation at pre-vegetative, vegetative, bulb formation, and flowering stage (95 DAT) and T_5 = Irrigation at pre-vegetative, vegetative, bulb formation, pre-flowering, and late flowering stage (115 DAT) up to field capacity. Soil moisture was measured by Neutron Moisture Meter (NMM) up to 90 cm having 15 cm intervals at the time of transplanting, before irrigation and at harvest. Other cultural practices were followed as and when necessary. Onion seed were harvested on 5th May 2014.

Results

Irrigation treatments showed significant effect on plant height, and cultivars showed significant effect on all yield attributes and seed yield of onion (Table 1).

Table 1. Mean effect of irrigation and cultivars on seed yield and yield attributing characters of onion

Treatments/ variety	Plant height cm	Plants with flower (% of total plants)	Diameter of bulb (cm)	Bulb yield (tha^{-1})	Seed yield (gmm^{-2})
T_1	70.84	90.00	3.46	6.79	48.44
T_2	65.28	78.57	3.12	8.14	40.49
T_3	72.98	89.29	3.50	8.98	57.83
T_4	74.44	95.00	3.43	7.23	76.98
T_5	76.28	92.14	3.50	9.25	68.09
$LSD_{0.01}$	10.01	NS	NS	NS	NS
Bp2/100/1	70.80	92.14	3.37	5.89	61.35
Bp2/100/2	72.58	95.00	3.15	6.79	66.20
Bp2/75/2	73.18	95.71	3.34	6.81	73.93
Bp2/100/12	71.82	93.57	3.21	7.23	61.12
Baripiaj2	71.44	68.57	3.94	13.69	29.19
$LSD_{0.01}$	NS	17.79	0.51	2.40	20.6

The highest seed yield was obtained from T_4 treatment (76.98 gm/m^2) which received four irrigations (total 11.06 cm), and all the mutants produced significant higher seed yield than Baripiaj2. The highest seed yield was found in Bp2/75/2 mutant (73.93gm/m^2). The highest water productivity was found in T_4 treatment (33.95 kg ha^{-1} cm^{-1}) (Table 2).

Table 2. Water requirement and water productivity of onion for seed production

Treatments	No. of irrigation	Irrigation water (cm)	Effective rainfall (cm)	Total water used (cm)	Seed yield (kgha^{-1})	Water productivity (kg ha^{-1} cm^{-1})
T_1	1	3.66	11.6	15.3	484.4	31.7
T_2	2	6.21	11.6	17.8	404.9	22.7
T_3	3	8.12	11.6	19.7	578.3	29.3
T_4	4	11.06	11.6	22.7	769.4	33.9
T_5	5	12.10	11.6	23.7	680.9	28.7

Conclusion

From the present results, it is revealed that irrigation at pre-vegetative, vegetative, bulb formation and flowering stages up to field capacity are required for optimum seed yield of onion at Mymensingh. The onion mutants produced higher seed yield than Baripiaj2. To confirm the result, the experiment will be repeated during the next season.

Response of sesame to water-logging

Objective

The experiment was aimed to determine the water-logging response and critical stage(s) of sesame mutant (developed by BINA) with respect to water-logging.

Methods

The experiment was conducted at the farm of BINA Head-quarter. The experimental design was RCBD. The water-logging treatments were: T_1 = Control (no water-logging), T_2 = Water-logging for 24 hours at vegetative stage, T_3 = Water-logging for 24 hours at flowering stage, and T_4 = Water-logging for 24 hours at pod formation stage. Sesame seeds were sown on 20th March 2014. Water-logging was imposed as per treatments. Other cultural practices were followed as and when necessary. The crop was harvested on 9th June, 2014. All agronomic data were collected at harvest time.

Results

The lowest yield was obtained when water-logging was imposed at vegetative stage followed by water-logging at flowering stage (Table 3). The straw yield also followed similar trend. The root weight per plant at harvest (oven-dried at 60 ^{0}C for 12 hrs) also indicated similar trend of sensitivity to water-logging (i.e. vegetative stage>flowering stage>pod formation stage) (Fig. 1).

A more elaborate scheme of water-logging (different duration of water-logging at different growth stages) experiment will be under-taken for testing during the coming year.

Conclusion

From the present results, the sensitiveness of the sesame mutant to water-logging is: vegetative stage>flowering stage>pod formation stage.

Table 3. Yield and yield attributes of sesame as affected by water-logging treatments

Treatment	Plant height (cm)	No. of Branch/plant (Nos.)	No. of pod/plant (Nos.)	Pod length (cm)	No. of seed/pod	1000-seed weight (g)	Seed yield (kgha^{-1})	Straw yield (kgha^{-1})
T_1	98.5	2.1	35.1	2.3	49.3	2.97	725.7	1749.7
T_2	87.1	2.4	23.9	1.9	54.1	3.08	560.3	1194.3
T_3	88.5	2.3	27.3	2.0	54.7	3.26	663.7	1277.7
T_4	89.5	2.1	35.4	2.1	60.6	3.09	723.7	1533.3
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS

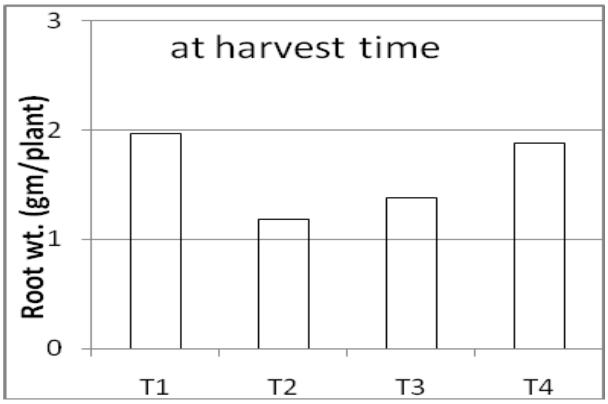


Fig. 1. Root weight of sesame at harvest as affected by water logging

Determination of optimum water requirement of BINA developed summer mungbean variety Binamoog-8

Objective

The objective of this experiment was to evaluate the yield response of Binamoog-8 under different irrigation regimes and to suggest appropriate irrigation schedule.

Methods

The experiment was conducted at BINA sub-station, Magura. The treatments were: T_1 = One irrigation at vegetative stage, T_2 = One irrigation at flowering stage, T_3 = irrigation at vegetative and flowering stages. The seeds were sown on 1st April, 2014. Pre-sowing irrigation (~ 5.0 cm) was applied to ensure proper germination. Soil moisture was recorded at sowing time, before and after irrigation, and at harvest time of crop. All the cultural practices were followed as and when necessary. The distribution of rainfall during the crop growing season is depicted in Fig.2. The crop was harvested on 1st June, 2014.

Results

Effects of irrigation on the yield and yield attributing characters of mungbean are shown in Table 4. Irrigation treatments did not show significant effect except the plant height. The highest seed yield (1062.3 kg ha^{-1}) was obtained under the treatment T_2 (irrigation at flowering stage), followed by T_3 (irrigation at vegetative and flowering stage). Two irrigations applied at vegetative and flowering stage did not increase yield rather it decreased. The amount of irrigation water requirement and irrigation water productivity of mungbean are shown in Table 5. The irrigation water productivity was the highest in T_2 treatment.

Table 4. Mean yield and yield attributing characters of mungbean (Binamoog-8) at Magura sub-station

Treatments	Plant height (cm)	No. of pod/plant	Pod length (cm)	No. of seed/pod	1000-seed wt. (g)	Seed yield (t ha^{-1})
T_1	36.47	21.13	8.37	10.67	42.09	893.67
T_2	33.70	21.73	8.20	10.20	47.07	1062.33
T_3	43.70	19.40	8.52	9.47	42.27	1027.67
$LSD_{(0.05)}$	3.67	Ns	NS	NS	NS	NS

Table 5. Water requirement and irrigation water productivity of Mungbean (Binamoog-8) at Magura sub-station

Treatments	Irrigation water, IR (cm)	Seasonal soil moisture depletion, ΔS (cm)	Water requirement, IR + ΔS + PSI (cm)	Yield (kg. ha^{-1})	Irrigation water productivity (kg.ha^{-1}.cm^{-1})
T_1	3	6.72	14.72	893. 7	111.7
T_2	3	5.49	13.49	1062.3	132.8
T_3	6	1.55	13.55	1027.7	93.4

PSI = pre-sowing irrigation by 5.0 cm

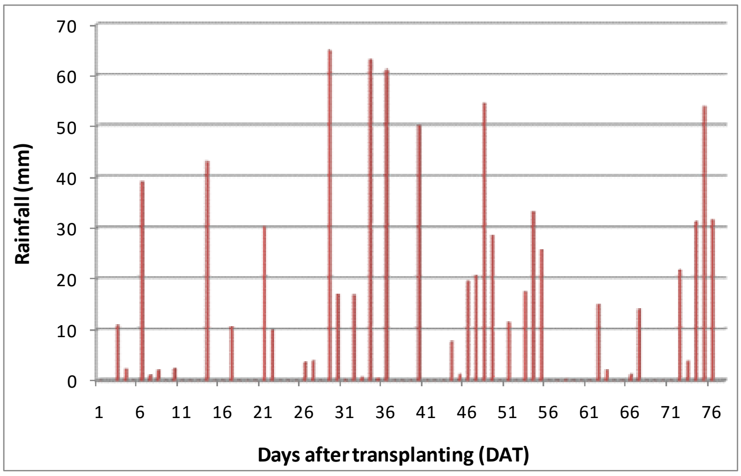


Fig. 2. Rainfall amount during the growing season of mungbean

Conclusion

Under the prevailing climatic condition, the highest seed yield and water productivity of mungbean at Magura substation can be obtained with one irrigation at flowering stage, in addition to pre-sowing irrigation.

STUDIES ON GROUNDWATER FOR ITS SUSTAINABLE USE IN IRRIGATION

This is an on-going project. Water quality aspects (mainly for irrigation) from different sub-stations (STW, DTW, canal water, etc.) have been monitored over time to observe the seasonal as well as long-term changes. This year, water quality of new sub-stations of BINA are observed for its sustainable use in agriculture.

Studies on the surface and groundwater quality for irrigation suitability

Objective

The study was conducted to determine the surface and groundwater quality at BINA sub-stations, specially the new ones.

Methods

The water samples were collected in June, 2014, to observe the seasonal effects on the water quality due to the irrigation pumping, monsoon recharge and agricultural practices. Different water quality parameters such as EC, pH, CO_3^{--}, HCO_3^{-} and Cl^- were analyzed.

Results

The quality parameters for the period 2013-14 at different locations are presented in Table 6. The CO_3^{--} was not detected anywhere. Results showed that the parameters are within the permissible limit for irrigation.

Table 6. Water quality parameters at different locations (during June, 2014)

Location	Source	Parameters				
		EC (dSm^{-1})	pH	CO_3^{--}	HCO_3^- (mgl^{-1})	Cl^- (mgl^{-1})
BINA, Mymensingh	DTW	0.37	7.02	NIL	1.88	2.00
	HTW	0.32	7.74	NIL	2.25	2.00
BINA Sub-station, Magura	SDTW	0.64	6.93	NIL	3.37	2.00
	HTW	0.63	7.00	NIL	3.25	3.00
Horticulture, Magura	HTW	0.59	7.13	NIL	3.00	2.75
Sub-station Comilla	SDTW	0.26	7.10	NIL	1.50	1.00
BRRI Commilla	DTW	0.23	7.08	NIL	1.25	0.50
Barisal, SRDI	DTW	0.99	7.65	NIL	3.25	3.60
Barisal, ATI	DTW	1.02	7.70	NIL	2.50	5.00
Barisal, Horticulture	DTW	2.58	7.41	NIL	3.75	6.50
Barisal, BARI	DTW	0.96	7.71	NIL	2.25	1.50
BINA Sub-station, Chapinoabgonj	DTW	0.91	7.13	NIL	3.00	0.62

Table 6 Contd.

Location	Source	Parameters				
		EC (dSm^{-1})	pH	CO_3^{--}	HCO_3^- (mgl^{-1})	Cl^- (mgl^{-1})
Chapinoabgonj, Horticulture	DTW	0.72	7.26	NIL	3.50	0.50
BINA Sub-station Chapinoabgonj	Pond	0.22	7.34	NIL	3.75	4.00
BINA Sub-station, Noakhali	Pond	0.59	7.44	NIL	1.12	0.50
Noakhali, Alamin group	DTW	0.50	7.40	NIL	1.75	0.50
Noakhali, Bhuyar Hat	HTW	0.51	7.40	NIL	2.50	0.25
Noakhali	River	0.57	7.48	NIL	1.13	2.00
BINA Sub-station, Sherpur	DTW	0.35	6.84	NIL	1.63	2.50
BINA Sub-station, Sherpur	STW	0.27	7.23	NIL	1.13	2.25
BINA Sub-station, Sherpur	Pond	0.21	7.32	NIL	1.63	0.25
BINA Sub-station, Gopalgonj field	DTW	1.01	7.22	NIL	4.50	1.00
BINA Sub-station, Gopalgonj Office	DTW	0.84	7.22	NIL	3.50	5.25
BINA Sub-station, Gopalgonj O.Q	STW	0.92	7.37	NIL	4.25	5.50
BINA Sub-station, Gopalgonj S.Q	STW	0.94	7.38	NIL	4.00	1.00
Gopalgonj filling station	HTW	0.78	7.21	NIL	4.25	1.63
Sub-station Satkhira,	Pond	1.82	7.02	NIL	2.25	3.50
Sub-station Satkhira, Office	STW	1.75	7.31	NIL	2.25	5.75
Sub-station Satkhira, O.Q.	STW	1.72	7.43	NIL	3.75	4.00
Satkhira	River	2.44	7.66	NIL	2.50	1.37
Satkhira, BARI	STW	0.75	7.03	NIL	4.75	3.25
Satkhira, BRRI	STW	1.16	7.04	NIL	5.00	4.25
FAO standard for irrigation		< 3 dSm^{-1}	6.5- 8.4		< 457 mgl^{-1}	As SAR<10
GOB standard for irrigation		< 1.2 dSm^{-1}	6 - 8.5		< 200 mgl^{-1}	< 600 mgl^{-1}

Conclusion

The groundwater of BINA sub-stations are within the permissible limit for irrigation.

UP-SCALING OF WATER MANAGEMENT PRACTICES FOR INCREASING CROP WATER PRODUCTIVITY AND CROPPING INTENSITY IN BARIND AREA

Objectives

i) To upscale the recommended pattern as water saving technique in producing higher rice and non-rice yield through pilot scale block demonstration trials in farmer's field
ii) To create awareness and improve knowledge and skill of the farmers
iii) To increase system productivity and farm income
iv) To validate yield potentialities of BINA developed promising high yielding modern rice and non-rice varieties

Project location(s)/site(s) : Nachole and Gomostapur upazilla, Chapai Nawabganj district

Cropping pattern followed : T. aman - Chickpea/Wheat/Mustard - Mungbean/Sesame

Up-scaling of transplanted aman variety, Binadhan-7

For transplanted aman, a high yielding and short- duration rice variety Binadhan-7 was selected for up-scaling in the project area. Sixteen block farming were carried out in Nachole and Gomostapur upazilla of Chapai Nawabganj district. Area of each block was 10 bighas. Seedlings of 20-25 days were transplanted during last week of July 2013. Fertilizers and all other management followed as per recommendation. The rice variety was harvested on the last week October 2013. The data recorded were: yield per hectare, crop duration, overall performance, and farmers' preference about the suitability of the variety. However, the result on yield and duration of the variety are given in Table 7.

Table 7. Location wise yield and duration of the variety Binadhan-7

Upazillas	Location	Transplanting date	Harvest date	Duration (Days)	Yield (t/ha)
Nachole	Takahara	15-07-2013	29-10-2013	126	4.30
	Mirzapur	21-07-2013	06-11-2013	122	3.60
	Hatbakoil	16-07-2013	07-10-2013	120	3.80
	Nijampur	03-07-2013	25-10-2013	118	3.80
	Ghion	27-07-2013	05-11-2013	122	4.20
	Deo para	20-07-2013	31-10-2013	125	4.50
	Cosba	24-07-2013	30-10-2013	121	3.90
	N. Chondipur	22-07-2013	03-10-2013	117	3.98
Gomostapur	Ishurpurganj	13-07-2013	21-10-2013	121	3.9
	Ishurpurganj	02-08-2013	04-11-2013	120	3.9
	Ishurpurganj	07-07-2013	23-10-2013	125	4.5
	Ishurpurganj	14-07-2013	30-10-2013	125	4.2
	Borodadpur	05-07-2013	29-10-2013	124	4.2
	Borodadpur	25-07-2013	03-11-2013	127	3.6
	Borodadpur	05-07-2013	29-10-2013	123	4.2
	Sotodadpur	15-07-2013	04-11-2013	119	3.6
Mean				122	4.01

From Table 7, it is indicated that Binadhan-7 produced average grain yield of 4.01 tha^{-1} and maturity duration was 122 days. Farmers were very interested for Binadhan-7 due short crop duration which facilitated water saving and profitable rabi crop cultivation in proper time. Economic analysis would be done annually covering the year round cropping pattern.

Field days

Two field days were arranged in the block farming areas of Binadhan-7 for motivating farmers to adopt this variety following to improved cropping pattern of Binadhan-7-Wheat/Mustard/Chickpea-Mungbean/ Sesame so that they could earn maximum profit by cultivating water saving crops.

Block farming of Rabi Crops:

In the rabi season of 2013-14, crops were cultivated as per scheduled pattern. Required seeds and inputs were supplied to the farmers. Irrigation, weeding and other practices were managed by the farmers. Results of Rabi crops at different locations of the project site were shown in Table.8. The high yielding varieties of each crop were used as; BARIgom 26 for wheat, Binasloa-4 for chickpea and Binasharisha-4 for mustard.

The result indicated that average yield of wheat, mustard and chickpea a were 3.23 t ha^{-1} , 1.41 t ha^{-1} and 1.15 t ha^{-1} respectively, It was also found that wheat and mustard needed two irrigations while chickpea needed one light supplemental irrigation. Moreover, it was observed that this 3 Rabi crops were harvested by the end of March and easily allowing time for the next successive kharif-I crops mungbean and sesame.

Table 8. Location wise yield of the variety Binadsola-4, Binasharisha-4 and BARI gom 26

Upazillas	Locations	Crops	Sowing date	Harvest date	No of Irrigation	Yield (t ha^{-1})
Nachole	Takahara	Wheat &	12-11-13	25-03-14	2	2.9
		Chickpea	20-11-13	28-01-14	-	1.2
	Mirzapur	Wheat &	18-11-13	24-03-14	2	2.7
		Mustard	15-11-13	24-03-14	-	1.5
	Hatbakoil	Wheat &	15-11-13	24-03-14	2	3.0
		Mustard		06-03-14	-	1.3
	Nijampur	Wheat	15-11-13	27-03-14	2	3.0
	Ghion	Wheat &	21-11-13	30-03-14	2	3.0
		Mustard	15-11-13	06-03-14	2	1.3
	Deo para	Wheat &	22-11-13	21-03-14	2	3.9
		Chickpea	09-11-13	21-02-14	1	0.75
	Cosba	Wheat &	15-11-13	28-03-14	2	3.1
		Chickpea	24-11-13	25-02-14	1	1.2
	N. Chondipur	Wheat &	25-11-13	28-03-14	2	2.2
		Mustard	20-11-13	23-02-14	2	0.9
Gomostapur	Ishurpurganj	Wheat &	16-11-13	24-03-14	2	4.0
		Chickpea		27-02-14	1	1.5
	Ishurpurganj	Wheat &	21-11-13	30-03-14	2	3.6
		Chickpea		13-03-14	1	1.2
	Ishurpurganj	Wheat &	21-11-13	25-03-14	2	4.2
		Chickpea		4-03-14	1	1.2
	Ishurpurganj	Wheat &	17-11-13	25-03-14	2	3.6
			18-11-13	07-03-14	1	1.2
	Borodadpur	Wheat &	23-11-13	25-03-14	2	3.9
		Mustard		28-02-14	2	1.2
	Borodadpur	Wheat &	18-11-13	25-03-14	2	3.3
		Mustard		01-03-14	2	1.0
	Borodadpur	Wheat &	20-11-13	25-03-14	2	4.2
		Mustard		10-03-14	2	1.5
	Sotodadpur	Wheat,	23-11-13	27-03-14	2	3.3
		Mustard &		07-03-14	2	1.2
		Chickpea		29-02-14	2	1.0
Average yield		Wheat,				3.23
		Mustard &				1.41
		Chickpea				1.15

Block farming of Kharif-I crops:

After Rabi crops, the same fields were used for kharif-1 crops, mungbean and sesame. Seeds of Binamoog-8 and Binatil-2 were supplied to the farmers as planed. Required inputs (fertilizers) were also provided to the farmers for cultivating the following Kharif-I crops timely. Sowing time the soil moisture was very low. For this reason, a 3 cm post-sowing irrigation water was applied for the germination of seeds of the crop. Results of kharif-I crops at different locations of the project site were shown in Table 9.

The result indicated that average yield of mungbean and sesame were 1.07 t ha^{-1} and 0.78 t ha^{-1} respectively, It was also found that mungbean and sesame needed one post sowing and while mungbean and sesame needed one light supplemental irrigation. Moreover, it was observed that mungbean and sesame were harvested by the end of June easily allowing time for the next successive kharif-II crop T. aman rice.

Table 9. Location wise yield of the variety Binamoog-5 and Binamoog-8, Binatil-1

Upazillas	Locations	Crops	Sowing date	Harvest date	No of Irrigation (Pre/post sowing)	Yield (t ha^{-1})
Nachole	Takahara	Mungbean & Sesame	30-03-2-14	10-06-14	1	1.2
				30-06-14	-	0.9
	Mirzapur	Sesame	30-03-14	26-06-14	1	1.1
	Hatbakoil	Mungbean & Sesame	15-03-14	15-06-14	1	1.25
			25-03-14		1	0.8
	Nijampur	Mungbean & Sesame	29-03-14	26-06-14	1	0.9
				30-06-14	1	0.7
	Ghion	Mungbean	28-03-14	20-06-14	1	1.2
	Deo para	Mungbean	30-03-14	18-06-14	1	1.3
	Cosba	Mungbean	30-03-14	20-06-14	2	1.2
			07-04-14	30-06-14	1	1.0
	N. Chondipur	Sesame	04-04-14	26-06-14	1	0.7
Gomostapur	Ishurpurganj	Sesame	27-03-14	25-06-14	1	0.8
	Ishurpurganj	Sesame	01-04-14	28-06-14	1	0.85
	Ishurpurganj	Mungbean & Sesame	01-04-14	20-06-14	1	1.1
				30-06-14	1	0.65
	Ishurpurganj	Mungbean & Sesame	01-04-14	22-06-14	1	0.9
			02-04-14	30-06-14	1	0.7
	Borodadpur	Mungbean	01-04-14	18-06-14	1	0.8
	Borodadpur	Mungbean & Sesame	02-04-14	25-06-14	1	0.85
				30-06-14	1	0.6
	Borodadpur	Mungbean	01-04-14	22-06-14	1	0.8
	Sotodadpur	Sesame	31-03-14	27-06-14	1	0.7
Average yield		Mungbean				1.07
		Sesame				0.78

COORDINATED PROJECT ON WATER MANAGEMENT FOR ENHANCING CROP PRODUCTION UNDER CHANGING CLIMATE: BINA COMPONENT (SPGR FUNDED PROJECT)

Studies on irrigation schedules of rice and non-rice crops for optimum yield and water use

The objectives of this experiment were to make the effective use of profile soil moisture for the cultivation of Rabi crops with minimum supplemental irrigation, effective utilization of water resources (surface water, rainfall and groundwater), determine critical stages, time and amount of irrigation need for optimum yield and increased water use efficiency, and identify and recommend water- resource based most profitable cropping pattern for the areas.

Alalpur (North), Alalpur (South) and Rahmatpur of Mymensingh Sadar Upazilla, Mymensingh district and Ramnagar, Rautola and Sachani of Magura Sadar Upazilla, Magura district were selected for different on farm experiments at farmers' field. Three cropping patterns i.e., T. aman–Fallow–Boro, T. aman –Mustard–Boro and T. aman–Wheat–T. aus for Mymensingh district and T. aman–Lentil–Sesame, T. aman–Mustard–Mungbean and T. aman–Chickpea–Jute for Magura district were followed.

Results

Irrigation schedules were made with short duration T. aman rice and low water demanding Rabi and Kharif-I crops for water saving, effective use of profile soil moisture, increasing cropping intensity and crop productivity. In this connection, based on water resources, a year round cropping sequence was developed as for Magura: T. aman (Binadhan-7) - Rabi (Lentil/Chickpea/Mustard) - Kharif-I (Mungbean/Sesame/Jute). For Mymensingh: T. aman (Binadhan-7) - Rabi (Mustard) - Boro (Binadhan-7, Binadhan-5 and BRRI dhan-28). This saved water resources, increased cropping intensity and rice and non-rice productivity in the project area.

Table 10. Highest annual rice or rice equivalent yield in Mymensingh for different annual cropping patterns followed

Patterns	T. aman ($t\ ha^{-1}$)	Rabi ($t\ ha^{-1}$)	Kharif-1 ($t\ ha^{-1}$)	Annual production, rice equivalent yield ($t\ ha^{-1}$)	Annual increased yield compared to farmers practices (%)
T. aman-Fallow-Boro (Farmers Practices)	4.69	-	6.22	10.91	-
T. aman-Fallow-Boro	4.96	-	6.18	11.14	2
T. aman-Mustard-Boro	5.07	1.57	5.92	15.35	41
T. aman-Wheat-Jute	4.96	3.38	3.02	14.68	35

Table 11. Benefit Cost Ratio (BCR) and percent water saving compared to farmer's practices in Mymensingh for different annual cropping patterns followed

Patterns	Total Income (Tk.)	Total Production cost (Tk.)	BCR	Total applied water (cm)	Water saved compared to farmers practices (%)
T. aman-Fallow-Boro (Farmers Practices)	242596	203614	1.19	199	-
T. aman-Fallow-Boro	242596	203614	1.19	195	2
T. aman-Mustard-Boro	328080	248001	1.32	189	5
T. aman-Wheat-Jute	316060	241948	1.31	120	39

In Mymensingh, the best cropping pattern was selected as T. aman-Mustard-Boro in terms of rice equivalent yield (REY, 15.35 t ha^{-1}). This pattern along with the best water management practice saved 5% water compared to farmers existing pattern (T. aman-Fallow-Boro) which produced REY 10.91 t ha^{-1}. The highest BCR (1.32) was obtained from T. aman-Mustard-Boro cropping pattern among all the annual cropping patterns followed. In Magura, the best cropping pattern was selected as T. aman-Lentil-Sesame in terms of rice equivalent production (22.49 t ha^{-1}). This pattern along with the best water management practice saved 44% water compared to farmers existing pattern (T. aman-Fallow-Boro) which produced REY 11.67 t ha^{-1}. The highest BCR (1.99) was obtained from T. aman-Lentil-Sesame cropping pattern among all the annual cropping patterns followed.

Table 12. Highest annual rice or rice equivalent yield in Magura for different annual cropping patterns followed

Pattern	T. aman (t ha^{-1})	Rabi (t ha^{-1})	Kharif-1 (t ha^{-1})	Annual production, rice equivalent (t ha^{-1})	Annual increased yield compared to farmer's practices (%)
T. aman-Fallow-Boro (Farmers Practices)	5.45	-	6.22	11.67	-
T. aman-Mustard-Mungbean	5.03	2.02	1.44	16.65	43
T. aman-Lentil-Sesame	5.45	1.99	2.1	22.49	93
T. aman-Chickpea-jute	5.35	2.04	4.45	18.58	59

Table 13. Benefit Cost Ratio (BCR) and percent water saving compared to farmer's practices in Magura for different cropping patterns followed

Patterns	Total income (Tk.)	Total production cost (Tk.)	BCR	Total applied water (cm)	Water saved compared to farmers practices (%)
T. aman-Fallow-Boro (Farmers Practices)	242596	196113	1.24	199	-
T. aman-Mustard-Mungbean	327270	216386	1.51	115	42
T. aman-Lentil-Sesame	426900	215037	1.99	111	44
T. aman-Chickpea-jute	370050	227941	1.62	117	41

Conclusion

Irrigation schedules were made with short duration T. aman rice and low water demanding Rabi and kharif-I crops for water saving, increasing cropping intensity and crop productivity. In this connection, based on water resources year round best cropping sequence was developed as; for Magura: T. aman (Binadhan-7) - Rabi (Lentil) - Kharif-I (Sesame) and for Mymensingh: T. aman (Binadhan-7) - Rabi (Mustard) – Boro. This saved water resources, increased cropping intensity and rice and non-rice crop productivity in the project areas.

Socio-economic impact study in the project area

In Mymensingh, crop coverage and cropping intensity increased by 2% and 45.85% respectively by project closing. Land and water productivity increased by 25.7%. Awareness and livelihood of study area increased by 55% and 18%, respectively among the farmers.

In Magura, crop coverage and cropping intensity increased by 9.03% and 20% respectively at the time of project closing. Land and water productivity increased by 64.86%. Awareness and livelihood of study area increased by 90.55%, 51% and 16%, respectively among the farmers.

Table 14. Summary Table for Agreed Project Output (Pre-project and Post project Statuses)

Site	Crop area coverage (%)		Cropping Intensity (%)		Land Productivity (t ha^{-1} yr^{-1})		Water Productivity (lkg^{-1})	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mymensingh	72.99	74.47	175	220.85	10.91	13.72	1812.90	1198.90
Magura	91.71	82.68	206	266.34	11.67	19.24	2035.00	715.87

Table 15. Project Output and Outcome

Output	Expected achievements	Achieved (Mymensingh)	Achieved (Magura)
Crop area coverage and cropping intensity increased	Crop coverage and cropping intensity will increase by 15% and 20% respectively by project closing	Increased crop coverage of 2.00% and cropping intensity of 45.85%	Achieved crop coverage of 9.03% and cropping intensity of 60.34%
Land and water productivity increased	Land and water productivity will increase by 20%	Achievement level of land and water productivity is 25.75%	Achievement level of land and water productivity is 64.86%
Water use efficiency increased	Water use efficiency will increase by 10%	Water use efficiency increased from 28.25% to 50%	Water use efficiency increased from 50% to 90.55%
Increased awareness of the farmer for using water management technologies	Awareness of farmers will increase by 40%	Awareness of farmers increased by 55% (Follow-up survey report)	Awareness of farmers increased by 51% (Follow-up survey report)
Improved livelihood of farmers	Livelihood of study area farmers will improve by 15%	Livelihood of study area farmers improve by 18%	Livelihood of study area farmers improve by 16%

Conclusion

Climatic condition and surface and groundwater availability for dry season crop planning were assessed and predicted. Based on water availability, year round rice based low water demanding non-rice cropping sequence was developed. Farmers practicing this schedule will be able to increase cropping intensity and crop productivity with judicious use of irrigation water.

AGRONOMY DIVISION

RESEARCH HIGHLIGHTS

Results of cropping pattern experiment of T. aman (Binadhan-7) – Mustard (Binasarisha-4/BARI Sharisha-14) – Boro (Binadhan-14/Binadhan-5) concluded that the proposed cropping pattern adopting BINA varieties of rice and mustard resulted higher cropping intensity (300%).

Study of relay cropping of wheat with T. aman rice showed positive indication for the farmers of saline areas. The results revealed that mean grain yield of Binadhan-7 (4.67 t ha^{-1}) and Binadhan-8 (4.70 t ha^{-1}) was similar. Among the wheat lines/variety, Prodip yielded higher (4.00 t ha^{-1}) than the advance lines.

The study on determination of optimum sowing time and spacing for growth and yield of soybean lines revealed that the yield of Binasoybean-1 was 2255 kg ha^{-1} at 20 cm spacing in Dec. 30 sowing at Magura and advance line SBM-9 produced 3812 kg ha^{-1} at 25 cm spacing in Jan.15 sowing.

In sesame trials with sowing time and spacing showed that mong different sowing dates, February 23 sowing produced highest seed yield (1579 kg ha^{-1}) by Binatil-3 with 25 cm row spacing and in March 10 sowing, Binatil-2 produced second highest seed yield (1560 kg ha^{-1}) with 30 cm row spacing.

Methods of sowing of tosa jute trial showed that mean fiber yield was produced 5.40 t ha^{-1} in broadcasting method when seeds were sown at 8.0 kg ha^{-1} and 5.24 t ha^{-1} in line sowing at the seed rate of 4.5 kg ha^{-1}

Development of cropping pattern using early maturing boro rice and mustard

Rice based cropping pattern experiments were evaluated during July 2013 to July 2014 at Mymensingh and Magura. The pattern under the study was: T. aman (Binadhan-7) - Mustard (Binasarisha-4/BARI Sharisha-14) – Boro (Binadhan-14/Binadhan-5). Results revealed that in aman season, Binadhan-7 produced grain yield of 4.60 t ha^{-1} at Mymensingh and 4.56 t ha^{-1} at Magura locations. The mean seed yield of Binasarisha-4 in rabi season was 1.38 t ha^{-1} BARI Sharisha-14 was 1.35 t ha^{-1}. Mean grain yield of rice varieties were 4.43 t ha^{-1} at Mymensing and 4.95 t ha^{-1} at Magura, respectively). Between two varieties, Binadhan-5 yielded higher (5.00 t ha^{-1}) than Binadhan-14 (4.38 t ha^{-1}). Duration of the two varieties was, 135 days for Binadhan-5 and 123 days for Binadhan-14. It can be concluded that the proposed cropping pattern adopting BINA varieties of rice and mustard resulted higher cropping intensity (300%).

Table 1. Yield and yield attributes of Binadhan-7 during 2013-14

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	1000 seed wt. (g.)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Duration (Days)
Location									
Mymensingh (L_1)	104.47	9.73	8.67	23.10	94.33	24.03	4.60	5.76	120
Magura (L_2)	105.80	7.36	7.10	23.10	94.87	23.83	4.56	5.40	115
T-values	ns	**	**	ns	ns	ns	ns	ns	

Table 2. Yield and yield attributes of mustard varieties during 2013-14

Treatments	Plant height (cm)	Branches $plant^{-1}$ (no.)	Siliqua $plant^{-1}$ (no.)	Siliqua length (cm)	Seed $siliqua^{-1}$ (no.)	1000 Seed wt. (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Duration (Days)
Locations									
Mymensingh (L_1)	88.93	2.73	37.17	4.82	22.92	3.05	1.35	3.08	
Magura (L_2)	96.65	3.03	44.13	4.72	24.25	3.25	1.38	3.23	
T-values	**	ns	**	ns	**	*	ns	ns	
Variety									
Binasarisha-4 (V_1)	101.15	2.63	48.63	6.00	24.76	3.21	1.38	3.23	91
BARI sarisha-14 (V_2)	84.43	3.13	32.67	3.53	22.40	3.08	1.35	3.08	82
$LSD_{0.05}$	**	ns	**	**	**	ns	ns	ns	
Interaction									
Location × Variety:									
L_1V_1	96.26	2.73	42.87	5.97	23.47	3.10	1.33	3.10	
L_1V_2	81.60	2.73	31.47	3.67	22.37	3.00	1.36	3.06	
L_2V_1	106.03	2.53	54.40	6.03	26.07	3.33	1.43	3.36	
L_2V_2	87.26	3.53	33.86	3.40	22.43	3.06	1.33	3.10	
$LSD_{0.05}$	1.92	ns	4.00	ns	1.54	ns	ns	ns	

Table 3. Yield and yield attributes of boro rice varieties during 2013-14

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Duration (Days)
Locations										
Mymensingh (L_1)	106.10	8.56	8.18	22.48	111.16	18.83	23.82	4.43	6.78	
Magura (L_2)	95.90	10.83	10.26	22.70	106.76	20.18	23.38	4.95	6.31	
T-values	**	**	**	ns	**	*	**	*	*	
Varieties										
Binadhan-5 (V_1)	113.30	10.53	10.02	23.48	111.58	21.75	23.85	5.00	6.93	135
Bina dhan-14 (V_2)	88.70	8.86	8.43	21.70	106.35	17.26	23.35	4.38	6.17	123
T-valuse	**	**	**	**	**	**	**	*	*	
Location × Variety										
L_1V_1	118.93	10.10	9.67	23.50	112.56	21.13	23.90	4.53	6.96	
L_1V_2	93.27	7.03	6.70	21.47	109.76	16.53	23.73	4.33	6.60	
L_2V_1	107.67	10.96	10.37	23.47	110.60	22.37	23.80	5.46	6.90	
L_2V_2	84.13	10.70	10.17	21.93	102.93	18.00	22.96	4.43	5.73	
$LSD_{0.05}$	ns	1.11	0.65	ns	ns	ns	0.39	ns	0.46	

Study of relay cropping of wheat with T.aman rice in saline areas

Four wheat lines/varieties were evaluated as relay cropping with T.aman rice varieties at farmers field of Satkhira during 2013-14. T. aman varieties were Binadhan-7 and Binadhan-8 and Wheat lines/varieties were, L-880-43, L-880-01, L-880-05 and prodip (Check). The objective was to increase cropping intensity of saline area. Wheat seeds were sown seven days before the harvest of T.aman. The experiment was laid out as factorial randomized complete block design with three replications. The unit plot was 4 m × 3 m. Thirty days-old seedlings were transplanted @ 2-3 seedlings hill^{-1} with a planting spacing of 20 cm x 15 cm on August 25, 2013. For T.aman cultivation, the recommended doses of fertilizers were applied. All fertilizers except urea were applied at final land preparation in full amount. Urea was applied in two splits- 50% at 7 days after transplanting (DAT) and rest 50% at 30 DAT. For wheat cultivation, only recommended doses of urea were top dressed after 30 days after sowing. The crops were harvested at different dates at maturity and data on yield and yield components were recorded at harvest and were statistically analyzed following the design used for the experiment and the means were compared with LSD.

The results revealed that mean grain yield (Table-4) of Binadhan-7 (4.67 t ha^{-1}) and Binadhan-8 (4.70 t ha^{-1}) was similar. Among the wheat lines/variety, Prodip yielded higher (4.00 t ha^{-1}). Second highest grain yield was produced by L-880-01 (3.13 t ha^{-1}). Among the lines/variety, L-880-05 matures in 114 days and Prodip matures in 119 days.

Table 4. Yield and yield contributing characters of rice varieties in aman season at Satkhira during 2013-14

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed weight (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Duration (Days)
Varieties:										
Bina dhan-7 (V_1)	92.17	12.51	12.33	23.73	123.00	10.00	23.60	4.67	8.20	116
Bina dhan-8 (V_2)	102.33	14.00	13.10	23.36	123.33	21.00	24.70	4.70	11.13	122
T-values	**	ns	ns	ns	**	**	ns	**	**	

Table 5. Yield and yield attributes of wheat lines/varieties in rabi season as relay crop during 2013-14

Treatments	Plant height (cm)	Effective tillers hill^{-1} (no.)	Spike length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 seed wt. (g)	Seed yield (t ha^{-1})	Duration (days)
Varieties								
L-880-43 (V_1)	99.80	3.40	10.16	40.03	7.13	34.13	3.00	98
L-880-01 (V_2)	99.10	5.00	9.13	36.23	5.97	30.00	3.13	99
L-880-05 (V_3)	98.17	5.76	8.00	35.20	8.00	28.97	2.77	102
Prodip (V_4)	96.13	7.13	11.03	45.23	11.90	47.17	4.00	106
$LSD_{0.05}$	5.90	5.24	4.59	4.97	4.06	4.59	4.38	ns

Determination of optimum sowing time and spacing for growth and yield of soybean lines

The experiment was conducted in the sub-station farm at Magura and Mymensingh during 2013-14 to evaluate the effect of sowing time (December 30 and January 15) and row spacing's (20 cm, 25 cm, and 30 cm) on the yield and yield contributing characters of five advanced soybean lines/variety viz. SBM-22, SBM-9, SBM-15 and SBM-18 along with one check variety, Binasoybean-1. The experiment was laid out in RCB design with 3 replications. The unit plot size was 4 m × 3 m. The recommended doses of fertilizers were applied. The experiment was harvested on different dates according to the maturity of the mutant lines/varieties. The data on yield and yield attributes were recorded from randomly selected 10 plants while the yield data were recorded from the harvest of whole plot. All the recorded data were statistically analyzed using MSTAT Statistical computer program according to the design used for the experiment. Least significant difference (LSD) was used to compare variations among treatments. The results of two locations are discussed below:

Results at Magura

Results showed that the mean seed yield was highest (1738.22 kg ha^{-1}) in December 30 sowing contributed by higher number of populations, pods plant^{-1} and branches plant^{-1}. Among different advance lines, SBM-9 produced highest seed yield (1805.33 kg ha^{-1}). The release variety, Binasoybean-1 produced second highest seed yield (1774.16 kg ha^{-1}). The lowest seed yield was obtained by SBM-15 (1420 kg ha^{-1}). In closer spacing (20 cm row), the Binasoybean-1 yielded higher (1792.57 kg ha^{-1}) than 25 cm and 30 cm row spacing. The interaction results of time × variety × spacing revealed that the yield of Binasoybean-1 was the highest (2255 kg ha^{-1}) at 20 cm spacing in Dec. 30 sowing. Mean effect of different spacing showed significant effect on seed yield.

Results at Mymensingh

The mean seed yield showed highest seed yield in Jan. 15 sowing (336.31 kg ha^{-1}) and Dec. 30 showed lowest (2361.73 kg ha^{-1}). Highest yield in Jan.15 contributed by highest branches $plant^{-1}$, pods $plant^{-1}$ and seeds pod^{-1}. Among different advance lines, SBM-18 produced highest seed yield (3083.72 kg ha^{-1}). Advance lines, SBM-12, SBM-9 and Binasoybean-1 produced almost similar yield (2867.61 kg ha^{-1}, 2837.50 kg ha^{-1} and 2812.44 kg ha^{-1}, respectively). Different spacing's showed significant effect on seed yield. Among different spacings, 20 cm row showed highest seed yield (1792.57 kg ha^{-1}).

Table 6. Determination of optimum time and spacing for growth and yield of soybean lines during 2013-2014 at Magura

Treatment	Populations (no. m^{-2})	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed yield (kg ha^{-1})	Duration (days)
Time									
Dec. 30 (T_1)	152.44	54.35	1.51	53.76	3.34	2.57	13.16	1738.22	112
Jan. 15 (T_2)	121.71	45.66	0.95	52.25	3.58	2.67	13.29	1562.31	115
T-valuse	**	*	*	ns	*	ns	ns	**	
Varieties/lines									
Bina Soybean-1 (V_1)	148.94	50.57	1.35	51.32	3.53	2.87	13.18	1774.16	115
SBM-22 (V_2)	147.72	55.72	1.25	56.08	3.35	2.61	13.03	1708.61	112
SBM-9 (V_3)	134.61	47.64	1.33	55.88	3.36	2.57	13.22	1805.33	116
SBM-15(V_4)	125.61	48.50	1.19	55.18	3.46	2.50	13.35	1420.16	113
SBM-18 (V_5)	128.50	47.58	1.05	46.56	3.59	2.54	13.39	1543.05	118
$LSD_{0.05}$	4.61	31.74	ns	6.48	ns	0.24	ns	132.7	
Interaction									
Time × Variety									
T_1V_1	147.56	52.80	1.71	54.02	3.31	3.00	13.17	1824.89	
T_1V_2	164.22	60.28	1.46	55.84	3.29	2.51	12.93	1687.67	
T_1V_3	150.44	51.20	1.61	59.70	3.38	2.45	13.15	1874.11	
T_1V_4	145.88	55.11	1.42	53.47	3.26	2.41	13.36	1523.67	
T_1V_5	154.11	52.37	1.37	45.75	3.46	2.47	13.20	1780.78	
T_2V_1	150.33	48.33	0.99	48.62	3.75	2.75	13.20	1723.44	
T_2V_2	131.22	51.16	1.03	56.32	3.40	2.71	13.14	1729.56	
T_2V_3	118.78	44.08	1.05	52.06	3.34	2.70	13.28	1736.56	
T_2V_4	105.33	41.88	0.96	56.88	3.67	2.59	13.34	1316.67	
T_2V_5	102.88	42.80	0.73	47.36	3.72	2.61	13.47	1305.33	
$LSD_{0.05}$	6.52	ns	ns	ns	ns	ns	ns	187.7	
Row spacing									
20 cm (S_1)	143.43	50.95	1.23	53.80	3.41	2.62	13.07	1792.57	
25 cm (S_2)	139.20	50.08	1.27	54.82	3.50	2.61	13.29	1675.67	
30 cm (S_3)	128.60	48.97	1.20	50.39	3.46	2.62	13.32	1482.57	
$LSD_{0.05}$	3.57	ns	ns	ns	ns	ns	0.19	102.8	
Time × Spacing									
T_1S_1	151.46	55.90	1.52	56.06	3.31	2.56	12.98	1878.20	
T_1S_2	151.60	54.38	1.51	54.75	3.42	2.56	13.20	1783.93	
T_1S_3	154.26	52.77	1.52	50.45	3.29	2.58	13.32	1552.53	
T_2S_1	135.40	46.03	0.95	51.54	3.51	2.68	13.16	1706.93	
T_2S_2	126.80	45.78	1.02	54.88	3.59	2.66	13.39	1567.40	
T_2S_3	102.93	45.17	0.89	5023	3.63	2.67	13.32	1412.60	
$LSD_{0.05}$	5.05	ns	ns	ns	ns	ns	ns	ns	

Table 6 Contd.

Treatment	Populations (no. m^{-2})	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed yield (kg ha^{-1})	Duration (days)
Variety × Spacing									
V_1 S_1	151.83	49.76	1.34	53.30	3.58	2.86	12.76	1908.16	
V_1 S_2	153.16	49.73	1.30	49.90	3.45	2.90	13.33	1713.33	
V_1 S_3	141.83	52.20	1.41	50.76	3.57	2.86	13.46	1701.00	
V_2 S_1	154.83	57.67	1.42	56.96	3.24	2.66	13.10	1815.00	
V_2 S_2	152.83	57.63	1.23	56.17	3.33	2.59	12.95	1738.83	
V_2 S_3	135.50	51.86	1.40	55.10	3.47	2.57	13.06	1572.00	
V_3 S_1	142.67	51.50	1.25	58.50	3.43	2.67	13.08	1957.67	
V_3 S_2	136.17	46.40	1.34	58.29	3.43	2.45	13.31	1903.00	
V_3 S_3	125.00	45.03	1.05	50.86	3.22	2.61	13.26	1555.33	
V_4 S_1	129.33	48.40	1.36	56.80	3.32	2.48	13.31	1550.50	
V_4 S_2	126.00	49.00	1.16	61.10	3.53	2.60	13.41	1430.33	
V_4 S_3	121.50	48.10	0.96	47.64	3.54	2.42	13.33	1279.67	
V_5 S_1	138.50	47.43	1.20	43.46	3.48	2.43	13.08	1731.50	
V_5 S_2	127.83	47.67	1.00	48.63	3.49	2.54	13.46	1592.83	
V_5 S_3	119.17	47.67	1.32	47.57	3.51	2.66	13.46	1304.83	
$LSD_{0.05}$	5.99	ns	ns	ns	ns	ns	ns	ns	
Time × Variety × Spacing									
T_1V_1 S_1	145.67	55.73	1.53	56.53	3.33	2.93	12.67	2255.00	
T_1V_1 S_2	151.00	51.13	1.60	54.20	3.18	3.06	13.33	1584.67	
T_1V_1 S_3	146.00	51.53	2.00	51.33	3.42	3.00	13.53	1635.00	
T_1V_2 S_1	156.33	64.26	1.66	57.80	3.33	2.67	13.06	1544.67	
T_1V_2 S_2	168.00	60.80	1.46	55.27	3.22	2.46	12.90	1852.67	
T_1V_2 S_3	168.33	55.80	1.26	54.46	3.32	2.40	12.83	1665.67	
T_1V_3 S_1	153.00	50.86	1.67	65.47	3.54	2.56	13.03	1893.67	
T_1V_3 S_2	149.00	50.73	1.60	60.78	3.46	2.40	13.26	2064.00	
T_1V_3 S_3	149.33	52.00	1.33	52.86	3.15	2.42	13.16	1664.67	
T_1V_4 S_1	140.00	55.06	1.46	56.73	3.70	2.33	13.23	1705.00	
T_1V_4 S_2	139.67	55.73	1.46	54.06	3.54	2.46	13.33	1501.33	
T_1V_4 S_3	158.00	54.53	1.40	49.62	3.17	2.43	13.53	1364.67	
T_1V_5 S_1	162.33	53.60	1.46	43.80	3.28	2.34	12.90	1992.67	
T_1V_5 S_2	150.33	53.53	1.26	49.46	3.71	2.43	13.16	1917.00	
T_1V_5 S_3	149.67	50.00	1.15	44.00	3.39	2.67	13.53	1432.67	
T_2V_1 S_1	158.00	43.80	1.00	50.06	3.82	2.80	12.86	1561.33	
T_2V_1 S_2	155.33	48.33	0.83	45.62	3.72	2.73	13.33	1842.00	
T_2V_1 S_3	137.67	52.87	1.18	50.20	3.72	2.73	13.40	1767.00	
T_2V_2 S_1	153.33	51.08	1.00	56.13	3.16	2.67	13.13	2085.33	
T_2V_2 S_2	137.67	54.46	0.93	57.08	3.43	2.71	13.00	1625.00	
T_2V_2 S_3	102.67	47.93	1.13	55.75	3.62	2.74	13.30	1478.33	
T_2V_3 S_1	132.33	52.13	0.93	51.53	3.33	2.80	13.13	2021.67	
T_2V_3 S_2	123.33	42.06	1.08	55.80	3.40	2.50	13.36	1742.00	
T_2V_3 S_3	100.67	38.06	0.76	48.87	3.30	2.80	13.36	1446.00	
T_2V_4 S_1	118.67	41.73	1.26	56.86	3.57	2.63	13.40	1396.00	
T_2V_4 S_2	112.33	42.27	0.86	68.13	3.52	2.73	13.50	1359.33	
T_2V_4 S_3	85.00	41.67	0.53	45.67	3.91	2.41	13.13	1194.67	
T_2V_5 S_1	114.67	41.27	0.93	43.13	3.68	2.53	13.26	1470.33	
T_2V_5 S_2	105.33	41.80	0.73	47.80	3.87	2.65	13.76	1268.67	
T_2V_5 S_3	88.67	45.33	1.42	51.13	3.60	2.67	13.40	1177.00	
$LSD_{0.05}$	11.29	58.40	ns	ns	ns	ns	ns	325.0	

Table 7. Determination of optimum time and spacing for growth and yield of soybean lines during 2013-2014 at Mymensingh

Treatment	Populations (no. m^{-2})	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed yield (kg ha^{-1})	Duration (days)
Time									
Dec. 30 (T_1)	136.15	38.16	1.96	29.34	3.43	2.43	15.75	2361.73	110
Jan. 15 (T_2)	136.02	44.60	2.40	46.65	3.15	2.46	13.07	3368.31	114
T-valuse	ns	ns	ns	*	ns	ns	**	**	
Varieties									
Bina Soybean-1 (V_1)	136.78	41.07	2.09	34.75	3.14	2.35	14.61	2812.44	118
SBM-22 (V_2)	129.72	44.64	2.32	42.23	3.30	2.41	13.81	2867.61	114
SBM-9 (V_3)	129.45	38.92	2.30	36.25	3.42	2.47	14.56	2837.50	112
SBM-15(V_4)	139.33	41.36	2.20	39.96	3.31	2.49	14.63	2723.83	114
SBM-18 (V_5)	145.16	40.96	2.06	36.78	3.29	2.51	14.45	3083.72	120
$LSD_{0.05}$	11.99	3.11	ns	ns	ns	ns	0.61	5.86	
Interaction									
Time × Variety									
T_1V_1	140.33	38.76	2.02	26.28	3.23	2.31	16.05	2397.78	
T_1V_2	127.56	39.52	1.86	32.97	3.42	2.37	14.79	2585.78	
T_1V_3	120.89	34.22	2.02	26.73	3.51	2.47	16.14	2017.11	
T_1V_4	144.78	39.71	2.04	29.46	3.48	2.56	16.01	2113.67	
T_1V_5	147.22	43.26	1.86	31.24	3.51	2.46	15.76	2694.33	
T_2V_1	133.22	49.80	2.15	43.22	3.04	2.40	13.17	3227.11	
T_2V_2	131.89	43.22	2.77	51.49	3.18	2.44	12.82	3149.44	
T_2V_3	138.00	44.51	2.57	45.76	3.33	2.47	12.99	3657.89	
T_2V_4	133.89	42.22	2.35	50.46	3.14	2.43	13.24	3334.00	
T_2V_5	143.11	47.22	2.14	42.31	3.08	2.56	13.18	3473.11	
$LSD_{0.05}$	12.47	ns	ns	ns	ns	ns	ns	8.29	
Row spacing									
20 cm (S_1)	141.43	42.31	2.18	36.63	3.28	2.46	14.09	3052.10	
25 cm (S_2)	138.43	42.00	2.23	39.26	3.35	2.45	14.70	2998.53	
30 cm (S_3)	128.40	39.84	2.13	38.09	3.26	2.43	14.45	2544.43	
$LSD_{0.05}$	9.29	ns	ns	ns	ns	ns	0.47	4.54	
Time × Spacing									
T_1S_1	132.80	38.84	1.97	29.37	3.43	2.44	15.32	2466.40	
T_1S_2	136.80	38.51	1.96	30.10	3.43	2.45	16.15	2595.13	
T_1S_3	138.86	37.14	1.96	28.57	3.43	2.41	15.78	2023.67	
T_2S_1	144.07	45.78	2.38	43.92	3.12	2.49	12.86	3637.80	
T_2S_2	146.06	45.49	2.51	48.42	3.26	2.45	13.24	3401.93	
T_2S_3	117.93	42.53	2.30	47.61	3.08	2.44	13.11	3065.20	
$LSD_{0.05}$	13.13	ns	ns	ns	ns	ns	ns	6.43	

Table 7 Contd.

Treatment	Populations ($no.\ m^{-2}$)	Plant height (cm)	Branches $plant^{-1}$ (no.)	Pods $plant^{-1}$ (no.)	Pod length (cm)	Seeds pod^{-1} (no.)	1000-seed weight (g)	Seed yield ($kg\ ha^{-1}$)	Duration (days)
Variety × Spacing									
V_1 S_1	141.67	41.50	1.96	34.23	3.23	2.40	14.04	2974.67	
V_1 S_2	144.00	43.15	2.07	31.96	3.12	2.30	14.92	2787.67	
V_1 S_3	124.67	38.40	2.23	38.06	3.06	2.37	14.88	2675.00	
V_2 S_1	137.16	45.01	2.26	40.60	3.26	2.33	13.76	3251.00	
V_2 S_2	133.33	45.53	2.46	44.70	3.36	2.40	14.01	2969.17	
V_2 S_3	118.67	43.43	2.23	41.40	3.29	2.50	13.65	2382.67	
V_3 S_1	127.33	41.67	2.50	34.67	3.46	2.53	14.39	2881.50	
V_3 S_2	133.50	37.96	2.26	34.53	3.41	2.46	15.11	2937.67	
V_3 S_3	127.50	37.33	2.13	39.55	3.39	2.41	14.20	2693.33	
V_4 S_1	140.00	41.83	2.06	38.03	3.23	2.56	14.48	2967.50	
V_4 S_2	145.33	42.20	2.36	43.09	3.46	2.46	14.76	2964.83	
V_4 S_3	132.67	40.06	2.16	38.76	3.26	2.45	14.65	2239.17	
V_5 S_1	146.00	41.76	2.10	35.63	3.21	2.50	13.79	3185.83	
V_5 S_2	151.00	41.16	2.01	42.03	3.39	2.63	14.69	3333.33	
V_5 S_3	138.50	39.97	1.90	32.67	3.29	2.40	14.84	2732.00	
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	10.16	
Time ×Variety × Spacing									
T_1V_1 S_1	146.33	39.40	2.06	25.20	3.31	2.40	15.72	2448.00	
T_1V_1 S_2	141.33	40.97	1.88	26.67	3.16	2.13	16.35	2660.33	
T_1V_1 S_3	133.33	35.93	2.13	27.00	3.23	2.40	16.09	2085.00	
T_1V_2 S_1	132.33	36.23	1.73	33.80	3.37	2.26	14.53	2751.33	
T_1V_2 S_2	129.00	41.67	1.93	32.67	3.38	2.40	15.26	2855.67	
T_1V_2 S_3	121.33	40.67	1.93	32.47	3.51	2.46	14.57	2150.33	
T_1V_3 S_1	111.67	38.33	2.06	28.53	3.48	2.46	15.78	2302.33	
T_1V_3 S_2	118.33	33.53	2.13	23.26	3.46	2.53	17.00	2062.667	
T_1V_3 S_3	132.67	32.00	1.87	28.40	3.58	2.42	15.63	1686.33	
T_1V_4 S_1	139.00	37.93	2.00	30.07	3.48	2.53	15.76	2184.67	
T_1V_4 S_2	147.00	38.67	1.93	30.91	3.44	2.60	16.09	2523.33	
T_1V_4 S_3	148.33	42.20	2.20	27.40	3.53	2.53	16.19	1633.00	
T_1V_5 S_1	134.67	38.47	2.00	29.13	3.53	2.53	14.84	2645.67	
T_1V_5 S_2	148.33	38.47	1.93	37.00	3.70	2.60	16.05	2873.67	
T_1V_5 S_3	158.67	43.60	1.67	27.60	3.13	2.26	16.40	2563.67	
T_2V_1 S_1	137.00	45.33	1.87	43.27	3.15	2.40	12.37	3501.33	
T_2V_1 S_2	146.67	40.87	2.26	37.27	3.08	2.46	13.47	2915.00	
T_2V_1 S_3	116.00	53.80	2.33	49.13	2.89	2.34	13.67	3265.00	
T_2V_2 S_1	142.00	49.40	2.80	47.40	3.15	2.40	12.98	3750.67	
T_2V_2 S_2	137.67	46.20	3.00	56.73	3.34	2.40	12.76	3082.67	
T_2V_2 S_3	116.00	44.60	2.53	50.35	3.06	2.53	12.73	2615.00	
T_2V_3 S_1	143.00	42.40	2.93	40.80	3.44	2.60	13.00	3460.67	
T_2V_3 S_2	148.67	42.67	2.40	45.80	3.35	2.40	13.22	3812.67	
T_2V_3 S_3	122.33	45.60	2.40	50.70	3.21	2.41	12.76	3700.33	
T_2V_4 S_1	141.00	46.47	2.13	46.00	2.97	2.60	13.20	3750.33	
T_2V_4 S_2	143.67	41.47	2.80	55.27	3.48	2.33	13.42	3406.33	
T_2V_4 S_3	117.00	41.33	2.13	50.13	2.98	2.38	13.20	2845.33	
T_2V_5 S_1	157.33	43.87	2.20	42.13	2.88	2.46	12.74	3726.00	
T_2V_5 S_2	153.67	41.47	2.10	47.07	3.08	2.66	13.33	3793.00	
T_2V_5 S_3	118.33	38.67	2.13	37.73	3.27	2.53	13.27	2900.33	
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	14.37	

Effect of sowing time and spacing on the growth and yield of Sesame varieties

The experiment was conducted at BINA Substation Ishurdi to evaluate the effect of sowing time and spacing on the yield and yield contributing characters of sesame varieties. Two release varieties Binatil-3 and Binatil-2 were grown under 3 sowing time Feb. 23, March 10 and March 25. The experiment was conducted in a split-split- plot design with 3 replications. The sowing time was placed in the main plots, varieties in the sub plots and spacing's in sub- sub plot. The recommended doses of fertilizers were applied. The data on yield attributes were recorded from randomly selected 10 plants while yield data were recorded from whole plots. All the data were analyzed statistically using MSTAT programme of computer and the mean values were judged by LSD. The results are discussed below.

Among different dates of sowing, Feb. 23 produced highest seed yield (1501.22 kg ha^{-1}). It is evident from Table-8 that between the varieties, Binatil-3 produced highest seed yield (1469.82 kg ha^{-1}) and contributed by higher number of population. Binatil-2 produced the second highest seed yield (1441.59 kg ha^{-1}). Different row spacing differs significantly in respect of yield. Interaction of date × variety × spacing showed highest seed yield (1579 kg ha^{-1}) in Feb. 23 sowing by Binatil-3 in 25 cm row spacing. In March 10 sowing, Binatil-2 produced second highest seed yield (1560 kg ha^{-1}) in 30 cm row spacing.

Table 8. Mean effect of mutant/variety, spacing and their interaction on the yield and yield attributes of sesame at sub-station farm of BINA at Ishurdi during 2013-2014.

Treatments	Plant populations (no.m^{-2})	Plant height (cm)	Branches $plant^{-1}$ (no.)	Capsules $plant^{-1}$ (no.)	Seed $capsule^{-1}$ (no.)	Length $capsule^{-1}$ (cm)	1000 seed wt. (g)	Seed yield (kg ha^{-1})	Duration (Days)
Time									
Feb.23 (T_1)	142.56	101.96	2.13	37.24	37.68	2.68	2.39	1501.22	
March 10 (T_2)	136.05	90.62	2.70	34.35	39.95	2.89	2.29	1492.22	
March 25 (T_3)	138.44	106.08	2.80	31.06	39.82	2.92	2.24	1337.67	
$LSD_{(0.05)}$	ns	2.68	0.26	2.29	ns	ns	0.14	46.21	
Varieties									
Binatil-3 (V_1)	140.26	99.07	2.43	34.31	39.06	2.93	2.31	1469.82	95
Binatil-2 (V_2)	137.78	100.03	2.66	34.12	39.25	2.73	2.28	1441.59	102
T-valuse	ns	ns	*	ns	ns	ns	ns	ns	
Spacing									
20 cm (S_1)	103.67	100.71	2.56	36.87	40.12	2.75	2.31	1415.83	
25 cm (S_2)	135.17	99.18	2.58	33.52	39.05	2.90	2.30	1457.11	
30 cm (S_3)	178.22	98.76	2.50	32.26	38.28	2.84	2.77	1494.17	
$LSD_{0.05}$	6.02	ns	ns	2.29	1.36	ns	ns	44.0	
Time × variety									
T_1V_1	142.89	102.46	2.14	37.20	36.45	2.87	2.38	1522.89	
T_1V_2	142.22	101.45	2.12	37.28	38.92	2.48	2.35	1479.56	
T_2V_1	133.78	90.37	2.53	34.28	39.97	2.84	2.32	1503.00	
T_2V_2	138.33	90.87	2.87	33.87	39.93	2.95	2.27	1481.44	
T_3V_1	136.67	104.38	2.62	30.92	40.74	3.07	2.24	1383.56	
T_3V_2	140.22	107.78	2.98	31.21	38.90	2.77	2.23	1363.78	
$LSD_{0.05}$	ns	ns	ns	ns	1.93	ns	ns	ns	

Table 8 Contd.

Treatments	Plant populations (no.m^{-2})	Plant height (cm)	Branches plant^{-1} (no.)	Capsules plant^{-1} (no.)	Seed capsule^{-1} (no.)	Length capsule^{-1} (cm)	1000 seed wt. (g)	Seed yield (kg ha^{-1})	Duration (Days)
Time × spacing									
T_1S_1	104.17	103.15	2.16	40.73	39.33	2.37	2.43	1465.67	
T_1S_2	138.50	102.16	2.16	36.50	37.61	2.82	2.36	1495.17	
T_1S_3	185.00	100.62	2.06	34.50	36.17	2.85	2.30	1542.83	
T_2S_1	102.00	91.97	2.80	35.91	40.17	2.89	2.30	1438.33	
T_2S_2	138.00	90.03	2.73	34.71	39.83	2.97	2.30	1490.17	
T_2S_3	168.17	89.87	2.58	32.41	39.90	2.82	2.27	1548.17	
T_3S_1	104.83	107.03	2.70	33.98	40.92	2.99	2.24	1343.50	
T_3S_2	129.00	105.41	2.86	29.37	39.70	2.92	2.23	1386.00	
T_3S_3	181.50	105.80	2.85	29.85	38.85	2.86	2.24	1391.50	
$LSD_{0.05}$	10.43	ns	ns	ns	ns	ns	ns	ns	
Interactions									
Variety × spacing									
V_1 S_1	104.33	100.78	2.33	37.04	40.21	2.98	2.37	1440.22	
V_1 S_2	132.22	99.16	2.51	33.61	38.87	2.91	2.30	1472.00	
V_1 S_3	176.78	97.28	2.46	32.28	38.07	2.90	2.26	1497.22	
V_2 S_1	103.00	100.65	2.77	36.71	40.03	2.51	2.28	1391.44	
V_2 S_2	138.11	99.22	2.64	3.45	39.22	2.90	2.29	1442.22	
V_2 S_3	179.67	100.23	2.54	32.22	38.50	2.79	2.28	1491.11	
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	0.19	ns	
Time × variety × spacing									
$T_1V_1S_1$	105.33	104.33	2.06	41.33	38.37	2.91	2.47	1517.67	
$T_1V_1S_2$	135.00	102.27	2.26	35.60	36.37	2.85	2.38	1579.00	
$T_1V_1S_3$	188.33	100.80	2.10	34.67	34.63	2.86	2.30	1532.00	
$T_1V_2S_1$	103.00	101.97	2.26	40.13	40.30	1.81	2.40	1413.67	
$T_1V_2S_2$	142.00	101.96	2.06	37.40	38.87	2.79	2.35	1471.33	
$T_1V_2S_3$	181.67	100.43	2.03	34.33	37.80	2.84	2.31	1553.67	
$T_2V_1S_1$	103.00	94.00	2.46	36.07	40.40	2.83	2.36	1473.00	
$T_2V_1S_2$	135.33	89.20	2.56	35.37	39.96	2.81	2.29	1499.67	
$T_2V_1S_3$	163.00	87.93	2.56	33.03	39.53	2.87	2.29	1536.33	
$T_2V_2S_1$	101.00	89.93	3.13	35.76	39.83	2.95	2.25	1403.67	
$T_2V_2S_2$	140.67	90.87	2.90	34.06	39.70	3.13	2.30	1480.67	
$T_2V_2S_3$	173.33	91.80	2.60	31.80	40.27	2.77	2.25	1560.00	
$T_3V_1S_1$	104.67	104.00	2.46	33.73	41.87	3.20	2.29	1330.00	
$T_3V_1S_2$	126.33	106.00	2.70	29.87	40.30	3.06	2.25	1397.33	
$T_3V_1S_3$	179.00	103.13	2.70	29.17	40.06	2.95	2.20	1423.33	
$T_3V_2S_1$	105.00	110.06	2.93	34.23	39.97	2.78	2.19	1357.00	
$T_3V_2S_2$	131.67	104.83	3.03	28.87	39.10	2.79	2.21	1374.67	
$T_3V_2S_3$	184.00	108.47	3.00	30.53	37.63	2.76	2.29	1359.67	
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	

Effect of seed rates on the yield and yield contributing characters of tosa jute mutant (O 97/90/72-3)

The experiment was conducted at BINA Substation, Rangpur to evaluate the effect of seed rates on the yield and yield contributing characters of tosa jute mutant. The mutant line O 97/90/72-3 was grown on April 30, 2014 under 2 methods of sowing i,e broadcasting and line sowing (30 cm row) with 3 seed rates (6.0 kg ha^{-1}, 7.0 kg ha^{-1} and 8.0 kg ha^{-1} in broadcasting and 3.5 kg ha^{-1}, 4.0 kg ha^{-1} and 4.5 kg ha^{-1} in line sowing) and harvested on August 30, 2014. The experiments were conducted in a RCB design with 3 replications. The recommended doses of fertilizers were applied. The data on yield attributes were recorded from randomly selected 10 plants while yield data were recorded from whole plots. All the data were analyzed statistically using MSTAT programme of computer and the mean values were adjudged by LSD. The results are discussed below.

Results from the table-9 showed that the crop characters were not influenced significantly by sowing methods. It was observed that mean fiber yield was highest (5.40 t ha^{-1}) in broadcasting method when seed were sown at 8.0 kg ha^{-1} and lowest fiber yield (4.17 t ha^{-1}) was produced at seed rate of 6.0 kg ha^{-1}. In line sowing, highest fiber yield (5.24 t ha^{-1}) was obtained at 4.5 kg ha^{-1} seed rate.

Higher fiber yield in broadcasting and line sowing might be the contribution of plant height, base diameter and green weight.

Table 9. Yield and yield contributing characters of tosa jute mutant as affected by population densities during 2013-14 at Rangpur

Treatments	Plant height (cm)	Base diameter (cm)	Green wt. (t ha^{-1})	Fiber wt. (t ha^{-1})	Stick wt. (t ha^{-1})	Duration (days)
Broadcasting						
6.0 $kgha^{-1}$	309.00	1.23	8.50	4.17	8.83	120
7.0 $kgha^{-1}$	310.33	1.29	8.83	4.76	11.16	
8.0 $kgha^{-1}$	315.67	1.77	10.73	5.40	9.50	
Line sowing						
3.5 $kgha^{-1}$	345.33	1.55	9.50	4.53	11.67	120
4.0 $kgha^{-1}$	348.33	1.36	9.57	4.86	11.03	
4.5 $kgha^{-1}$	350.33	1.98	10.43	5.24	10.50	
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	

TRAINING, COMMUNICATION AND PUBLICATION DIVISION

RESEARCH HIGHLIGHTS

During 2013-14 a total of 1101 adaptation trials/block demonstrations with BINA developed different crop varieties were conducted at the farmers' field in collaboration with the Department of Agriculture Extension (DAE) and in-charge of different BINA sub-stations.

A total of 162 block demonstrations with Binadhan-7 produced average grain yield of 4.5 t ha^{-1} and matured in 117 days, which was three weeks earlier than the check variety, Sharna and BR-11. Popularity of Binadhan-7 is tremendously increasing due to its better grain yield and earliness, which facilitates rabi crop cultivation timely after rice harvest. Adopting this variety an additional rabi crop can easily be cultivated.

A total of 272 block demonstrations with salt tolerant rice variety Binadhan-8 produced average yield of 5.24 t ha^{-1}, which was 7 percent higher than the check variety. Barisal, Cox's bazar, Satkhira, Patuakhali, Barguna, Bagerhat and Chittagong districts were found suitable for Binadhan-8 extension.

A total of 79 block demonstrations with salt tolerant rice variety Binadhan-10 produced average yield of 5.15 t ha^{-1}, which was 12 percent higher than the check variety. Barisal, Patuakhali, Barguna, Bagerhat, Cox's Bazar, Satkhira and Chittagong districts were found suitable for Binadhan-10 extension.

A total of 33 block demonstrations of submergence tolerant rice variety Binadhan-11 produced average seed yield 4.38 t ha^{-1}, which was 11 percent higher then the popular cultivar. Flood prone areas of Bangladesh are suitable area for massive Binadhan-11 extension.

In Barind areas, 48 block farming were conducted with drought escaping cropping pattern of T.aman-Rabi-Kharif 1 crops under CCTF project. In T.aman, Binadhan-7 produced average grain yield of 4.08 t $ha^{-1}$and in Rabi season, Binasarisha-4/Binasola-4/BARI gom-26 produced average yield of 1.47, 1.16 and 4.27 t ha^{-1}, respectively. In Kharif season, Binamoog-8 and Binatil-1 produced average seed yield of 0.77 and 0.83 t ha^{-1}, respectively, which were very low due to proper irrigation problem.

Forty five block demonstrations were carried out in Rabi season with mustard variety Binasarisha-4 in 9 districts. Binasarisha-4 produced average seed yield of 1.55 t ha^{-1}, which was 74 percent higher than the check variety Tori-7. Madaripur, Narayanganj, Faridpur, Jessore, Kushtia, Chuadanga and Narail were identified as suitable area for large-scale cultivation of Binasarisha-4. Five block demonstrations were carried out in Rabi season with mustard variety Binasarisha-9 in 3 districts. Binasarisha-9 produced average seed yield of 1.49 t ha^{-1}, which was 64 percent higher than the check variety Tori-7. It needs further trials to identify suitable area for large-scale cultivation of Binasarisha-9. Forty block demonstrations were carried out in Kharif-1 season with groundnut variety, Binachinabadam-4 in 6 districts. Binachinabadam-4 produced average seed yield of 2.13 t ha^{-1}, which was 62 percent higher than the check variety Dhaka-1 (1.32 t ha^{-1}). Farmers showed their interest to cultivate Binachinabadam-4 for its higher yield and attractive pod size. Kishoreganj, Lalmonirhat, Panchagar and Jhenaidah were identified as suitable area for large-scale cultivation of Binachinabadam-4.

Thirty block demonstrations were carried out with sesame variety, Binatil-2 in 6 districts. Binatil-2 produced average seed yield of 1.40 t ha^{-1}, which was 2.09 percent higher than the check variety Atshira. Farmers showed their interest to cultivate Binatil-2 for its higher seed yield and oil content, attractive seed and oil colour. Jessore, Chuadanga, Jhenaidah, Kushtia, Magura and Faridpur were identified as suitable area for its large-scale cultivation.

Seven block demonstrations were carried out in rabi season with soybean variety, Binasoybean-1, Binasoybean-2, Binasoybean-3 and Binasoybean-4 in Chandpur and Lakshmipur districts. All Binasoybean varieties produced higher average seed yield (2.60, 2.71, 2.69 and 2.20 t $ha^{-1)}$ than that of the check variety Shohag (2.09 t ha^{-1}). Further trials would be needed to identify the best variety and suitable area for large-scale extension.

In checkpea variety, fourteen block demonstrations with Binasola-4 produced average seed yield of 1.51 t ha^{-1}, which was 21.16 percent higher compared to cheek cultivar. Farmers of Jessore and Magura district were found enthusiastic to continue this variety for its higher seed yield. Binasola-6 produced average seed yield of 1.18 t ha^{-1}, which was 21 percent higher over check variety. Among the lentil varieties forty nine block demonstrations conducted with Binamasur-5, average seed yield of Binamasur-5 was 2.03 t ha^{-1} which was 3 percent higher than the check variety BARI masur-6 (1.59 t ha^{-1}). In case of mungbean varieties average yield of Binamoog-5, Binamoog-6, Binamoog-7 and Binamoog-8 were 1.06, 1.01, 1.15 and 1.19 t ha^{-1}, respectively.

A total of 215 block demonstrations with only promising BINA developed crop varieties were carried out in order to establish BINA technology villages around BINA headquarter and its old five sub-stations. Based on the BINA developed technology adoption and overall activities in different areas established BINA technology villages are; In BINA head quarters, Parangonj and Khagdahar under sadar upazila of Mymensingh; In Ishwardi- Auronkhola, Athaishimul, Kalikapur and Dulti; In Rangpur- Parbotipur, Auviram and Lahirirhat under sadar upazila of Rangpur; Satkhira- Jhapaghat and Daulatpur under sadar upazila and Brahmarajpur and Shenergati in Tala upazila and in Magura- West Ramnagar, Echakhada and Alamkhali village. However, establishment of BINA technology villages in Comilla are in progress.

TCP division made necessary arrangements for nominating 89 (In-country-52 and abroad-37) Scientist/Staffs in different training courses or workshop organized by other organizations in home and abroad. In order to promotion of BINA generated crop varieties, 5 workshops were organized with DAE, BADC and NGOs personnel. A total of 34 farmers training courses were organized during this period and 1585 male and female farmers including some Sub-Assistant Agricultural Officers (SAAO) were also trained on cultivation of BINA developed improved crop varieties across the country.

A total of 40 field days were also organized in different areas of the country to motivate farmers and popularize the BINA developed crop varieties/technologies to the end users

For technology transfer through printed media, publications were made on 10 types of leaflets totaling 50,000 copies during this period. Besides these, thirty TV programmes were telecasted to popularize some BINA crop varieties

PROGRAMME AREA: TECHNOLOGY TRANSFER AND IMPACT ASSESMENT

Farmers' Observation Trials (FOTs)/Block Demonstration with rice varieties developed by BINA

Block Demonstrations with Binadhan-7 compared to popular cultivar in different locations

During Aman season of 2013-14, 162 block demonstrations with Binadhan-7 were conducted at the farmer's fields in different agro-ecological zones in collaboration with the Department of Agricultural Extension (DAE). The main objectives were to evaluate the performance of this variety at different sites and widening its adoption by the farmers. Area of each demonstration plot was one acre. Spacing between line-to-line and plant-to-plant was 20 cm × 15 cm. All fertilizers were applied by farmers as per recommendation. Transplanting dates ranged from 15 July to 05 August 2013, and age of seedlings was 20 to 25 days. Based on the available reports, data of demonstration plots are presented in Table 1.

Table 1. Performance of Binadhan-7 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of Demons.	Duration (days)		Yield ($t\ ha^{-1}$)		Yield increased over check (%)
			Binadhan-7	check	Binadhan-7	check	
Sherpur	Sadar	1	113	108 V2	3.90	3.00	23.08
	Nalitabari	1	115	121	3.90	3.00	23.08
	Nakla	1	114	123 V2	3.90	3.10	20.51
Khagrachari	Sadar	1	120	125	3.61	3.85	-6.65
	Matiranga	2	120	118	4.00	3.98	0.50
	Ramgar	2	112	126	3.90	4.10	-5.13
Nawgaon	Raninagar	8	120	138	5.40	4.20	22.22
	Mohadevpur	14	97	138V5	4.50	4.80	-6.67
	Patnitola	15	125	138 V3	4.94	4.60	6.88
	Manda	8	125	133 V1	5.30	4.90	7.55
	Badalgachi	5	115	126	3.80	3.10	18.42
	Dhamuirhat	10	125	128	4.00	3.20	20.00
Feni	Parsuram	1	114	136 V3	5.10	4.90	3.92
	Sadar	1	117	138 V6	5.10	4.80	5.88
	Sonagazi	1	114	120 V5	5.20	3.90	25.00
Panchagarh	Debiganj	2	112	109 V5	4.44	3.90	12.16
Gopalganj	Tungipara	1	117	120 V4	4.50	4.20	6.67
Jamalpur	Sharishabari	1	118	-	5.00	4.20	16.00
	Melandah	1	122	134 V3	3.60	3.00	16.67
	Sadar	1	120	127 V2	3.70	3.20	13.51
Satkhira	Sadar	5	117	-	4.52	4.70	-3.98
Mymensingh	Sadar	12	121	125	4.80	4.00	16.67
	Fulpur	5	119	123	4.40	3.60	18.18
	Gouripur	5	118	135 V2	4.60	4.20	8.70
Netrakona	Sadar	5	119	133	5.10	4.70	7.84
Rangpur	Sadar	15	118	123 V4	4.85	3.98	17.94
	Pirganj	3	115	136 V3	4.20	3.96	5.71
	Gongachara	5	119	122 V4	4.50	4.12	8.44

Table 1 Contd.

District	Upazila	Number of Demons.	Duration (days)		Yield ($t\ ha^{-1}$)		Yield increased over check (%)
			Binadhan-7	check	Binadhan-7	check	
Gaibanda	Sundarganj	10	119	135 V3	5.01	4.23	15.57
Kurigram	Sadar	12	121	136 V3	4.84	4.21	13.02
Lalmonirhat	Patgram	8	116	125 V4	4.78	4.02	15.90
Total		162					
Mean			117	120	4.50	3.99	11.21
V1 Mean (Sharna)				133	5.30	4.80	9.43
V2 Mean (Pazam)				123	4.03	3.38	16.15
V3 Mean (BRRI dhan 49)				139	4.62	4.15	10.08
V4 Mean (BRRI dhan 33)				122	4.66	4.08	12.40
V5 Mean (Local)				122	4.71	4.20	10.89
V6 Mean (BR11)				138	5.10	4.80	5.88

Data in Table 1 reveal that average grain yields of Binadhan-7 produced 4.50 $t\ ha^{-1}$ which was 11.21 percent higher compared to check varieties. Average maturity period of Binadhan-7 was 117 days. Six popular cultivars were used as check, which were: V1=Sharna, V2=Pazam, V3=BRRI dhan49, V4=BRRI dhan33, V5=local, V6=BR11. Binadhan-7 demonstrated better yield performance and harvested about 3-4 weeks earlier, which facilitated rabi crop cultivation timely after rice harvest. Adopting this variety an additional rabi crop can easily be cultivated. That means Binadhan-7 enables farmers getting higher aman production with an additional rabi crop which encouraged farmers massive adoption of this variety. That's why almost in all the locations farmers were found very much keen to cultivate Binadhan-7 in the up coming years. The results of Binadhan-7 reveal that this variety is suitable for massive extension in all the districts mentioned above. All over Bangladesh, especially moderately high land is suitable areas for cultivation of Binadhan-7. Northern region of Bangladesh including Satkhira, Gopalganj, Rangpur, Gaibandha, Panchagarh, Lalmonirhat, Feni, Nawgaon, Jamalpur, Netrakona, Sherpur and Mymensingh were found the most suitable area for Binadhan-7 cultivation.

Block Demonstrations with salt tolerant boro rice variety Binadhan-8 for massive extension in different locations

During boro season of 2013-14, 272 block demonstrations with Binadhan-8 were conducted at the farmer's fields in different agro-ecological zones in collaboration with the DAE. The main objectives were to demonstrate the yield performance of these varieties and widening their adoption by the farmers. Area of demonstration plots was one acre. Spacing between line-to-line and plant-to-plant was 20 cm × 15 cm. All fertilizers were applied as per recommended dose. Transplanting dates ranged from 10 to 31 January 2014, and age of seedlings was 35 to 40 days. The farmers managed all the production practices as per recommendation. Based on the available reports, data of demonstration plots are presented in Table 2.

Table 2. Performance of salt tolerant rice variety Binadhan-8 compared to popular cultivar in different locations during 2013-14

Districts	Upazila	Number of Demons.	Crop duration (days)		Seed yield (t ha^{-1})		Yield increase over check (%)
			Binadhan-8	Check	Binadhan-8	Check	
Satkhira	Debhata	6	137	140 V1	6.27	5.60	10.69
	Sadar	10	136	139 V1	6.12	5.61	8.33
	Kaliganj	7	138	137 L	4.54	4.37	3.74
	Shyamnagar	5	135	141 V1	5.32	5.45	-2.44
Noakhali	Companiganj	15	133	135 V1	4.86	4.12	15.23
Feni	Daganbhuiyan	15	139	128 V1	4.28	4.13	3.50
Chittagong	Bashkhali	10	136	147 L	5.87	4.79	18.40
Cox`s Bazar	Sadar	8	140	124 V1	6.56	4.14	36.89
	Teknaf	5	136	125 L	3.90	3.46	11.28
	Chakaria	12	141	132 V1	6.48	5.53	14.66
	Pakua	10	136	145	4.97	5.58	-12.27
	Ukhia	10	142	143 V1	5.60	4.83	13.75
	Ramu	5	138	139	5.42	5.97	-10.15
	Kutubdia	10	142	140 V1	4.45	4.34	2.47
Patuakhali	Dashmina	17	144	-	4.65	-	-
	Galachipa	17	127	-	5.17	-	-
	Kolapara	40	136	-	4.89	-	-
Barguna	Patharghata	15	132	-	4.72	-	-
	Amtali	15	129	141	4.83	5.13	-6.21
Bagerhat	Sadar	5	134	145 V2	4.69	3.98	15.14
	Fakirhat	10	145	143 V1	6.42	5.92	7.79
	Mollarhat	10	144	142 V1	3.95	3.76	4.81
	Rampal	5	139	146 V2	5.38	5.14	4.46
	Chitalmari	10	145	144 V2	6.32	5.85	7.44
Total		272					
Mean (Total)			138	140	5.24	4.89	6.70
V_1 Mean (BRRI dhan28)				137	5.48	4.86	11.41
V_2 Mean (BRRI dhan47)				145	5.46	4.99	8.66
L Mean (Local)				137	4.77	4.21	11.81

Data in Table 2, it was revealed that Binadhan-8 produced average grain yield of 5.24 t ha^{-1} with average maturity period of 138 days. Check varieties were BRRI dhan28, BRRI dhan 47and local cultivar, which produced average gain yield of 4.86, 4.99 and 4.21 t ha^{-1}, respectively. Farmers were found interested to cultivate Binadhan-8. They also made request BINA authority to conduct more demonstration at three localities for farmer’s motivation and their better understanding about the variety, Binadhan-8. Patuakhali, Barguna, Bagerhat, Satkhira, Feni, Noakhali, Cox`s Bazar and Chittagang were found suitable areas for cultivation of Binadhan-8. It needs more demonstration trials in different locations for identifying suitable areas of Binadhan-8 cultivation and thereby its massive promotion.

Block Demonstrations with salt tolerant rice variety Binadhan-10 compared to popular cultivar in different locations

During Boro season of 2013-14, 79 block demonstrations with Binadhan-10 were conducted at the farmer's fields in different agro-ecological zones in collaboration with the DAE. The main objectives were to demonstrate the yield performance of these varieties and widening their adoption by the farmers. Area of demonstration plots was one acre. Spacing between line-to-line and plant-to-plant was 20 cm × 15 cm. All fertilizers were applied by farmer as per recommendation. Transplanting dates ranged from 10 to 31 January 2014 and age of seedlings was 40 to 50 days. The farmers managed all the production practices. Based on the available reports, data of demonstration plots are presented in Table 3.

Table 3. Performance of salt tolerant rice variety Binadhan-10 compared to popular cultivar in different locations during 2013-14

Districts	Upazila	Number of Demons.	Crop duration (days)		Seed yield (t ha^{-1})		Yield increase over check (%)
			Binadhan-10	Check	Binadhan-10	Check	
Feni	Daganbhuiyan	5	136	130	5.31	4.85	8.66
Chittagang	Bashkhali	5	133	150L	5.94	4.89	17.68
Cox`s Bazar	Sadar	6	139	150L	6.53	5.43	16.85
	Teknaf	5	138	131V1	3.89	3.52	9.51
	Chakaria	4	143	132V1	6.52	5.50	15.64
	Pakua	3	137	-	4.99	-	-
	Uthia	2	145	139V1	5.69	6.05	-6.33
	Ramu	2	135	-	6.51	-	-
	Kutubdia	3	142	141V1	4.43	4.49	-1.35
Patuakhali	Dashmina	3	140	-	2.1	-	-
	Galachipa	3	128	-	5.13	-	-
	Kolapara	10	143	-	6.15	-	-
Borguna	Patharghata	10	136	-	5.03	-	-
	Amtali	5	148	146	4.98	4.80	3.61
Bagerhat	Sadar	3	134	152V1	4.78	4.56	4.60
	Fakirhat	3	143	147V2	6.36	5.90	7.23
	Mollarhat	2	132	147V2	3.94	3.00	23.86
	Rampal	2	136	149V2	5.25	5.67	-8.00
	Morrelganj	3	138	145V2	4.27	4.48	-4.92
Total		79					
Mean			138	143	5.15	4.86	12.43
V_1 Mean (BRRI dhan 28)				138	5.06	4.82	4.70
V_2 Mean (BRRI dhan 47)				147	4.95	4.76	3.79
L Mean (Local)				150	6.24	5.16	17.24

Data in Table 3 reveal that Binadhan-10 Produced average grain yields of 5.15 t ha^{-1}. Average maturity period of this variety was 138 days. Check varieties were BRRI dhan28, BRRI dhan47 and local cultivar which produced average gain yield of 4.82, 4.76 and 5.16 t ha^{-1}. Farmers were found very much interested to cultivate Binadhan-10 due to its better performance in both saline and non saline soils. They also made request BINA authority to conduct more demonstrations for farmers' motivation and their better understanding about the variety. Bagerhat, Barguna, Patuakhali, Cox`s Bazar, Feni and Chittagang were found suitable areas for cultivation of Binadhan-10. It needs more trials in different locations for identifying suitable areas of Binadhan-10 cultivation and thereby massive extension.

Block Demonstrations with submergence tolerant aman rice variety Binadhan-11 compared to popular cultivar in different locations

During aman season of 2013-14, 33 block demonstrations with submergence tolerant aman rice Binadhan-11 were conducted at the farmer's fields in different agro-ecological zones in collaboration with the DAE. The main objectives were to evaluate the performance of this variety at different flood prone areas and widening its adoption by the farmers. Area of each demonstration plot was one acre. Spacing between line-to-line and plant-to-plant was 20 cm × 15 cm. All fertilizers were applied by farmers as per recommendation. Transplanting dates ranged from 15 July to 05 August 2013 and age of seedlings was 20 to 25 days. Based on the available reports, data of demonstration plots are presented in Table 4.

Table 4. Performance of submergence tolerant aman rice Binadhan-11 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of Demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binadhan-11	check	Binadhan-11	check	
Sherpur	Sadar	1	119	111 V3	2.96	3.46	-16.89
	Nalitabari	2	130	156 V1	4.10	2.50	39.02
	Nokla	2	129	133 V1	4.50	3.00	33.33
	Jhenaigati	3	112	136 V5	4.00	3.8	5.00
	Shribardi	2	134	150	3.95	2.77	29.87
Jamalpur	Sadar	2	125	142 V5	4.45	4.50	-1.12
	Melandah	1	134	141 V4	4.12	3.80	7.77
	Islampur	1	120	130 V4	4.50	3.80	15.56
	Dewanganj	1	133	148	4.10	3.30	19.51
	Madarganj	1	138	146 V6	4.73	3.62	23.47
	Bakshiganj	1	122	127 V5	4.00	3.10	22.50
Netrakona	Kendua	1	131	137 V5	3.95	2.96	25.06
Sunamgonj	Sadar	2	124	140 V2	4.49	4.10	8.69
	Dakkhin Sunamgonj	1	115	135 V5	4.00	3.00	25.00
	Duarabazar	2	133	158 V5	4.10	3.50	14.63
	Bishsambarpur	2	124		4.20	-	-
	Jagannathpur	1	133	153 V5	4.00	2.60	35.00
	Jamalganj	1	111	145	3.70	3.20	13.51
	Tahirpur	1	136	140 V5	3.41	2.71	20.53

	Darmapasha	1	120	150	2.13	1.76	17.37
	Chatak	2	115	137 V2	4.40	4.00	9.09
	Derai	1	121	120 V5	4.14	2.30	44.44
	Sallah	1	137	-	4.00	-	-
Total		33					
Mean			126		4.38	3.23	11.21
V1 Mean (Tulshimala)				140	4.30	2.75	36.05
V2 Mean (BR11)				138	4.45	4.05	8.89
V4 Mean (Pajam)				135	4.31	3.8	11.83
V5 Mean (Local)				138	4.01	3.16	21.03
V6 Mean (BRRI dhan32)				146	4.73	3.62	23.47

Table 4 reveals that Binadhan-11 produced average grain yields of 4.38 t ha^{-1}, which was 11.21 percent higher compared to check varieties. Average maturity period of Binadhan-11 was 126 days. Nine popular cultivars were used as check, which were: V1=Tulshimala, V2=BR-11, V4=Pazam, V5=Local, V6=BRRI dhan32. Binadhan-11 demonstrated better yield performance in both submerged and normal condition. That's why almost in all the locations farmers were found very much keen to cultivate Binadhan-11 in the up coming years. The results of Binadhan -11 reveal that this variety is suitable for massive extension in all the districts mentioned above.

Piloting of drought escaping BINA developed improved cropping pattern in Barind area

BINA developed drought escaping cropping pattern of short duration T.aman-Rabi-Kharif 1 was piloted in Barind areas for its dessiminations and adoption. Details of the results are given below:

Piloting of transplanted aman variety Binadhan-7 during 2013-14

During the transplanted aman season a high yielding and short duration rice variety, Binadhan-7 was selected for piloting in the Barind area. Sixteen block farming with Binadhan-7 were carried out in Godagari and Tanore upazilla of Rajshahi district. Ten block farming were carried out in Ghoraghat, Birampur, Fulbari and Nababganj upazila of Dinajpur district and Ranisongkoyl of Thakurgaon district. Area of each block was 10 bighas. Seedlings of 20-25 days were transplanted. Applied fertilizers and all other management were as per recommendation. The results are given in Table-5(a) and Table-5(b):

Table 5(a). Location wise average yield and duration of Binadhan-7 in Rajshahi district during 2013-14

Upazilas	Number of Demons.	Date of transplanting	Date of harvesting	Duration (Days)	Yield (t ha^{-1})
Godagari	08	13-31 July, 2013	24 Oct-04 Nov. 2013	117	4.26
Tanore	08	26 June-08 July, 2013	23 Oct- 07 Nov, 2013	116	3.90
Total	16				
Mean				117	4.08

Table-5 (a) indicates that Binadhan-7 produced average grain yield of 4.08 t ha^{-1} and maturity duration was 117 days. Farmers were very interested for Binadhan-7 due to its short duration and encouraging grain yield that facilitated water saving and profitable rabi crop cultivation in proper time.

Table 5(b). Location wise average yield and duration of Binadhan-7 in Dinajpur and Thakurgaon district during 2013-14

Upazilas	Number of Demons.	Date of transplanting	Date of harvesting	Duration (Days)	Yield (t ha^{-1})
Ghoraghat	02	16-18 July, 2013	21-25 Oct, 2013	118	4.28
Birampur	02	08-03 July, 2013	05-15 Oct, 2013	115	4.19
Fulbari	02	17-18 July, 2013	22-26 Oct, 2013	118	4.28
Nababgonj	03	01-11 July, 2013	04-18 Oct, 2013	117	4.35
Ranisongkoyl	01	17 July, 2013	22 Oct, 2013	119	3.95
Total	10				
Mean				117	4.21

Data in Table 5 (b) indicates that Binadhan-7 produced average grain yield of 4.21 t ha^{-1} and maturity duration was 117 days while crop duration of extensively cultivated cultivar sharna is 145-150 days having similar yield with the Binadhan-7. Farmers were very interested for Binadhan-7 due to short duration and encouraging grain yield which facilitated water saving and profitable rabi crop cultivation in proper time.

Piloting of selected rabi crops during 2013-14

In the rabi season of 2013-14 sixteen blocks farming with Binasarisha-4, Binasola-4 and BARIgom-26 were carried out in Godagari and Tanore upazilla of Rajshahi district and ten block farming with Binasarisha-4 were carried out in Ghoraghat, Birampur, Fulbari and Nababgonj upazila of Dinajpur district and Ranisongkoyl of Thakurgoan district. Area of each block was 10 bighas. Required seeds and inputs were supplied to the farmers. Details of the cultivated different crops are given in Table 6(a) and Table 6(b).

Table 6(a). Location wise yield and duration of selected rabi crops in Rajshahi district during 2013-14

Upazilas	Number of Demons.	Crops	Date of sowing	Date of harvesting	Duration (Days)	Yield (t ha^{-1})
	3	Wheat	07-12 Nov, 2013	25 Feb–11 Mar, 2014	115	3.87
Godagari	4	Chickpea	10-17 Nov, 2013	06-11 Mar, 2014	116	1.41
	1	Mustard	11 Nov, 2013	07 Feb, 2014	87	1.34
	2	Wheat	18 Nov, 2013	08 Mar, 2014	112	4.67
Tanore	4	Chickpea	09-22 Nov, 2013	09 Mar-01 Apr, 2014	119	0.91
	2	Mustard	10-21 Nov, 2013	17–20 Feb, 2014	88	1.59
Total	16					
		Mustard (Binasarisha-4)			88	1.47
Mean		Wheat (BARIgom-26)			114	4.27
		Chickpea (Binasola-4)			118	1.16

Table 6(a) indicates that Binasarisha-4, BARIgom-26 and Binasola-4 produced average seed/grain yield of 1.47, 4.27 and 1.16 t ha^{-1}, respectively and maturity durations were 88, 114 and 118 days, respectively.

Table 6(b). Location wise yield and duration of Binasarisha-4 in Dinajpur and Thakurgoan district during 2013-14

Upazilas	Crops	Number of Demons.	Date of transplanting	Date of harvesting	Duration (Days)	Yield (t ha^{-1})
Ghoraghat		02	15-18 Nov, 2013	12-15 Feb, 2014	87	1.05
Birampur		02	12-14 Nov, 2013	09-10 Feb, 2014	86	1.15
Fulbari	Mustard	02	07-08 Nov, 2013	15-17 Feb, 2014	92	1.48
Nobabgonj		03	11-14 Nov, 2013	13-16 Feb, 2014	91	1.50
Ranisongkoyl		01	20 Nov, 2013	18 Feb, 2014	88	1.38
Total		10				
Mean					89	1.31

Data in Table 6(b) indicates that Binasarisha-4 produced average grain yield of 1.31 t ha^{-1} and maturity duration was 89 days.

Piloting of selected kharif-1 crops during 2013-14

During the kharif season of 2013-14 sixteen block farming with Binamoog-8 and Binatil-1 were carried out in Godagari and Tanore upazilla of Rajshahi district and 10 block farming with Binamoog-8 and Binatil-1 were carried out in Ghoraghat, Birampur, Fulbari and Nababgonj upazila of Dinajpur district and Ranisongkoyl of Thakurgoan district. Area of each block was 10 bighas. Required seeds and inputs were supplied to the farmers as per recommendation. Details of the cultivated different crops are given in Table- 7(a) and Table 7(b):

Table-7(a). Location wise yield and duration of the varieties Binamoog-8 and Binatil-1 in Rajshahi district during 2013-14

Upazilas	Number of Demons.	Crops	Date of sowing	Date of harvesting	Duration (Days)	Yield (t ha^{-1})
Godagari	5	Mungbean	20 Mar-09 Apr, 2013	07 June-07 July, 2013	86	0.71
	3	Sesame	07-10 Apr, 2013	30 June-09 July, 2013	85	0.87
Tanore	3	Mungbean	18 Mar-11 Apr, 2013	28 May-21 June, 2013	77	0.83
	5	Sesame	21 Mar-15 Apr, 2013	25 June-08 July, 2013	89	0.78
Total	16					
Average		Mungbean (Binamoog-8)			82	0.77
		Sesame (Binatil-1/2)			87	0.83

Data in Table 7(a) indicates that Binamoog-8 and Binatil-1 produced average seed yield of 0.77 and 0.83 t ha^{-1} and maturity duration was 82 and 87 days, respectively. Binamoog-8 and Binatil-1 produced poor yield due to irrigation problem in this seasons.

Table 7(b). Location wise yield and duration of the varieties Binamoog-8 and Binatil-1 in Dinajpur and Thakurgoan district during 2013- 14

Upazilas	Crops	Number of Demons.	Date of transplanting	Date of harvesting	Duration (Days)	Yield (t ha^{-1})
Ghoraghat	Mungbean	01	18 Mar, 2013	01June, 2013	75	0.77
	Sesame	01	26 Mar, 2013	25 June, 2013	90	0.76
Birampur	Sesame	02	29 Mar, 2013	26 June, 2013	87	0.84
Fulbari	Mungbean	01	14 Mar, 2013	01 June, 2013	76	0.82
	Sesame	01	21 Mar, 2013	15 June, 2013	84	0.72
Nobabgonj	Mungbean	02	27-28 Mar, 2013	14-15 June, 2013	80	0.85
	Sesame	01	15 Mar, 2013	12 June, 2013	88	0.81
Ranisongkoyl	Mungbean	01	17 Mar, 2013	05 June, 2013	78	0.95
Total		10				
Mean			Mungbean (Binamoog-8)		77	0.85
			Sesame (Binatil-1/2)		87	0.78

Data in Table 7(b) indicates that Binamoog-8 and Binatil-1 produced average grain yield of 0.85 t ha^{-1} and 0.78 t ha^{-1}, respectively and maturity duration was 77 and 87 days, respectively. Binamoog-8 and Binatil-1 produced lower yield due to irrigation problem in this seasons. Ground water level is highly declining in these areas.

Identify the best cropping pattern with water saving condition in Barind area during 2013-14

Table 8. Best cropping pattern in Barind areas with BCR during 2013-14

No.	Demonstrated cropping sequence of	Total income	Total cost	BCR	Comments
1.	T. aman-chickpea-mungbean	194670.00	146215.00	1.33	Ranked 6
2.	Cropping sequence of T. aman-mustard-mungbean	206010.00	142142.00	1.45	Ranked 2
3.	Cropping sequence of T. aman-wheat-mungbean	218260.00	147959.00	1.48	Ranked 1
4.	Cropping sequence of T. aman-chickpea-sesame	189210.00	147798.00	1.28	Ranked 7
5.	Cropping sequence of T.aman-mustard-sesame	200550.00	143725.00	1.40	Ranked 4
6.	Cropping sequence of T.aman-wheat-sesame	212800.00	149542.00	1.42	Ranked 3
7.	Check (T. aman-boro)	205400.00	146434.00	1.40	Ranked 5

Block Demonstration/Farmers' Observation Trials with oilseed varieties developed by BINA

Block Demonstrations with mustard varieties, Binasarisha-4 compared to best local variety

During the Rabi season of 2013-14, 45 block demonstrations were conducted with Binasarisha-4 in 9 different districts in collaboration with the DAE. The main objectives were to demonstrate the performance of Binasarisha-4 to evaluate their location specific suitability and widen adoption by the farmers. Unit plot size of block demonstrations was one acre at all the locations. Seeds were sown during October to November 2013 at the rate of 7.5 kg ha^{-1}. The local check varieties were Tori-7. All fertilizers were applied as per recommendation and 1-2 irrigation was applied in the demonstration plots. Pesticides were sprayed as and when necessary to control insects and pests. Data were recorded on crop duration and seed yield. The results are presented in Table 12.

Table 9. Performance of Binasarisha-4 compared to best control variety at block demonstrations in different districts during 2013-2014

District	Upazila	No. of Demons.	Crop duration (seed to seed) in days		Seed yield (t ha^{-1})		Yield increased over check (%)
			Binasarisha-4	Tori-7 (Check)	Binasarisha-4	Tori-7 (Check)	
Faridpur	Madhukhali	4	89	74	1.61	0.88	82.95
Jessore	Bagharprara	4	88	75	1.62	0.93	74.19
Chuadanga	Alamdanga	4	87	74	1.51	0.85	77.65
Jhenaidah	Kotchandpur	4	86	78	1.35	0.87	55.17
Kushtia	Sadar	4	87	76	1.59	0.89	78.65
Narail	Lohagora	4	86	75	1.63	0.92	77.17
Tangail	Ghatail	3	87	76	1.56	0.89	75.28
	Kalihati	3	88	77	1.54	0.82	87.80
Madaripur	Sadar	2	87	75	1.71	0.96	78.13
	Rajoir	3	87	75	1.37	0.85	58.82
	Kalkini	3	86	76	1.53	0.87	75.86
	Shibchar	2	87	77	1.61	0.92	75.00
Narayanganj	Rupganj	5	89	84	1.58	0.96	64.58
Total		45					
Mean			87	76	1.55	0.89	73.90

Table 12 shows that Binasarisha-4 produced average seed yield of 1.55 t ha^{-1}, which was 73.90 percent higher than the control variety Tori-7 (0.89 t ha^{-1}). The highest yield of Binasarisha-4 was produced at Sadar in Madaripur (1.71 t ha^{-1}) while the lowest seed yield was at Kotchandpur in Jhenaidah (1.35 t ha^{-1}).

Block Demonstrations with mustard varieties, Binasarisha-9 compared to best local variety

During the rabi season of 2013-14, 5 block demonstrations were conducted with Binasarisha-9 in 3 different districts in collaboration with the DAE. The main objectives were to demonstrate the performance of Binasarisha-9 to evaluate their location specific suitability and widen adoption by the farmers. Unit plot size of block demonstrations was one bigha at all the locations. Seeds were sown during October to November 2013 at the rate of 7.5 kg ha^{-1}. The local check varieties were Tori-7. All fertilizers were applied as per recommendation and 1-2 irrigation was applied in the demonstration plots. Pesticides were sprayed as and when necessary to control insects and pests. Data were recorded on crop duration and seed yield. The results are presented in Table 13.

Table 10. Performance of Binasarisha-9 compared to best control variety at block demonstrations in different districts during 2013-14

District	Upazila	No. of Demons	Crop duration (seed to seed) in days		Seed yield (t ha^{-1})		Yield increased over check (%)
			Binasarisha-9	Tori-7 (Check)	Binasarisha-9	Tori-7 (Check)	
Mymensingh	Sadar	1	84	75	1.51	0.97	55.67
		1	83	76	1.52	0.89	70.79
Narail	Lohagara	1	83	74	1.25	0.91	37.36
Jessore	Baghar para	1	85	75	1.58	0.88	79.55
		1	82	77	1.59	0.89	78.65
Total		5					
Mean			83	75	1.49	0.91	64.10

Table 13 shows that Binasarisha-9 produced average seed yield of 1.49 t ha^{-1}, which was 64.10 percent higher than the control variety Tori-7 (0.91 t ha^{-1}). The highest yield of Binasarisha-9 was produced at Baghar para in Jessore (1.59 t ha^{-1}) while the lowest seed yield was at Lohagara in Narail (1.25 t ha^{-1}).

Block Demonstrations with mustard varieties, Binasarisha-10 compared to best local variety

During the rabi season of 2013-14, 5 block demonstrations were conducted with Binasarisha-10 in 3 different districts in collaboration with the DAE. The main objectives were to demonstrate the performance of Binasarisha-10 to evaluate their location specific suitability and widen adoption by the farmers. Unit plot size of block demonstrations was one bigha at all the locations. Seeds were sown during October to November 2013 at the rate of 7.5 kg ha^{-1}. The local check varieties were Tori-7. All fertilizers were applied as per recommendation and 1-2 irrigation was applied in the demonstration plots. Pesticides were sprayed as and when necessary to control insects and pests. Data were recorded on crop duration and seed yield. The results are presented in Table 14.

Table 14. Performance of Binasarisha-10 compared to best control variety at block demonstrations in different districts during 2013-14

District	Upazila	No. of Demons	Crop duration (seed to seed) in days		Seed yield (t ha^{-1})		Yield increased over check (%)
			Binasarisha-10	Tori-7 (Check)	Binasarisha-10	Tori-7 (Check)	
Mymensingh	Sadar	1	76	75	1.41	0.89	58.43
		1	75	73	1.46	0.83	75.90
Narail	Lohagara	1	76	74	1.35	0.88	53.41
Jessore	Baghar para	1	76	75	1.52	0.79	92.41
		1	75	76	1.53	0.87	75.86
Total		5					
Mean			76	75	1.45	0.85	70.66

Table 14 indicated that Binasarisha-10 produced average seed yield of 1.45 t ha^{-1}, which was 70.66 percent higher than the control variety Tori-7 (0.85 t ha^{-1}). The highest yield of Binasarisha-10 was produced at Baghar para in Jessore (1.53 t ha^{-1}) while the lowest seed yield was at Sadar in Madaripur (1.35 t ha^{-1}).

Block Demonstrations with Binachinabadam-4 compared to local variety

During kharif-2 season of 2013-2014, 40 block demonstrations with Binachinabadam-4 were conducted at farmers' plots in 4 districts in collaboration with DAE. The objectives were to demonstrate and evaluate the performance of Binachinabadam-4 for its dissemination and encourage the farmers for adopting these varieties as well as making available seeds for the farmers for the next Rabi and Kharif-1 seasons. Unit plot size of individual block demonstrations was 1 bigha at all the locations. Seeds were sown during July to August 2010. The local check variety was Dhaka-1. Fertilizers were applied as per recommendation. Pesticides were also sprayed as and when necessary to control insects and pests. Data were recorded on crop duration and grain yield. The results are presented in Table 15.

Table 15. Performance of Binachinabadam-4 at block demonstration in different districts during Kharif-2 season of 2013-14

District	Upazila	Number of Demons.	Crop duration (days)		Grain yield (t ha^{-1})		Yield increased over check (%)
			Bina chinabadam-4	Dhaka-1 (check)	Bina chinabadam-4	Dhaka-1 (check)	
Lalmonirhat	Kaliganj	5	143	145	1.98	1.37	44.53
	Aditmari	5	141	143	2.08	1.33	56.39
Jhenaidah	Moheshpur	5	143	145	2.22	1.28	73.44
	Kaligonj	5	145	146	2.01	1.36	47.79
Kishoregonj	Bhairab	5	139	141	2.45	1.39	76.26
Natore	Sadar	5	140	143	2.04	1.35	51.11
Panchagarh	Sadar	2	141	142	2.18	1.28	70.31
	Debiganj	3	137	138	2.26	1.26	79.37
Jessore	Sharsha	5	142	143	1.96	1.25	56.80
Total		40					
Mean			141	143	2.13	1.32	61.58

In observes from table 15 that Binachinabadam-4 produced average seed yield of 2.13 t ha^{-1}, which was 61.58 percent higher than the check variety Dhaka-1 (1.32 t ha^{-1}). Binachinabadam-4 produced the highest seed yield (2.45 t ha^{-1}) at Bhairab in Kishoreganj while the lowest was at Sharsha in Jessore (1.96 t ha^{-1}). It is well known that Lalmonirhat, Natore and Jhenaidah were the popular seed growing as well as groundnut growing areas. Farmers of said districts were growing their groundnut seeds throughout the year for their personal use and for commercial purpose. Therefore, there was a great opportunity to disseminate Binachinabadam-4 in those districts. That's why farmers of other groundnut growing districts will be able to collect their seeds from Lalmonirhat, Natore and Jhenaidah.

Block Demonstrations with Binatil-2 compared to local check variety

During Kharif-1 season of 2013-14, 30 block demonstrations with variety Binatil-2 were conducted at farmers' plots in 5 districts in collaboration with DAE. The objectives were to demonstrate and evaluate the performance of Binatil-1 for their dissemination and encourage the farmers for adopting these varieties. Unit plot size of individual block demonstration was 1 bigha at all the locations. Seeds were sown during February to March 2014. The local check variety was atshira. Fertilizers were applied as per recommendation. Pesticides were also sprayed as and when necessary to control insects and pests. Data were recorded on crop duration and seed yield. The results are presented in Table 16.

Table 16. Performance of Binatil-2 compared to local check variety at block demonstrations in different districts during 2013-14

District	Upazila	No. of Demons	Crop duration (seed to seed) in days		Seed yield (t ha^{-1})		Yield increased over Check (%)
			Binatil-2	Atshira	Binatil-2	Atshira	
Kushtia	Sadar	4	94	93	1.63	1.61	1.24
Jessore	Bagharpara	4	96	95	1.41	1.38	2.17
Faridpur	Madhukhali	4	92	92	1.42	1.37	3.65
Chuadanga	Alamdanga	4	93	92	1.39	1.31	6.11
Jhenaidah	Cotchandpur	4	95	93	1.33	1.34	-0.75
	Kaliganj	4	94	92	1.23	1.19	3.36
Magura	Shalikha	6	97	96	1.38	1.39	-0.72
Total		30					
Mean			94	93	1.40	1.37	2.09

Table 16 reveals that Binatil-2 produced average seed yield of 1.40 t ha^{-1}, which was 2.09 percent higher than the control variety atshira (1.37 t ha^{-1}). Highest seed yield (1.63 t ha^{-1}) was found at Sadar in Kushtia while the lowest (1.23 t ha^{-1}) was at Kaliganj in Jhenaidah.

Block Demonstrations with soybean varieties, Binasoybean-1, Binasoybean-2, Binasoybean-3 and Binasoybean-4 compared to local variety

During kharif-1 season of 2013-14, 7 block demonstrations with Binasoybean-1, 2, 3 and 4 were conducted at farmers' plots in 2 districts (Chandpur, Lakshmipur) in collaboration with DAE. The objectives were to demonstrate and evaluate the performance of Binasoybean-1, Binasoybean-2, Binasoybean-3 and Binasoybean-4 for its dissemination and encourage the farmers for adopting these varieties as well as making available seeds for the farmers for the next seasons. Unit plot size of individual block demonstrations was 1 bigha at all the locations. Seeds were sown during mid January, 2014 in kharif-1 season. The local check variety was Shohag in all the locations. Fertilizers were applied as per recommendation. Data were recorded on crop duration and grain yield. The results are presented in Table 15.

Table 15. Performance of Binasoybean-1, -2, -3 & -4 compared to local check variety at block demonstrations in different districts during Kharif-1 season of 2013-14

District	Upazila	No. of Demons	Crop Duration (days)				
			Binasoybean-1	Binasoybean-2	Binasoybean-3	Binasoybean-4	Shohag
Chandpur	Haimchor	3	106	107	110	110	115
Lakshmipur	Komolnagar	4	103	100	102	103	107
District	Upazila	No. of Demons	Yield (t ha^{-1})				
			Binasoybean-1	Binasoybean-2	Binasoybean-3	Binasoybean-4	Shohag
Chandpur	Haimchor	3	2.63	2.66	2.70	2.17	2.20
Lakshmipur	Komolnagar	4	2.60	2.71	2.69	2.20	2.09
Total	7						
Mean		2.62	2.68	2.70	2.19	2.15	

Table 15 shows that in kharif-1 season, Binasoybean-3 produced the highest seed yield (2.70 t ha^{-1}) at Haimchar in Chandpur while the lowest was at Kamalnagar in Lakshmipur (2 t ha^{-1}). Comments of farmers' and extension personnel on Binasoybean-3 were, it was a high yielding and larger pod bearing variety, that's why market price was higher than that of local variety, almost no pest infestations observed and most of the farmers' interested to cultivate this variety next year. In addition, it should be noted that farmers said of districts were growing their soybean seeds throughout the year for their own use and for commercial purposes. Therefore, there was a great opportunity to disseminate Binasoybean-3 in those districts. That's why farmers of other soybean growing districts will be able to collect their seeds from Chandpur and Lakshmipur. Further trials should be needed to identify suitable area for large-scale cultivation of Binasoybean varieties.

Farmers Observation Trials (FOTs)/ Block Demonstration with Pulse Varieties Developed at BINA

Block Demonstration of chickpea variety Binasola-4 in different AEZ in collaboration with DAE

During the rabi season of 2013-14, a total of 14 demonstrations on Binasola-4 were set up at the farmer's fields in three upazila of two districts Jessore and Magura. The main objectives were to demonstrate and evaluate the performance of Binasola-4 across the locations and encourage the farmers to continue the variety in their fields. The area for each of the demonstration plots was one acre where 5 decimal was allocated for check variety. Sowing time ranged from mid November to mid December, 2013. It is notable here that sowing dates within a month have been categorized into three intervals; first 10 days as early, middle 10 days as mid and last 10 days as late of the respective month. In all cases seeds were sown using broadcast method at the rate of 30 kg ha^{-1}. The fertilizers like urea, TSP, MoP, gypsum and zinc sulphate were applied at the rate of 35, 120, 70, 90 and 4 kg ha^{-1}, respectively. All intercultural operations were managed by the farmers as and when required. Data on sowing time, crop duration, seed yield, and insect and disease infestation were recorded. The results are presented in the Table 16:

Table 16. Performance of Binasola-4 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binasola-4	Check*	Binasola-4	check	
Magura	Sadar	3	121	119	1.67	1.21	27.54
Jessore	Sadar	6	118	113	1.31	1.12	14.50
	Jhikargacha	5	121	121	1.54	1.21	21.43
Total		14					
Mean			120	118	1.51	1.18	21.16

It is evident from the Table 16, that average duration of Binasola-4 was 120 days. The average seed yield of Binasola-4 was 1.51 t ha^{-1}, which was 21 percent higher than the check cultivar. The highest yield (1.67 t ha^{-1}) was recorded at sadar of Magura district and the lowest yield (1.31 t ha^{-1}) was recorded at sadar of Jessore. Late sowing might be one of the vital reasons of low yield. Shiny seed coat of Binasola-4 was also marked by the farmers as an additional advantage, especially for higher market price. However, farmers shown their deep interest to cultivate Binasola-4 due to its more yields, shinny seed coat, less pest and disease infestation.

Block demonstration of chickpea variety Binasola-6 in different AEZ in collaboration with DAE

During the rabi season of 2013-14, a total of 15 block demonstrations with Binasola-6 were set up at the farmer's fields in three upazila of two districts Jessore and Magura for adoption. In all cases seeds were sown using broadcast method at the rate of 30 kg ha^{-1}. The fertilizers like urea, TSP, MoP, gypsum and zinc sulphate were applied at the rate of 35, 120, 70, 90 and 4 kg ha^{-1}, respectively. The farmers managed all intercultural operations as and when required. Data on sowing time, crop duration, seed yield, and insect and disease infestation were recorded. The results are presented in the Table 17.

Table 17. Performance of Binasola-6 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binasola-6	check (BARIsola-5)	Binasola-6	check (BARIsola-5)	
Magura	Sadar	3	126	119	1.61	1.29	19.88
Jessore	Sadar	4	120	113	1.31	1.11	15.27
	Jhikargacha	5	121	122	1.65	1.18	28.48
Rajshahi	Tanore	3	123	118	1.44	1.13	21.53
Total		15					
Mean			123	118	1.50	1.18	21.29

The Table 17 indicates the facts that the average crop duration of Binasola-6 was 123 days. But the average yield of Binasola-6 was 1.50 t ha^{-1}, which was 21 percent higher than the check variety BARIsola-5. The highest yield (1.65 t ha^{-1}) was recorded at Jhikargacha of Jessore district and the lowest yield was at sadar, Jessore district. The yield data revealed the facts that more area of Jessore and Rajshahi districts could be brought under the cultivation of Binasola-6 through massive extension and media campaign among the farmers.

Block demonstration of lentil variety Binamasur-5 in different AEZ in collaboration with DAE

A total of forty nine block demonstrations with Binamasur-5 were set up at the farmer's fields in forteen upazila under eight districts. The main objectives were to demonstrate and evaluate the performance of Binamasur-5 compared to check variety across the locations and encourage the farmers to continue the variety in their fields. The area for each of the demonstration plots was one acre where 5 decimal were allocated for control variety BARI masur-6. Data on crop duration, insect and disease infestation and seed yield were recorded. The results are presented in the Table 18.

Table 18. Performance of Binamasur-5 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binamasur-5	BARI masur-6	Binamasur-5	BARI masur-6	
Magura	Sadar	1	104	98	2.12	1.87	1.78
Madaripur	Kalkini	3	106	95	2.21	1.95	1.85
	Shibchar	3	102	92	2.04	1.65	2.79
Gopalganj	Sadar	4	105	98	1.89	1.71	1.29
	Moksedpur	2	100	93	2.02	1.69	2.36
Rajbari	Sadar	3	107	94	2.17	1.86	2.21
	Pangsha	4	103	97	1.95	1.74	1.5
Faridpur	Sadar	4	101	91	1.97	1.92	0.35
	Bhanga	5	112	93	2.01	1.3	5.07
Natore	Sadar	5	106	95	2.11	1.33	5.57
	Baraigram	3	102	99	1.81	1.14	4.78
Kushtia	Sadar	3	108	97	2.14	1.19	6.78
	Mirpur	4	105	96	2.03	1.02	7.21
Bogra	Dhunat	5	109	96	2.01	1.88	0.93
Total		49					
Mean			105	95	2.03	1.59	3.18

The data in Table 18 indicates that no difference was observed in duration of Binamasur-5 and the check variety. But the average yield of Binamasur-5 was 2.03 t ha^{-1}, which was three prcent higher than the check variety. The highest seed yield (2.21 t ha^{-1}) was recorded at Kalkini upazila of Madaripur district. No influence of sowing time was observed on yield of Binamasur-5.

Block Demonstration of mungbean variety, Binamoog-5 in different AEZ in collaboration with DAE

During the Kharif-1 season of 2013-14, a total of 12 block demonstrations with mungbean variety, Binamoog-5 were conducted at farmers' fields in 4 districts. The Department of Agriculture Extension (DAE) was the main collaborator in implementing the demonstrations programme. The main objectives were to demonstrate and evaluate the performance of Binamoog-5 for its dissemination and adoption among the farmers. The area of each of the demonstrations was one acre. The trials were conducted under farmers' own management. Farmers of the southern districts like Patuakhali and Barisal have started sowing in mid February and continued up to end February. On the other hand, sowing started in late March and continued up to end April in the north-western districts like Dinajpur, Jessore and Pabna. In all cases, seeds were sown using broadcast method at the rate of 30 kg ha^{-1}. The fertilizers like urea, TSP, MoP, gypsum and zinc sulphate were applied at the rate of 35, 120, 70, 90 and 4 kg ha^{-1}, respectively. The available data on sowing time, crop duration and seed yield are presented in the Table 19.

Table 19. Performance of Binamoog-5 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binamoog-5	BARImoog-6	Binamoog-5	BARImoog-6	
Panchagarh	Sadar	3	77	74	1.21	1.00	17.36
Pabna	Atgaria	2	81	76	1.09	0.86	21.10
	Ishwardi	1	78	75	1.12	1.11	0.89
Jessore	Sadar	3	79	71	1.02	1.00	1.96
Magura	Sadar	3	81	73	0.87	0.95	-9.20
Total		12					
Mean			79	74	1.06	0.98	6.42

It is revealed from the Table 19 that Binamoog-5 required average crop duration of 79 days to mature. The average yield of Binamoog-5 was 1.06 t ha^{-1} across the locations. Drought tolerance and consistent higher seed yield characteristics of Binamoog-5 encouraged the farmers in taking decision to continue this variety in their fields. However, farmers showed their interest to cultivate this variety for its shinny seed coat, drought tolerance and higher seed yield.

Block demonstration of mungbean variety, Binamoog-6 in different AEZ in Collaboration with DAE

A total of 8 block demonstrations with mungbean variety, Binamoog-6 were conducted at farmers' fields in four districts. The DAE was the main collaborator in making the demonstrations successful. The objectives were to demonstrate and evaluate the performance of Binamoog-6 for its dissemination and adoption among the farmers. The area of each of the demonstrations was one acre. The seed rate and fertilizer dose were similar as of Binamoog-5. The trials were conducted under farmers' own management in rain-fed condition. Data on sowing time, crop duration and seed yield are presented in the Table 20.

Table 20. Performance of Binamoog-6 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binamoog-6	BARImoog-6	Binamoog-6	BARImoog-6	
Panchagarh	Sadar	3	72	69	1.14	1	12.28
Pabna	Ishwardi	2	69	68	0.92	0.84	8.70
Jessore	Sadar	1	72	70	0.87	0.89	-2.30
Magura	Sadar	2	71	71	1.12	0.98	12.50
Total	8						
Mean			71	70	1.01	0.93	7.79

The average seed yield of Binamoog-6 was 1.01 t ha^{-1}, which was 7.79% higher than the check variety. The highest yield was recorded at Sadar, Panchagar district. Farmers show their positive attitude to cultivate this variety.

Block demonstration of mungbean variety, Binamoog-7 in different AEZ in Collaboration with DAE

A total of 6 block demonstrations with mungbean variety, Binamoog-7 were conducted at farmers' fields in four districts. The Department of Agriculture Extension (DAE) was the main collaborator in making the demonstrations successful. The objectives were to demonstrate and evaluate the performance of Binamoog-7 for its dissemination and adoption among the farmers. The area of each of the demonstrations was one acre. The seed rate and fertilizer dose were similar as of Binamoog-5. The trials were conducted under farmers' own management. Data on sowing time, crop duration and seed yield are presented in the Table 21.

Table 21. Performance of Binamoog-7 compared to popular cultivar in different locations during 2013-14

District	Upazila	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
			Binamoog-7	BARImoog-6	Binamoog-7	BARImoog-6	
Panchagarh	Sadar	2	73	71	1.12	1.12	0.00
Pabna	Ishwardi	2	71	73	1.29	1.01	21.71
Jessore	Sadar	2	81	69	0.91	0.89	2.20
Magura	Sadar	2	79	69	1.26	0.79	37.30
Total	8						
Mean			76	70.5	1.15	0.95	15.30

The table revealed that the duration of Binamoog-7 and the check variety was very much identical; Seed yield of Binamoog-7 was 15.30% higher than the check variety. The highest yield (1.48 t ha^{-1}) was recorded at Ishwardi at Pabna district.

Block demonstration of mungbean variety, Binamoog-8 in different AEZ in Collaboration with DAE

A total of 103 block demonstrations with mungbean variety, Binamoog-8 were conducted at farmers' fields in eleven districts. The Department of Agriculture Extension (DAE) was the main collaborator in making the demonstrations successful. The objectives were to demonstrate and evaluate the performance of Binamoog-8 for its dissemination and adoption among the farmers. The area of each of the demonstrations was one acre. The trials were conducted under farmers' own management. Data on sowing time, crop duration and seed yield are presented in the Table 22.

It is revealed from the data in Table 22 that there was no remarkable difference between the duration of Binamoog-8 and the check variety BARImoog-6. Binamoog-8 produced average seed yield of 1.19 t ha^{-1} which was 7.69% higher than the check variety. The highest yield (1.53 t ha^{-1}) was recorded at Sadar upazila under Magura district.

Table 22. Performance of Binamoog-8 compared to popular cultivar in different locations during 2013-14

District	Number of demons.	Duration (days)		Yield (t ha^{-1})		Yield increased over check (%)
		Binamoog-8	BARImoog-6	Binamoog-8	BARImoog-6	
Panchagarh	5	70	69	1.13	1.11	1.77
Thakurgaon	5	72	73	1.24	1	19.35
Dinajpur	5	73	74	1.14	1.12	1.75
Rajshahi	5	75	72	1.09	1.25	-14.68
Joypurhat	25	71	70	1.11	0.98	11.71
Naogaon	40	69	72	0.97	0.87	10.31
Bogra	5	74	69	0.89	1.03	-15.73
Pabna	5	70	76	1.12	0.87	22.32
Natore	4	68	69	1.42	1.28	9.86
Jessore	2	76	75	1.46	1.24	15.07
Magura	2	73	70	1.53	1.18	22.88
Total	103					
Mean		72	72	1.19	1.08	7.69

Establishment of BINA-Technology Pilot Area (BINA-Village)

In order to establish BINA-Tech. village, Block Demonstrations and other extension work were done in collaboration with the DAE and BINA-substations at the farmer's fields in surrounding areas of BINA Head quarter and its sub-stations. Results of overall promotional activities related to BINA-Technology village establishment at different locations are presented below:

Block Demonstration with BINA developed different crop varieties in surrounding areas of BINA Headquarter, Mymensingh

During 2013-14, 95 Block Demonstrations were conducted with BINA developed two crop varieties at Sutiakhali, Khagdahar and Poranganj villages under sadar upazila of Mymensingh district. Results of Demonstrations are presented in Table 23.

Table 23. Performance of BINA varieties in some areas of sadar upazila, Mymensingh district during 2013-14

Variety	Total No. of Demonstration	Av. Duration in days	Yield (t ha^{-1})
Rice			
Binadhan-7	25	117	4.43
Binadhan-11	10	123	4.52
Binadhan-12	10	126	4.34
Binadhan-5	20	155	6.25
Binadhan-10	5	136	5.65
Binadhan-14	7	117	5.78
Total	77		
Oil seeds:			
Binasarisha-4	18	82	1.31
Total	18		
Grand Total	95		

Mymensingh district is mostly suitable for rice cultivation and that of partly for mustard growing. Results in Table 23 depict that rice varieties of Binadhan-7, Binadhan-11, Binadhan-12, Binadhan-5, Binadhan-10 and Binadhan-14 produced grain yield of 4.43 t ha^{-1}, 4.52 t ha^{-1}, 4.34 t ha^{-1}, 6.25 t ha^{-1}, 5.65 t ha^{-1} and 5.78, respectively. Binasarsha-4 also produced seed yield of 1.31 t ha^{-1}. An extra rabi crop could easily be cultivated adopting Binadhan-7 in aman season having higher yield of aman rice. A cropping pattern of "Binadhan-7 - Binasarisha-4 - Boro rice" has demonstrated very suitable and highly profitable in Poranganj of sadar upazila. These BINA varieties following above cropping pattern are disseminating spontaneously among the farmers.

COMILLA SUB-STATION

Block Demonstration with different BINA developed crop varieties around Comilla Sub-station

During 2013-14, 17 block demonstrations were conducted with BINA developed three crop varieties at Rasulpur and Palpara villages under Sadar upazila of Comilla district. Results of Demonstrations are presented in Table 24.

Table 24. Performance of BINA varieties in some areas of sadar upazila, Comilla district during 2013-14

Variety	Total No of Demonstration	Av. Duration in days	Yield (t ha^{-1})
Rice			
Binadhan-5	4	152	5.65
Binadhan-14	2	121	6.21
Binadhan-10	3	132	5.58
Binadhan-7	5	117	4.22
Total	14		
Oil seeds			
Binasarisha-4	4	85	1.43
Total	3		
Grand Total	17		

Rasulpur village in Comilla district is mostly suitable for rice cultivation and partly that of vegetables and oilseeds. Results in Table 24 indicate that Binadhan-5 produced higher grain yield. Farmer's interest seemed to be most positive for Binadhan-7 in Aman. Mustard variety, Binasarisha-4 showed immense potentials in terms of yield and duration for cultivation in between aman and boro rice. However, it needs further trials for technical support and farmers motivation. Establishment of BINA technology village is underway through promotional activities of mutant varieties in Rasulpur villlage.

ISHWARDI SUB-STATION

Block Demonstration with different BINA developed crop varieties around Ishwardi sub-station

During 2013-14, 27 block demonstrations were conducted with BINA developed promising 8 crop varieties at some villages under Ishwardi upazilla of Pabna district around the BINA sub-station. Results of demonstrations are presented in Table 25.

Table 25. Performance of BINA varieties in some areas of Ishwardi upazila, Pabna district during 2013-14

Variety	Total Number of Demonstration	Av. Duration in days	Yield (t ha^{-1})
Rice:			
Binadhan-7	5	118	4.90
Binadhan-14	3	117	6.35
Total	8		
Oil seeds:			
Binasarisha-4	5	87	1.46
Binasarisha-7	1	102	2.25
Binasarisha-8	1	105	2.12
Total	7		
Pulses:			
Binamoog-5	3	88	1.38
Binamoog-8	4	75	1.76
Binamasur-5	5	101	1.97
Total	12		
Grand Total	27		

Ishwardi under Pabna district is very suitable area for growing pulse, oilseeds and rice. Results in Table-25 showed the identical yield of Binadhan-14 with short crop duration. Farmers had been interested to cultivate BINA developed rice varieties in boro season for their good yield, short crop duration and getting varietal diversification. Transplanted aman variety Binadhan-7 produced higher grain yield. It matured one month earlier than the local cultivar Sharna, which created enough farmers' interest to adopt Binadhan-7. Mustard variety Binasarisha-4 showed immense yield potential over the local cultivar Tori-7 and preferred by the farmers. Another two newly released mustard varieties Binasarisha-7 and Binasarisha-8 produced maximum yield but crop duration of these mustard varieties was higher than the check variety. However, Binamoog-5 and Binamoog-8 produced remarkably higher yield compared to existing cultivars these two varieties are extending spontaneously in this area. However, lentil variety Binamasur-5 produced encouraging seed yield. The establishment of BINA technology village is in progress.

RANGPUR SUB-STATION

Block Demonstration with different BINA developed crop varieties around Rangpur sub-station

During 2013-14, 19 block demonstrations were conducted with BINA developed promising two crop varieties at two villages under sadar upazila of Rangpur district. Results of Demonstrations are presented in Table 26.

Table 26. Performance of BINA varieties in some areas of sadar upazila, Rangpur district during 2013-14

Variety	Total Number of Demonstration	Av. Duration in days	Yield ($t\ ha^{-1}$)
Rice			
Binadhan-7	5	117	4.45
Binadhan-11	5	116	4.43
Binadhan-14	3	112	6.05
Total	13		
Oil seeds			
Binasarisha-4	4	84	1.43
Binasarisha-7	1	101	1.91
Binasarisha-8	1	93	1.73
Total	6		
Grand Total	19		

Rangpur district mainly is suitable for growing rice, potato, partly tomato and mustard. Results in Table 26 revealed that in late boro season Binadhan-14 produced higher grain yield. Farmers were interested to adopt these varieties. However, Binadhan-7 proved as the miraculous transplanted aman variety for this area as it produced higher yield, matured earlier that facilitate earlier rabi crop cultivation and help in management of Manga problem effectively. Farmer's interest seemed to be most positive for Binadhan-11 in flood affected areas. Binasarisha-4 also produced good seed yield of 1.43 $t\ ha^{-1}$ which is suitable for cultivation in between aman and boro rice. Another two newly released mustard varieties Binasarisha-7 and Binasarisha-8 proved their higher yield potentials but crop duration of those varieties was higher than check variety. BINA technology village establishment is underway.

SATKHIRA SUB-STATION

Block Demonstration with different BINA developed crop varieties around Satkhira sub-station

During 2013-14, 28 Block Demonstrations were carried out with BINA developed promising three crop varieties at some villages in sadar and Tala upazilas of Satkhira district. Results of Demonstrations are presented in Table 27

Table 27. Results of block demonstrations conducted around Satkhira sub-station during 2013-14

Variety	Total Number of Demonstration	Av. Duration in days	Yield ($t\ ha^{-1}$)
Rice			
Binadhan-7	3	116	4.58
Binadhan-8	10	134	5.78
Binadhan-10	10	133	5.85
Total	23		
Pulse			
Binamasur-5	5	96	1.18
Oil seeds			
Binasarisha-4	1	87	1.46
Binasarisha-7	1	102	1.78
Binasarisha-8	1	101	1.85
Total	3		
Grand Total	28		

Satkhira district is suitable for cultivation of rice and that of partly pules and oilseeds. Data in Table 27 indicate that Binadhan-7 produced exhibited similar yield performance. However, Binamasur-5 and Binasarisha-4 produced encouraging yield and farmers showed positive response to those mutant varieties. Above performance of BINA developed mutant varieties depicted the good sign for establishing BINA technology village in this locality. However, BINA developed salt tolerant rice variety, Binadhan-8 and Binadhan-10 demonstrated with encouraging performance. It was expected that these varieties would be extended rapidly in this area.

MAGURA SUB-STATION

Block Demonstration with different BINA developed crop varieties around Magura sub-station

Reports of 29 block demonstrations were conducted during 2013-14 with BINA developed promising five crop varieties at West Ramnagar and Alamkhali villages under sadar upazila of Magura district. Results of demonstrations are presented in Table 28.

Magura district is suitable for growing almost all the crops. Some of the promising BINA developed pulse, oilseeds and rice varieties are demonstrating good yield and other better attributes. In this location demonstrations were conducted with 13 BINA varieties. Demonstrated varieties were produced higher yield. Farmers preferred all of the above BINA varieties and diffusing spontaneously among the farming community. Establishment of BINA technology village is in progress.

Table 28. Results of block demonstrations conducted at two villages around Magura sub-station during 2013-14

Variety	Total Number of Demonstration	Av. Duration in days	Yield (t ha^{-1})
Rice			
Binadhan-7	3	118	4.20
Binadhan-14	2	119	5.75
Total	5		
Pulse			
Binasola-4	1	117	1.79
Binasola-6	1	119	1.58
Binamasur-5	5	105	2.21
Binamasur-6	2	112	2.19
Binamoog-5	2	85	1.16
Binamoog-6	2	70	1.18
Binamoog-7	1	78	1.18
Binamoog-8	5	69	1.65
Total	19		
Oil seeds			
Binasarisha-4	1	92	1.50
Binasarisha-7	2	101	1.74
Binasarisha-8	2	105	2.03
Total	5		
Grand Total	29		

Progress in BINA technology Village establishment

Sl. No.	Location	Working village	Establishment Status	Most suitable BINA variety
1.	Mymensingh sadar	Sutiakhali Poranganj	Established BINA Technology village.	Binadhan-5, Binadhan-7 and Binasarisha-4
		Khagdahar	Underway	do
2.	Magura	West Ramnagar, Khalimpur, Echakhada, Alamkhali	Established BINA Technology village.	Binamoog-5, Binamoog-6, Binamoog-8, Iratom-24, Binadhan-5, Binadhan-7, Binamasur-2, Binamasur-5, Binasola-4, Binasarisha-4, Binasarisha-7 and Binasarisha-8
		Shidhrampur	Underway	do
3.	Iswardi	Dulti, Aurankhola Athaishimul	Established BINA Technology village.	Binadhan-7, Binadhan-5, Binamasur-2, Binamoog-5, 6, 7, 8, Binasarisha-4, 7 and 8
		Kalikapur	Underway	do
4.	Rangpur	Auviram, Parbotipur	Established BINA Technology village.	Binadhan-5, Binadhan-7 & Binasarisha-4, 7 and 8.
		Najirarhat	Underway	do
5.	Satkhira	Jhapaghat in Kolaroa, Daulatpur	Established BINA Technology village.	Binadhan-8 & 10, Binadhan-7, Binamasur-2 and Binamoog-7, 8
		Brahmorajpur Shenergati in Tala	Underway	Binadhan-8, Binadhan-10, Binasarisha-7 and 8
6.	Comilla	Palpara	Underway	Binasarisha-7, Binadhan-5 and Binadhan-7
		Rasulpur	do	Binadhan-5, Binadhan-7 and Binasarisha-4

Training of Scientists, Farmers, Extension Personnel and Workers

Under this project manpower development and technology transfer activities are usually done through nomination of BINA personnel for participation in different national and overseas training programme, arranging training and workshops for extension personnel, farmers and field days. Training related functions, which were done during this period, were as follows:

Manpower Development

Necessary arrangements were made to nominate 52 BINA personnel for participation in different in-country training courses/workshop/seminar organized by other national organizations. All process was also made to nominate 37 BINA personnel for participation in foreign training/workshop/seminar. Details of the nomination activities regarding national and overseas training courses are presented in Table 29 and Table 30.

Table 29. Arrangement of Nomination of BINA Personnel for foreign Training Course/ Workshop/ Seminar During 2013-14

SL. No.	Title of training/workshop	Trainee	Duration	Venue
1.	"Regional Training course on GEX testing seed storage and farmer participation"	Julker Nain, SO	01-11 July, 2013	Philippine
2.	"Regional Training course on GEX testing seed storage and farmer participation"	Md. Elias Hossain, SO	01-11 July, 2013	Philippine
3.	1st coordination meeting on landscape salanity and water management for Improving Agricultural Productivity	Md. Ekram ul Haque, PSO	15-19 July, 2013	Vienna Austria
4.	Post Doctoral Fellowship	Dr. M. M. Islam, PSO & Head, Biotechnology	12 August, 2013-11 February 2014	Cornell University, USA
5.	Fellowship	Khandoker Shamsul Arefin, SSO	30 Sept. 20 Dec. 2013	Vienna Austria
6.	Translocation of carbon reserves under different source sink ratio using carbon tracer techniques in rice	Dr. M. A. Manjurul Alam, SSO	01 Sept. 2013-28 Feb., 2014	University of Putra, Malaysia
7.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou, China	Reza Mohammad Emon, SSO	20 Sept. 2013 – 19 Sept. 2014	China
8.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr. Md. Jahingir Alam, PSO	27 Sept. 2013 – 28 March, 2014	Malaysia
9.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr. Md. Zaharul Islam, SSO	27 Sept. 2013 – 28 March, 2014	Malaysia
10.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr. Mohammad Azizul Haque, SSO	27 Sept. 2013 – 28 March, 2014	Malaysia
11.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr. Md. Abul Kashem, SSO	27 Sept. 2013 – 28 March, 2014	Malaysia
12.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr.Md. Hossain Ali, SSO	Do	Do
13.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr. Shahidul Islam, SSO	Do	Do
14.	Post Doctoral Fellowship china national rice research institute (CNRRF) Hangzhou	Dr. Md. Ibrahim Khalil, SSO	Do	Do
15.	Fellowship/Training	Dr. Md. Tariqul Islam, PSO	01 Sept. 2013 – 28 Feb., 2014	Germany

16.	Workshop on Nuclear techniques in Agriculture	Dr. M. A. Samad, PSO	24 Sept. – 07 Oct., 2013	Malaysia
17.	Workshop on Nuclear techniques in Agriculture	Dr. Md. Abdul Malek, PSO	24 Sept. – 07 Oct., 2013	Malaysia
18.	Workshop on Nuclear techniques in Agriculture	Dr. Md. Harun ar Rashid, SSO	24 Sept. – 07 Oct., 2013	Malaysia
19.	Workshop on Nuclear techniques in Agriculture	Sayra Chowdhury, SSO	24 Sept. – 07 Oct., 2013	Malaysia
20.	Workshop on Nuclear techniques in Agriculture	Shamima Begum, SSO	24 Sept.– 07 Oct., 2013	Malaysia
21.	Workshop on Nuclear techniques in Agriculture	Fahmina Yasmin, SO	24 Sept.– 07 Oct., 2013	Malaysia
22.	Workshop on Nuclear techniques in Agriculture	Md. Fardus Iqbal, SO	24 Sept.– 07 Oct., 2013	Malaysia
23.	Workshop on Nuclear techniques in Agriculture	Ahmed Nomari Ashraful, SO	24 Sept.–07 Oct., 2013	Malaysia
24.	Workshop on Nuclear techniques in Agriculture	Shilpi Dash, SO	24 Sept.– 07 Oct., 2013	Malaysia
25.	Workshop on Nuclear techniques in Agriculture	Md. Azadul Haque, SO	24 Sept.– 07 Oct., 2013	Malaysia
26.	Workshop on Nuclear techniques in Agriculture	Md. Mahbubul Haque, SO	24 Sept.– 07 Oct., 2013	Malaysia
27.	Workshop on Nuclear techniques in Agriculture	Md. Rashidul Haque, SO	24 Sept.– 07 Oct., 2013	Malaysia
28.	Workshop on Nuclear techniques in Agriculture	Md. Mahmudul Hasan Shohag, SO	24 Sept.– 07 Oct., 2013	Malaysia
29.	Fellowship/Training	Md. Hasanuzzaman, SO	29 Sept. 2013 to 28 March 2014	China
30.	Agricultural land management for Improving soil fertility and irrigation efficiency	Dr. Md. Mahbubul Alam, SSO	21-25 Oct., 2013	Indonesia
30.	Second Coordination Meeting for Project RAS/5/064 9003-01 Meeting	Dr. Md. Monowar Karim Khan CSO and Head soil science Division	03-07 February,2014	Indonesia
31.	Scientific Visit	Dr. Md. Monowar Karim Khan CSO and Head soil science Division	04-08 November, 2013	Austria
32.	Second Coordination Meeting for Project RAS/5/064 9003-01 Meeting	Dr. A.M. A Samad, CSO and Head Plant Breeding Division	03-07 February, 2014	Indonesia
33.	Implementing Isotope Techniques in field Experiments	Md. Ekram ul Haque, PSO	03-07 February,2014	Myanmar
34.	Scientific writing	Md. Elias Hossain, SO	24-28 March,2014	Philippine
35.	Stress Tolerant Rice for Africa and South Asia Review workshop	Dr. A H M Razzaque Director General	20-23May,2014	India

36.	Stress Tolerant Rice for Africa and South Asia Review workshop	Dr. Mirza Moffazal Islam, PSO &Head, Biotechnologi Division	20-23May,2014	India
37.	Stress Tolerant Rice for Africa and South Asia Review workshop	Md.Mahbubur Rahman Khan SO	20-23May,2014	India
38.	Technical meeting to evaluate agronomic performances on supporting climate proofing rice production system	Md. Ekram ul Haque, PSO	12-15 Nov. 2013	Penning, Malaysia
39.	Workshop on "Food value chaina analysis: Tools and application for economists/social selentists in the national system"	Dr. Md. Habibur Rahman, SSO	04-08 Dec. 2013	Thailand
40.	Second project coordination meeting and the development of precision soil conservation strategies at landscape levels	Dr. M. A. Sattar Director General	09-13 Dec. 2013	Vietnum
41.	Attend the meeting Tc Project CI-BGD/5/028900/01	Dr. M. A. Sattar Director General	13-15, February, 3013	Austria
42.	Attend the meeting Tc Project CI-BGD/5/028900/01	Dr. Md Asgar Ali Sarker	do	
43.	Attend the meeting Tc Project CI-BGD/5/028900/01	Dr. Md. Monowar Karim Khan,PSO, Soil Science Division	do	
44.	Attend the meeting Tc Project CI-BGD/5/028900/01	Dr. A.M. A Samad		
45.	Technical Cooperation Project (BGD5028)	Ferdus Iqbal	15March-14 June, 2013	Philippine
46.	Scientific Visit	Dr. M.A.Salam	18-22March, 2013	Austria
47.	Post Doctoral Fellowship	Dr. Imtiaz Uddin,SSO	01April2013-31March.2014	Malaysia
48.	Accelerated breeding techniques in developing mutant lines: rapid generation cycling, embryo culture, doubled haploidy and marker assisted selection.	Md. Hasanuzzaman Roni, SO	14 Dec. 2013 to 17 May, 2014	Austria
49.	Accelerated breeding techniques in developing mutant lines: rapid generation cycling, embryo culture, doubled haploidy and marker assisted selection.	Md. Kamruzzaman, SO	14 Dec. 2013 to 17 May, 2014	Austria
50.	Study Tour	Dr. Md. Harun ar Rashid, SSO	13-18 Jun, 2014	Thailand
51.	Government Approval to participate in the 3rd Regional coordination meeting of ICARDA-SACRP	D. A H M Razzaque Director General	16-21 Jun, 2014	Beijing China

Table 30. Arrangement made for nomination of BINA Personnel for in-country Training Course/ Workshop/Seminar during 2013-14

SL. No.	Title of training/workshop	Trainee	Duration	Venue
1.	Third Regional Technical Training workshop on the Land Degradation Assessment and Monitoring for sustainable Land management and climate change adaptation in south Asia	Dr. Md. Mohsin Ali, PSO	14-18 July, 2013	Cox`s Bazar
2.	National Workshop on The Development of Radio active waste Management policy and strategy of Bangladesh	Dr. Md. Shariful Haque Bhuiyan, PSO	29 July-01 Aug, 2013	BAEC Building, Agargawn, Dhaka-1207
3.	Cover Open of Master Plan for Agricultural Development in Southern Region of Bangladesh.	Dr. M. A. Sattar, Director General Dr. M. A. Salam, Director (Research) Dr. A.H.M. Razzak, Director (Admin. & SS.)	30 July, 2013	BARC, Dhaka
4.	Nomination of mid level Scientists for Participation in Training Course on Research Proposal Preparation and Scientific Report Writing	Dr. Md. Habibur Rahman, SSO Dr. Sakina Khanam, SSO Dr. Mohammad Ali, SO	24-29 Aug., 2013	BRAC-CDM, Gazipur
5.	Annual Review Workshop on Crop Protection	Dr. Hosneara Begum, CSO Dr. Md. Abul Kashem, SSO Dr. Mahbuba Kaniz Hasna, SSO Dr. Ibrahim Khalil, SSO	26-27 Aug., 2013	BARC, Dhaka
6.	Soil Fertility and Fertilizer Management for Crops and Cropping Patterns``	Dr. Md. Mahbubul Alam, SSO Md. Mahbubur Rahman Khan, SO Md. Shaikat Hossain Bhuiyan, SO Rakhi Rani Sharker, SO Md. Ashikur Rahman, SSO Md. Habibur Rahman SO	01-02 Oct. 2013	BARC, Dhaka
7.	RCO	Md. Mahbubul Hassan Shohag, SO	28-31 Oct., 2013	BAEC Building, Agargawn, Dhaka
8.	Administrative and Financial management	Dr. Hosne ara Begum, CSO Dr. Md. Abdul Malek, PSO	27 Oct.-09 Nov., 2013	BARD, Cumilla By BARC
9.	Capacity Building Project on Agricultural Remote Sensing (SAFE mini project) Inception Workshop	Dr. Md. Asgar Ali Sarker, Director (Admin. & S. S.) Md. Ashikur Rahman, SSO	27-31 Oct., 2013	BARI, Gazipur
10.	Foundation Training	Ahmed Numeri Ashfaqur Rahman, SO Md. Azadul Haque, SO	10 Nov-5 Mar., 2013	BARD, Comilla

11.	Prospects, needs, benefits and risk assessment of Agriculture Related genetically modified products in SAARC countries	Dr. M. A. Samad, CSO	06-07 Dec., 2013	BARI, Gazipur
12.	Participatory Rural Development	Md. Mahbubul Haque, SO	16-20 Feb., 2014	Cotbari, Comilla
13.	Workshop on HYV Jute and Jut Seed Production	Dr. Md. Abdul Malek, PSO Dr. Md. Abul Kalam Azad, PSO Md. Ali, SO	15 Feb., 2014	BJRI, Dhaka
14.	Training on Quality Control of Seed & Seed Law and Order	Md. Ferdos Iqbal, SO	23-25 Feb., 2014	BARI, Gazipur
15.	Mid term budget (MTBF)	Md. Monjurul Hossain Khan Assistand Director	27 Feb., 2014	Public Administration Training Center, Dhaka
16.	Production and Services of Agro metrological Information for the Adaptation to Climate Change	Md. Ashiqur Rahman, SSO	9 March, 2014	BARC, Dhaka
17.	Workshop on ``Enhancing Understanding and Implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture in Asia``	Dr. Shamsunnahar Begum, SSO Dr. Snigdha Ray, SSO	19 March, 2014	BARC, Dhaka
18.	Regional Consultation Workshop on Research And Development Programme for more Intensive but less Irrigation Requiring Production in North West Bangladesh	Dr. Md. Asgar Ali Sarker, Director (Admin. & S.S) Md. Habibur Rahman, SO Md. Nurun-Nabi-Majumder, SO	22 Mar., 2014	RDA, Bogra
19.	Use of Fertilizer Recommendation Guide 2012``	Dr. Md. Habibur Rahman, SSO Dr. Md. Harun-ar-Rashid, SSO Dr. Md. Mahbubul Alam Tarafder, SSO	30 Mar – 1 Apr., 2014	BARC, Dhaka
20.	Phyto Sanitary Measures and Food Safety Issue in Bangladesh	Dr. Md. Lutfor Rahman Mollah, SSO Dr. Mahbuba Kaniz Hasna, SSO	02-03 Apr., 2014	-
21.	Use of Farm Machinery and Efficient Irrigation System Management	Md. Hasanuzzaman, SO Md. Ashiqur Rahman, SSO	5-8 Apr & 19-22 Apr., 2014	BARC, Dhaka & BARI, Gazipur
22.	Method of Fertilizer Analysis	Ahmed Numeri Ashfaqul Haque, SO Md. Shikat Hossain Bhuiyan, SO	06-10 Apr., 2014	SSDI, Dhaka
23.	Research Methodology	Md. Elias Hossain , SO Ahmed Numeri Ashfaqul Haque, SO Md. Azadul Haque, SO Md. Mahbubul Haque, SO	19 Apr - 1 May., 2014	GTI, BAU, Mymensingh
24.	Project Development and Management	Dr. Md. Hossain Ali, SSO Dr. Md. Abul Kashem, SSO Dr. A F M Feroj Hassan, SSO Dr. Md. Azizul Haque, SSO	20-24 Apr., 2014	BARC, Dhaka

25.	Good Agricultural Practies (GAP) in Fruits and vegetables Production	Md. Nurun-Nabi-Majumder , SO	21 Apr, 2014	BARC, Dhaka
26.	Administrative and Financial management	Dr. Mr. Abul Kashem, SSO Dr. Md. Siddiqur Rahman, SSO Dr. Md. Habibur Rahman, SSO	04-17 May., 2014	BARD, Comilla
27.	National Workshop on Occupation Radiation Protection in Facilities and Activities	Md. Mahbubul Hassan Shohag, SO	18-20 May., 2014	BARC, Dhaka
28.	Use of Fertilizer Recommendation Guide 2012	Md. Mahbubur Rahman Khan, SO Md. Julker Nain, SO Md. Elias Hossain, SO Md. Asad Ullah, SO	25-27 May., 2014	BARC, Dhaka
29.	Training on Selected Software Tutorial for Economic Analysis	Mohammad Rashidul Haque, SO Razia Sultana, SO	25-29 May., 2014	BARC, Dhaka
30.	Financial Management and Project Accounting Procedure for NARS Accounts Personnel	Md. Shamsul Haq, Audit Officer Md. Abdul Malek, Accountant	05-07 June., 2014	BARC, Dhaka
31.	Knowledge and Awareness Building on Agricultural Policies of Bangladesh	Dr. Md. Manjurul Islam, PSO Dr. A F M Firoj Hassan, SSO	23-25 June., 2014	BARC, Dhaka
32.	Workshop on Maintenance Breeding and Breeder Seed Production	Dr. Mirza Mofazzal Islam, PSO Dr. Md. Abul Kalam Azad, PSO	18-19 June., 2014	BADC, Dhaka
33.	Workshop on Course Curriculum Development of Agricultural Extension Education	Dr. M, Raisul Haider, CSO (RC)	25-26 June 2014	BAU, Mymensingh
34.	Annual NATP National Workshop-2014	Dr. Md. Tariqul Islam, PSO	22 June, 2014	BARC, Dhaka
35.	GIS Based Land Suitability assessment soft	Dr. Md. Habibur Rahman, SSO	28-29 June, 2014	BARC, Dhaka
36.	Review of Socio-economic Research Programme(2013-2014) and Future Research Programme (2014-2015) of NARS Institute.	Md. Rashidul Haque, SO Begum Razia Sultana, SO	26 June, 2014	BARC, Dhaka
37.	Nuclear Seed Production and Delivery of Rice	Dr. Mirza Mofazzal Islam, PSO Dr. Md. Abul Kalam Azad, PSO	28 June, 2014	BADC, Dhaka
38.	NATP Second Phase Preparation Workshop	Dr. A H M Razzak, Director General Dr. Md. Monwar Karim Khan, Director (Research) Dr. Md. Jahangir Alam, PSO	25 June, 2014	DAE, Khamarbari, Dhaka
39.	Financial Management	Md. Jahangir Kabir, Assistant Director (CC)	01-12 June, 2014	RPTC, Dhaka
40.	ICT and E-Governess	Md. Nurun-Nabi-Majumder, SO	22 June, 2014	BARC, Dhaka
41.	Annual NATP National Workshop-2014	Dr. Md. Abdus Samad, CSO Dr. Md. Tariqul Islam, PSO	22 June, 2014	BARC, Dhaka

Training on the use of BINA developed technologies

In order to technology promotion 5 workshops courses were organized during the period of 2013-14. A total of 292 DAE, BADC and NGOs personnel and 29 farmers training for 1585 female and male farmers including some Sub-assistant Agriculture Officers were trained on cultivation of BINA developed improved crop varieties. Details of the training and workshops are presented in Table 31 and 32.

Table 31. Training-Workshops on the use of BINA developed technologies during 2013-14

Sl. No.	Topic	Place of Workshop	No. of participants	Source of fund
1.	Workshop on “Role of DAE, BADC and NGOs personnel to disseminate of BINA developed high yielding late transplanted boro rice Binadhan-14	Ishwardi sub-station, Pabna	48	BARC (Rice) Project
2.	Workshop on “Role of DAE, BADC and NGOs personnel to disseminate of BINA developed high yielding promising crops varieties	Rangpur sub-station, Rangpur	100	SRSD Project
3.	Workshop on “Role of DAE, BADC and NGOs personnel to disseminate of BINA developed high yielding promising crops varieties	BADC farm, Thakurgoan	48	CCTF Project
4.	Workshop on “Role of DAE, BADC and NGOs personnel to disseminate of BINA developed high yielding promising crops varieties	Magura sub-station, Magura	48	BARC (Rice) Project
5.	Workshop on “Role of DAE, BADC and NGOs personnel to disseminate of BINA developed high yielding promising crops varieties	Rangpur sub-station, Rangpur	48	CCTF Project

Table 32. Farmers Training on the use of BINA developed technologies during 2013-14

Sl. No.	Topic	Place of Training	No. of participants	Source of fund
1.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding short duration rice Binadhan-7	Porangonj, Mymensingh	100	SRSD Project
2.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Sadar, Cox's bazar	30 30	Molecular Project
3.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Ramu, Cox's bazar	30	Molecular Project
4.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Pakua, Cox's bazar	30	Molecular Project
5.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Chokoria, Cox's bazar	30	Molecular Project
6.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Ukhia, Cox's bazar	30	Molecular Project
7.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Moheshkhali, Cox's bazar	30	Molecular Project
8.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Teknaf, Cox's bazar	30	Molecular Project
9.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Kutubdia, Cox's bazar	30	Molecular Project
10.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding mungbean variety Binamoog-8	DD, DAE office, Bogra	50	CCTF Project
11.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding mungbean variety Binamoog-8	DD, DAE office, Nawgoan	50	CCTF Project
12.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding mungbean variety Binamoog-8	DD, DAE office, Joypurhat	50	CCTF Project
13.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding mungbean variety Binamoog-8	DD, DAE office, Joypurhat	120	SRSD Project
14.	Farmers training on "Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	DD, DAE office, Netrokona	100	SRSD Project

Table 32 Contd.

Sl. No.	Topic	Place of Training	No. of participants	Source of fund
15.	Farmers training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	DD, DAE office, Sirajgonj	100	SRSD Project
16.	Farmers training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	DD, DAE office, Kurigram	100	SRSD Project
17.	Farmers training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	DD, DAE office, DD, Sherpur	100	SRSD Project
18.	Farmers training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	Sadar, UAO office, Mymensingh	100	SRSD Project
19.	Farmers training on “Demonstration set up, cultivation method and management of Binadhan-7	Mohangonj, Netrakona	40	SPGR-387 project
20.	Farmers training on “Demonstration set up, cultivation method and management of Binasarisha-4”	Rupgonj, Narayangonj	40	SRSD project
21.	Farmers training on “Demonstration set up, cultivation method and management of Binasarisha-4	Magura	40	SRSD project
22.	Farmers training on “Demonstration set up, cultivation method and management of Binasarisha-4	Madhukhali, Faridpur	40	SRSD project
23.	Farmers training on “Demonstration set up, cultivation method and management of Binasarisha-4	Bagharpara, Jessore	40	SRSD project
24.	Farmers training on “Demonstration set up, cultivation method and management of Binatil-1 and Binatil-2	Madhukhali, Faridpur	40	SRSD project
25.	SAAO training on “Cultivation & seed preservation method BINA developed high yielding mungbean variety Binamoog-8	DD, DAE office, Joypurhat	80	CCTF Project
26.	SAAO training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	Sadar, UAO office, Mymensingh	80	SRSD Project
27.	SAAO training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	DD, DAE office, Sirajgonj	80	SRSD Project
28.	SAAO training on “Cultivation & seed preservation method BINA developed high yielding submergence tolerant rice Binadhan-11	DD, DAE office, DD, Sherpur	80	SRSD Project
29.	SAAO training on “Cultivation & seed preservation method BINA developed high yielding salt tolerant rice Binadhan-8 & 10	Bashkhali, Chittagang	45	MolecularP roject

Field Day

In order to motivate the farmers to adopt BINA developed varieties/technologies, 40 field days/on-farm farmers' training on different crop varieties was organized across the country. Details of the field day activities are presented in Table 33.

Table 33. Field days arranged at the farmers fields on different crop varieties during 2013-14

Sl. No.	Crops	Varieties	Locations	Participants
1.	Rice	Binadhan-7	Sadar, Bogra	200
2.		Binadhan-7	Bhoirab, Kishogonj	200
3.		Binadhan-7	Sadar, Magura	200
4.		Binadhan-7	Tanore, Rajshahi	200
5.		Binadhan-7	Godagari, Rajshahi	200
6.		Binadhan-7	Nachole, Chapainobabgonj	200
7.		Binadhan-7	Gomostapur, Chapainobabgonj	200
8.		Binadhan-11	Nalitabari, Sherpur	200
9.		Binadhan-11	Chilmari, Kurigram	200
10.		Binadhan-11	Rajibpur, Kurigram	200
11.		Binadhan-11	Roumari, Kurigram	200
12.		Binadhan-11	Belkuchi, Sirajgonj	200
13.		Binadhan-11	Sadar, Sirajgonj	200
14.		Binadhan-11	Sadar, Sunamgonj	200
15.		Binadhan-13	Sadar, Mymensingh	200
16.		Binadhan-8&10	Sadar, Cox's bazar	200
17.		Binadhan-8&10	Ramu, Cox's bazar	200
18.		Binadhan-8&10	Pakua, Cox's bazar	200
19.		Binadhan-8&10	Chokoria, Cox's bazar	200
20.		Binadhan-8&10	Ukhia, Cox's bazar	200
21.		Binadhan-8&10	Moheshkhali, Cox's bazar	200
22.		Binadhan-8&10	Teknaf, Cox's bazar	200
23.		Binadhan-8&10	Kutubdia, Cox's bazar	200
24.		Binadhan-8	Koyra, Khulna	200
25.		Binadhan-10	Koyra, Khulna	200
26.		Binadhan-14	Boraigram, Natore	200
27.		Binadhan-14	Sadar, Comilla	200
28.	Groundnut	Binachinabadam-4	Bhairab, Kishorgonj	200
29.		Binachinabadam-4	Kaligonj, Jhenaidah	200
30.	Sesame	Binatil-1	Salikha, Magura	200
31.		Binatil-1	Sadar, Magura	200
32.		Binatil-1	Bagharpara, Jessore	200
33.	Mungbean	Binamoog-8	Sadar, Joypurhat	200
34.		Binamoog-8	Ishwardi, Pabna	200
35.		Binamoog-8	Tanore, Rajshahi	200
36.		Binamoog-8	Godagari, Rajshahi	200
37.	Lentil	Binamasur-5	Sadar, Natore	200
38.	Mustard	Binasarisha-4	Tanore, Rajshahi	200
39.		Binasarisha-4	Godagari, Rajshahi	200
40.		Binasarisha-4	Bagarpara, Jessore	200

Publications and photographic enrichment

For technology transfer through printed media, publications were made on 10 types of leaflets totaling 50,000 copies during this period. Besides these, 29 programmes were telecast to popularize some BINA crop varieties. Details of the publication activities are presented in Table 34.

Table 34. List of publications made on different crop varieties and electronic media exposure during 2013-14

Sl. No.	Name of crops/varieties	Name of publication	Language	Copies printed
01.	Binadhan-7			5000
02.	Binadhan-8			5000
03.	Binadhan-10			5000
04.	Binadhan-11&12			5000
05.	Binadhan-14	Leaflet	Bangla	5000
06.	Binasarisha-7 & 8			5000
07.	Binamasur-5 & 6			5000
08.	Binasoybean-1 & 2			5000
09.	Binasola-5 & 6			5000
10.	Binamoog-8			5000
			Total =	**50,000**

Electronic media exposure

Sl. No.	Name of crops/varieties	Name of the channel	Location	Remarks
01.	Binadhan-8 & Binadhan-10	BTV, Chennel I, Bangla Vision, Machranga, R-TV	Cox's bazar	It was very effective for Awareness creation
02.	Binadhan-7	BTV, Bangla Vision, R-TV	Bogra, Rangpur, Dinajpur	
03.	Binadhan-14	Chennel I, Bangla Vision, Machranga, R-TV	Bhoirab, Kishoreganj and Comilla	
04.	Binadhan-11	BTV, Chennel I, Bangla Vision, Machranga, R-TV	Sirajgonj, Sunamgonj, Kurigram, Sherpur	
05.	Binamasur-5	Chennel I, Bangla Vision, Machranga, R-TV	Natore	
06.	Binasarisha-4	Mati-O-Manus, BTV, Chennel I, Bangla Vision	Mymensingh Jessore	
07	Binatil-1&2	Chennel I	Magura, Jessore	
08	Binamoog-8	Bangla Vision, Chennel-24	Natore	

BIOTECHNOLOGY DIVISION

RESEARCH HIGHLIGHTS

Evaluation and molecular characterization of 22 rice genotypes for salinity tolerance at different growth stages have been done using SSR markers.

Genetic diversity analysis of 29 drought tolerant NERICA-4 mutants using SSR and RAPD markers has been done.

Marker based screening of 14 aman rice landraces for deepwater tolerance at seedling and vegetative stages has been conducted.

Expression analysis of *saltol* and *sub1*genes in 16 rice genotypes by restriction digestion of cDNA has been done.

Ciherang-*sub1* and Samba mahsuri-*sub1* have been selected for submergence tolerant under 25 days of complete submergence and possesses higher yield (5.5 and 4.5 t/ha, respectively) and early mature (110 and 120 days, respectively). These two lines have already been released as Binadhan-11 and Binadhan-12 on November 2013.

The proposed premium quality rice line IR-50 (fine medium slender grain) and early maturing (100-105 days) rice line OMCS-2007 have been released as Binadhan-15 and Binadhan-16; respectively on August 2014.

The proposed (Binadhan-17 GSR) Green Super Rice line BINA-GSR-3 exhibited 3-4 days earlier and higher yield (7.2 t/ha) than check variety (BRRI dhan39). This genotype has been applied to SCA for variety release.

Morphological and molecular characterization of three geographical indications (GI) crops: Mungbean (Sonamoog), Blackgram (Kalikolai) and Sesame (Local til) and 35 BINA released varieties and 57 germplasm have been done.

Promising four NERICA rice mutants have been identified for drought tolerance are now in Advanced yield trial.

NERICA-1, NERICA-4 and NERICA-10 were irradiated with γ-rays and selected 111 M_5 generation which have been tested in drought and saline prone areas.

MOLECULAR CHARACTERIZATION OF RICE GENOTYPES FOR SALINITY TOLERANCE AT DIFFERENT GROWTH STAGES

Twenty two rice lines were used to evaluate salt tolerance at vegetative and reproductive stages using SSR markers. Salinity screening was performed at the seedling stage using hydroponic system and reproductive stage in sustained water bath in glasshouse following IRRI standard protocol (Fig. 1). Based on Standard Evaluation Scoring (SES) system; eight genotypes (Binadhan-8, Binadhan-10, FL478, RC217, RC221, RC222, RC225 and BR11) were identified as salt tolerant, five genotypes (RC191, RC192, RC193, RC251 and RC249) were found moderately tolerant, the rest eight genotypes showed susceptible and Binadhan-7 was highly susceptible at seedling stage. At vegetative stage; RC193, RC222, BR11, Binadhan-8 and Binadhan-10 were identified as salt tolerant where RC217, RC192 and RC191were found as susceptible (Table 1). At reproductive stage; Binadhan-8, Binadhan-10, FL478, RC217, RC221, RC222, RC225 and BR11 were found as tolerant while RC227, RC229, Binadhan-12, Joli Aman, Binadhan-11, BRRI dhan29, Pajam and BRRI dhan39 were found as susceptible (Table 2).

Fig. 1. Performance of rice lines under non-salinized and salinized (EC 14 dSm^{-1}) condition at the reproductive stage

Table 1. Mean performance for plant height, tiller and leaf length of rice genotypes at vegetative stage grown under salinized and non-salinized conditions

Genotypes	Plant height (cm)			Effective tillers plant^{-1} (no.)			Leaf length (cm)		
	Non salinized	Salinized (14dSm^{-1})	% Reduction	Non salinized	Salinized (14dSm^{-1})	% Reduction	Non salinized	Salinized (14dSm^{-1})	% Reduction
RC191	41	46	-12.20	4	6	-50.0	29	34	-17.24
RC192	45	47	-4.44	5	4	20.0	32	33	-3.13
RC193	47	52	-10.64	7	4	42.9	34	36	-5.88
RC217	45	47	-4.44	7	5	28.6	31	36	-16.13
RC221	47	44	6.38	7	3	57.1	31	31	0.00
RC222	46	49	-6.52	5	5	0.0	32	35	-9.38
BR11	47	49	-4.26	4	5	-25.0	32	34	-6.25
FL478	48	42	12.50	4	4	0.0	30	30	0.00
Binadhan-8	52	48	7.69	7	5	28.6	35	35	0.00
Binadhan-10	50	48	4.00	6	5	16.7	33	34	-3.03
Range	41-52	42-49	-	4-7	3-6	-	29-35	30-36	-
Mean	46.5	45.5	-	5.5	4.5	-	32	33	-
LSD	2.5	1.6	-	1.3	1.07	-	4.53	3.8	-

Table 2. Mean performance for plant height, panicle length and filled grains of rice lines at reproductive stage under non-salinized and salinized condition

Genotypes	Plant height (cm)			Panicle length (cm)			Filled grains panicle^{-1} (no.)		
	Non-salinized	Salinized (14dSm^{-1})	% Reduction	Non-salinized	Salinized (14dSm^{-1})	% Reduction	Non-salinized	Salinized (14dSm^{-1})	% Reduction
RC191	110	115	-4.55	25	16	36.0	63	43	31.75
RC192	112	96	14.29	25	15	40.0	66	68	-3.03
RC193	133	92	30.83	24	17	29.2	51	70	-37.25
RC217	137	96	29.93	23	19	17.4	70	73	-4.29
RC221	132	106	19.70	22	18	18.2	52	78	-50.00
RC222	110	83	24.55	24	11	54.2	77	105	-36.36
RC225	114	77	32.46	25	10	60.0	57	55	3.51
RC227	119	91	23.53	24	12	50.0	85	61	28.24
RC229	117	93	20.51	27	13	51.9	74	95	-28.38
RC251	125	89	28.80	22	14	36.4	90	75	16.67
RC249	99	97	2.02	28	16	42.9	80	41	48.75
BR11	117	89	23.93	25	21	16.0	44	86	-95.45
Binadhan-7	126	100	20.63	24	19	20.8	55	72	-30.91
Binadhan-8	114	111	2.63	25	15	40.0	69	80	-15.94
Binadhan-10	106	95	10.38	23	19	17.4	76	79	-3.95
Binadhan-11	109	115	-5.50	17	15	11.8	60	66	-10.00
Range	99-137	77-106	-	17-28	10-19	-	44-90	43-105	-
Mean	118	92.75	-	22.25	14.85	-	67	74	-
LSD (0.05)	5.2	6.3	-	3.1	2.4	-	4.4	6.2	-

Table 3. Mean performance for unfilled grains and effective tillers of rice genotypes at reproductive stage under non-salinized and salinized condition

Genotypes	Unfilled grains panicle^{-1} (no.)			Effective tillers plant^{-1} (no.)		
	Non-salinized	Salinized (14dSm^{-1})	% Reduction	Non-salinized	Salinized (14dSm^{-1})	% Reduction
RC191	44.	30	31.82	6	4	33.33
RC192	38	10	73.68	5	3	40.00
RC193	36	14	61.11	6	4	33.33
RC217	48	10	79.17	5	4	20.00
RC221	62	13	79.03	11	3	72.73
RC222	48	14	70.83	7	4	42.86
RC225	31	13	58.06	5	4	20.00
RC227	40	14	65.00	6	5	16.67
RC229	33	11	66.67	8	3	62.50
RC251	20	11	45.00	6	2	66.67
RC249	25	55	-120.00	7	6	14.29
BR11	33	19	42.42	7	5	28.57
Binadhan-7	31	11	64.52	7	4	42.86
Binadhan-8	61	16	73.77	5	4	20.00
Binadhan-10	21	19	9.52	8	4	50.00
Binadhan-11	33	17	48.48	8	3	62.50
Range	20-62	10-55	-	5-10.8	2.-5	-
Mean	41	32.5	-	5.50	3.95	-
LSD	3.47	2.58	-	2.38	2.11	-

In this experiment three selected linked SSR markers viz. RM7075, RM10701 and RM11504 were used to screen the germplasm for salt tolerance (Fig. 2 & 3). According to the SSR analysis, it was found that an average number of 7.33 alleles per locus were detected with Polymorphism information content (PIC) values ranged from 0.5192 (RM10701) to 0.8878 (RM7075) (Table 4). The highest genetic diversity (0.8967) was observed in RM7075 and the lowest gene diversity (0.5537) was observed in RM10701 with a mean diversity of 0.7231. The bands obtained from other lines were compared to the band obtained from salt tolerant variety like FL478, Binadhan-8 and Binadhan-10.

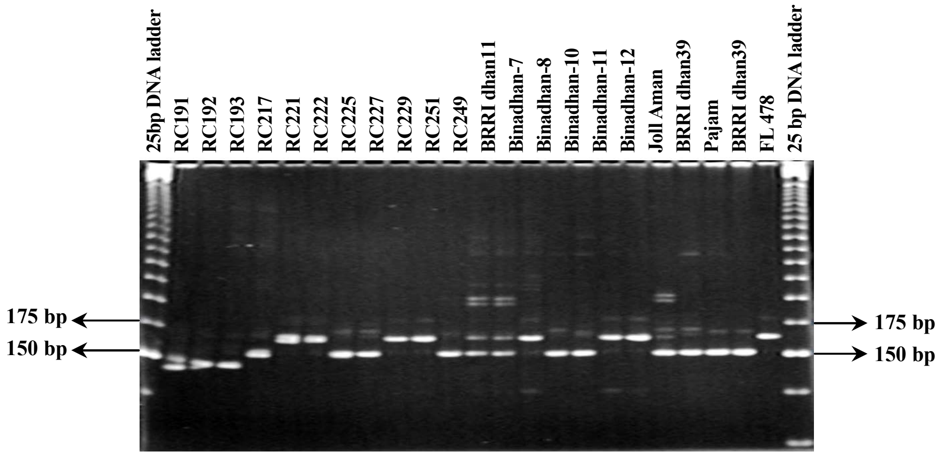


Fig. 2. SSR profiles of 22 rice genotypes using primer RM7075

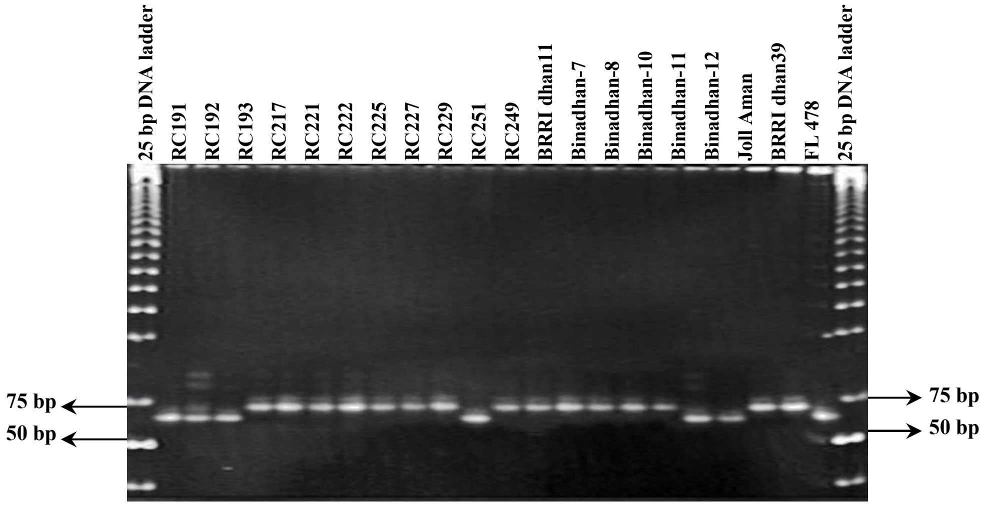


Fig. 3. SSR profiles of 22 rice genotypes using primer RM10701

Table 4. Data of allele size ranges, difference, number of alleles, number of rare alleles, Null alleles PIC value found among 22 rice genotypes for 3 microsatellite (SSR) markers

Locus	Allele size ranges (bp)	Difference (bp)	No. of alleles	*Rare alleles	Null alleles	PIC
RM7075	143 - 166	23	12	5	-	0.8878
RM10701	62 - 72	10	5	2	-	0.5192
RM11504	280 - 290	10	5	1	5	0.6735
Mean	-	-	7.33	2.66	1.66	0.6935

* = Motif of the SSR and number of repeats as previously published on http://www.gramene.org
* = Rare alleles are defined as alleles with a frequency less than 5%

Unweighted Pair Group Method of Aroithmetic Means (UPGMA) dendrogram

Dendrogram based on Nei's (1973) genetic distance using UPGMA cluster analysis led to the grouping of the 22 genotypes in five major clusters (Fig. 4). RC222 and Binadhan-10 formed cluster-I. Observed similarity value between RC222 and Binadhan-10 was 0.333 and genetic distance value was 0.667. Cluster II was formed by BR11 and FL478. Cluster III showed three sub clusters (Sub cluster IIIa, Sub cluster IIIb and Sub cluster IIIc). Sub cluster IIIa had two genotypes RC251 and Binadhan-8. The similarity value between RC251 and Binadhan-8 was 0.333. In Sub cluster IIIb had two varieties RC221 and RC225. Similarity value between RC221 and RC225 was 0.333. The remaining group (Sub cluster IIIc) had only one variety, which is RC249. Cluster IV was formed two sub clusters (Sub cluster IVa, Sub cluster IVb). Sub cluster IVa had five genotypes RC192, RC193, Joli aman, RC229 and RC217. The similarity value between two lines RC217 and RC229 was 1.000. Cluster V showed only three lines which were BRRI dhan29, RC227 and Binadhan-7.

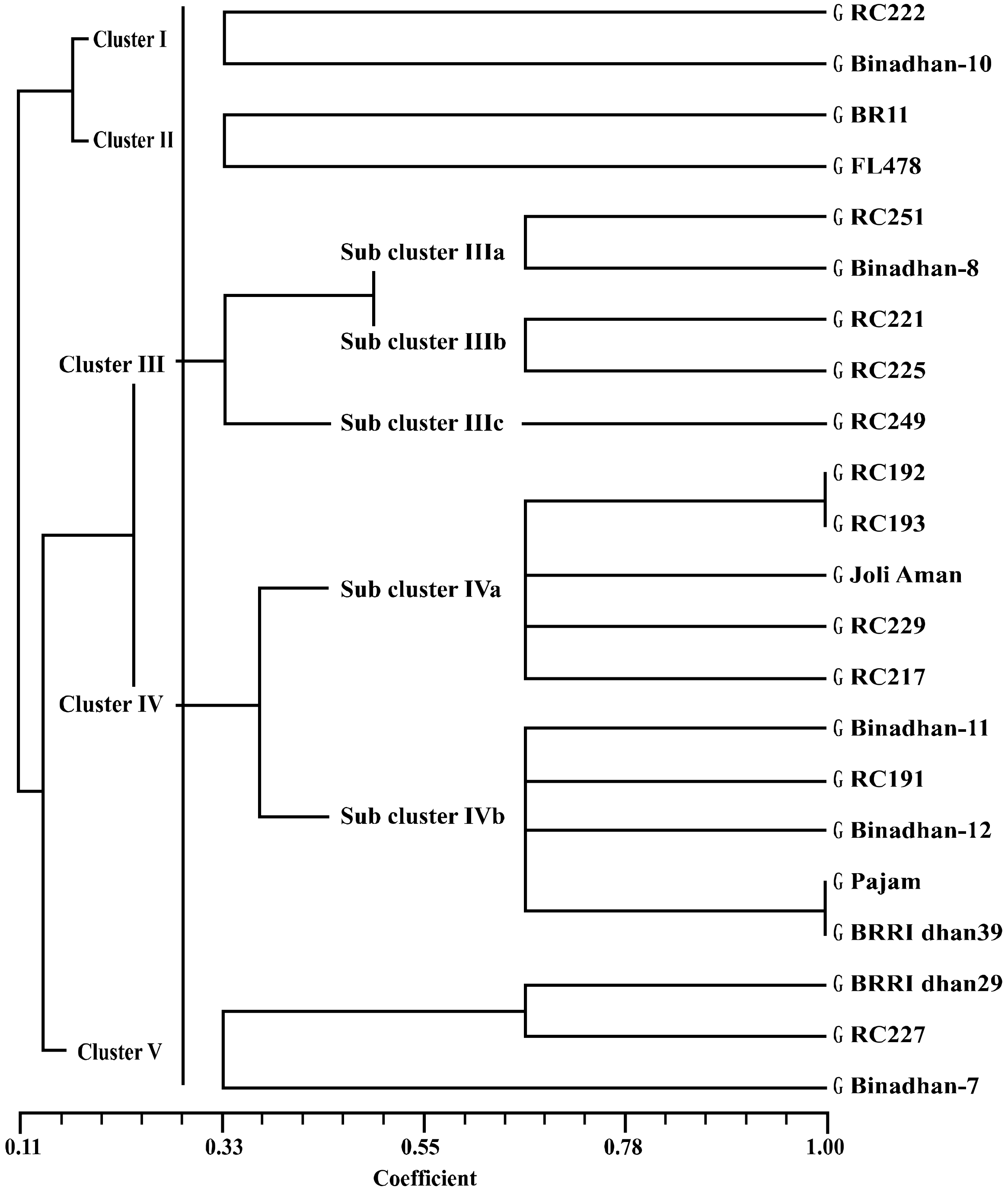


Fig. 4. UPGMA dendrogram based on Nei's (1973) genetic distance summarizing the data on differentiation among 22 rice lines according to SSR analysis. Arrow line indicates the scale of genetic distance (0.11-1.00)

DNA FINGERPRINTING OF RICE VARIETIES FOR SALINITY TOLERANCE AT REPRODUCTIVE STAGE

The experiment was undertaken to assess the genetic diversity among salt tolerant and susceptible rice lines using SSR markers. Salinity screening was performed at reproductive stage using sustained water bath following IRRI standard protocol. Twenty two rice lines were used for molecular analysis using three selected SSR markers: RM1287, RM342 and RM493 to determine salinity tolerance at reproductive stage (Fig. 5 and Fig. 6). Scoring Based on 1-9 scale, nine genotypes (RC 221, RC 225, Binadhan-8, RC 222, RC 229, RC 249, RC 251 and FL 478) were identified as highly salt tolerant and eight genotypes (RC 191, RC 192, RC 193, BR11, RC 217, Pajam, Binadhan-11 and Binadhan-12) showed tolerant. Joli aman, RC 227, BRRI dhan29, Binadhan-7 and BRRI dhan39 also observed moderately susceptible. At reproductive stage, Binadhan-8, Binadhan-10, RC19, RC192, RC19, RC217, RC 221, RC 225, RC 229 and RC 251 were identified as highly tolerant (Table 6).

Table 6. Performance of rice germplasm under salinized condition at the reproductive stage

Sl. No.	Variety name	SES scoring	Tolerance
G1	RC 191	3	T
G2	RC 192	3	T
G3	RC 193	3	T
G4	RC 217	3	T
G5	RC 221	1	HT
G6	RC 222	1	HT
G7	RC 225	1	HT
G8	RC 227	7	S
G9	RC 229	1	HT
G10	RC 251	1	HT
G11	RC 249	1	HT
G12	BR11	3	T
G13	Binadhan-7	7	S
G14	Binadhan-8	1	HT
G15	Binadhan-10	3	HT
G16	Binadhan-11	3	T
G17	Joli aman	7	S
G18	Binadhan-12	3	T
G19	BRRI dhan29	7	S
G20	Pajam	3	T
G21	BRRI dhan39	7	S
G22	FL 478	1	HT

*T = Tolerant, HT = HighlyTolerant, S = Susceptible,

Table 6. Mean performance of rice genotypes at reproductive stage under salinized and non-salinized condition

Germplasm	Plant height (cm)			Panicle length (cm)			Effective tillers plant^{-1} (no.)		
	Non salinized	Salinized (8 dSm^{-1})	% Reduction	Non salinized	Salinized (8dSm^{-1})	% Reduction	Non salinized	Salinized (8dSm^{-1})	% Reduction
RC191	126	124	1.59	27	28	-3.70	9	6	33.3
RC192	123	117	4.88	27	24	11.11	6	9	-50.0
RC193	145	184	-26.90	21	20	4.76	8	8	0.0
RC217	133	140	-5.26	25	25	0.00	5	6	-20.0
RC 221	123	133	-8.13	25	26	-4.00	4	4	0.0
RC 222	115	96	16.52	22	22	0.00	7	4	42.8
RC 225	118	115	2.54	26	27	-3.85	6	6	0.0
RC 227	116	130	-12.07	25	22	12.00	5	4	20.0
RC 229	127	115	9.45	29	24	17.24	7	7	0.0
RC 251	140	141	-0.71	29	28	3.45	5	7	-40.0
RC 249	118	116	1.69	25	29	-16.00	5	6	-20.0
BR11	128	118	7.81	23	27	-17.39	6	7	-16.7
Binadhan-7	115	133	-15.65	28	18	35.71	3	4	-33.3
Binadhan-8	115	111	3.48	23	25	-8.70	3	3	0.00
Binadhan-10	113	136	-20.35	24	23	4.17	6	5	16.7
Binadhan-11	93	111	-19.35	21	23	-9.52	5	4	20.0
JoliAman	97	121	-24.74	21	20	4.76	4	5	-25
Binadhan-12	111	122	-9.91	21	22	-957.14	5	6	-20.0
BRRI dhan29	111	105	5.41	25	22	12.00	10	10	0.0
Pajam	77	103	-33.77	17	22	-29.41	3	7	-133.3
FL 478	122	123	-0.82	25	26	-4.00	10	11	-10.0
BRRI dhan39	121	109	9.92	26	21	19.23	9	6	33.3
Mean	108.5	140		21.5	23.5		6.5	7	-
Range	77-140	96-184	-	17-26	18-29	-	3-10	3-11	-
LSD	3.45	4.25	-	2.34	4.1	-	5.6	6.2	-
CV (%)	12	9	-	8	14	-	9	11	-

Table 6. Contd.

Germplasm	Flag leaf length			Flag leaf breath		
	Non salinized	Salinized ($8dSm^{-1}$)	% Reduction	Non salinized	Salinized ($8dSm^{-1}$)	% Reduction
RC191	27.8	25.3	8.9	1.3	1.0	23.08
RC192	19.8	19.0	4.2	1.1	1.1	0.00
RC193	20.5	22.7	-10.5	1.1	1.0	9.09
RC217	23.5	19.3	17.7	1.1	1.1	0.00
RC 221	32.7	40.0	-22.5	1.0	0.7	30.00
RC 222	27.25	34.7	-27.2	1.3	1.1	15.38
RC 225	31.0	36.5	-17.7	1.2	1.3	-8.33
RC 227	28.0	20.8	25.6	1.1	1	9.09
RC 229	38.8	23.0	40.8	1.2	0.9	25.00
RC 251	30.7	36.0	-17.4	1.2	1.1	8.33
RC 249	35.23	25.0	29.08	1.1	1	9.09
FL 478	29.7	27.7	8.9	1.1	1.3	-18.18
BR11	34.0	46.3	-32.3	1.2	1.1	8.33
Binadhan-7	29.0	22.5	22.4	1.1	1.0	9.09
Binadhan-8	23.83	31.0	-30.1	1.0	1.4	-40.00
Binadhan-10	24.0	20.2	16.0	1.0	1.0	0.00
Binadhan-11	27.8	27.5	0.9	1.0	1.0	0.00
Joli aman	22.0	19.3	12.1	1.0	1.1	-10.00
Binadhan-12	28.5	21.8	23.4	1.0	1.1	-10.00
BRRI dhan 29	25.3	22.3	11.8	1.2	1.1	8.33
Pajam	19.8	9.5	52.1	1.1	0.6	45.45
BRRI dhan 39	22.0	24.8	-12.9	1.3	1.1	15.38
Mean	29.2	27.9		1.15	1.0	
Range	19-388	9.5-46.3	-	1.0-1.3	0.6-1.4	-
LSD	5.24	7.10	-	1.45	1.61	-
CV (%)	14	10	-	6	8	-

For DNA fingerprinting of rice genotypes, DNA was extracted from leaf samples using CTAB mini prep method. After PCR amplification, the alleles were separated using Polyacrylamide Gel Electrophoresis (PAGE). The polymorphism information content (PIC) reflect the diversity alleles frequency among the lines, which ranged from 0.590 to 0.883 with an average of 0.742. The SSR marker RM493 was the best marker for identification of genotypes as revealed by PIC values (Table 7).

Table 7. Summary statistics-I analysis found among 22 rice genotypes for 3 SSR markers

Locus	Repeat Motif*	Allele Size ranges (bp)	No. of alleles	*Rare alleles	Null allele	PIC
RM1287	(AG)17	159-172	6	-	2	0.75
RM493	(CTT)9	203-221	12	6	-	0.88
RM342	(CAT)12	142-159	7	4	-	0.59
Mean			8.333	3.33	2	0.74

Table 8. Summary statistics-II analysis found among 22 rice genotypes for 3 SSR markers

Locus	Sample size	Major allele		Availability	Gene diversity	Heterozygocity
		Size (bp)	Frequency (%)			
RM1287	22	160	36	1.0000	0.7810	0.0000
RM493	22	212	18	1.0000	0.8926	0.000
RM342	22	150	59	1.0000	0.6157	0.0000
Mean	22	174	38	1.0000	0.7631	0.0000

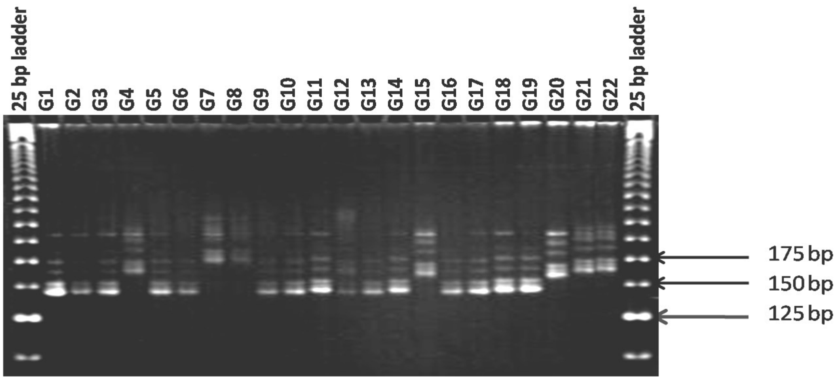


Fig. 5. SSR profile of 22 rice genotypes using primer RM1287

Here, G1- RC 191, G2 – RC 192, G3- RC 193, G4- RC 217, G5- RC 221, G6- RC 222, G7- RC 225, G8- RC 227, G9- RC 229, G10- RC 251, G11- RC 249, G12- BR11, G13- Binadhan-7, G14- Binadhan-8, G15- Binadhan-10, G16-Binadhan-11, G17- Joli aman, G18- Binadhan-12, G19- BRRI dhan29, G20- Pajam, G21- BRRI dhan39, G22- FL 47

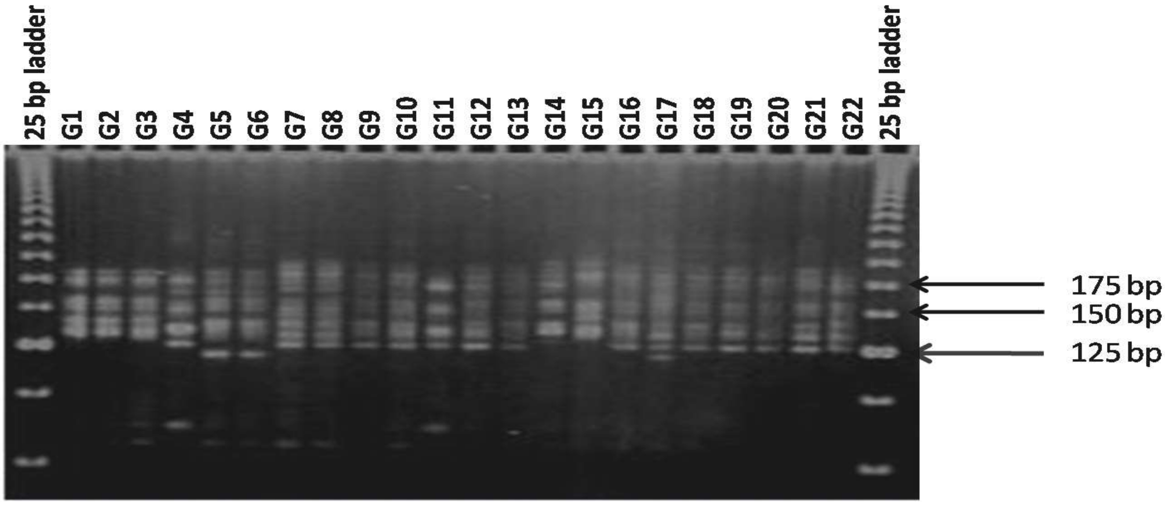


Fig. 6. SSR profile of 22 rice genotypes using primer RM342

Here,G1- RC 191, G2 – RC 192, G3- RC 193, G4- RC 217, G5- RC 221, G6- RC 222, G7- RC 225, G8- RC 227, G9- RC 229, G10- RC 251, G11- RC 249, G12- BRRI dhan11, G13- Binadhan-7, G14- Binadhan-8, G15- Binadhan-10, G16-Binadhan-11, G17- Joli aman, G18- Binadhan-12,G19- BRRI dhan29, G20- Pajam, G21- BRRI dhan39, G22- FL 478

Unweighted Pair Group Method of Arithmetic Means UPGMA dendrogram

The UPGMA cluster analysis led to the grouping of 22 genotypes in two major clusters (Fig.7). The two main cluster is cluster II and cluster III contains more varieties. Here, cluster I accession RC 191, RC 192, RC 193 formed whose are tolerant under salt stress. Cluster II contains accession RC221, RC225, Binadhan-8, RC 222, RC 229, RC 249, RC 251, FL 478 those are highly tolerant under salt stress at reproductive stage. BR11, Binadhan-10, RC 217, Pajam, Binadhan-11, Binadhan-12 are under cluster III. Those varieties are moderately tolerant at salt stress. On the other hand, Cluster IV contains three varieties Joli aman, RC 227 and BRRI dhan39 are moderately susceptible. On the contrary, cluster V contains Binsdhan-7 and cluster VI contains one variety BRRI dhan39 which are susceptible at reproductive stage. The highest inter-genotype similarity is found in Binadhan-8 and FL478.

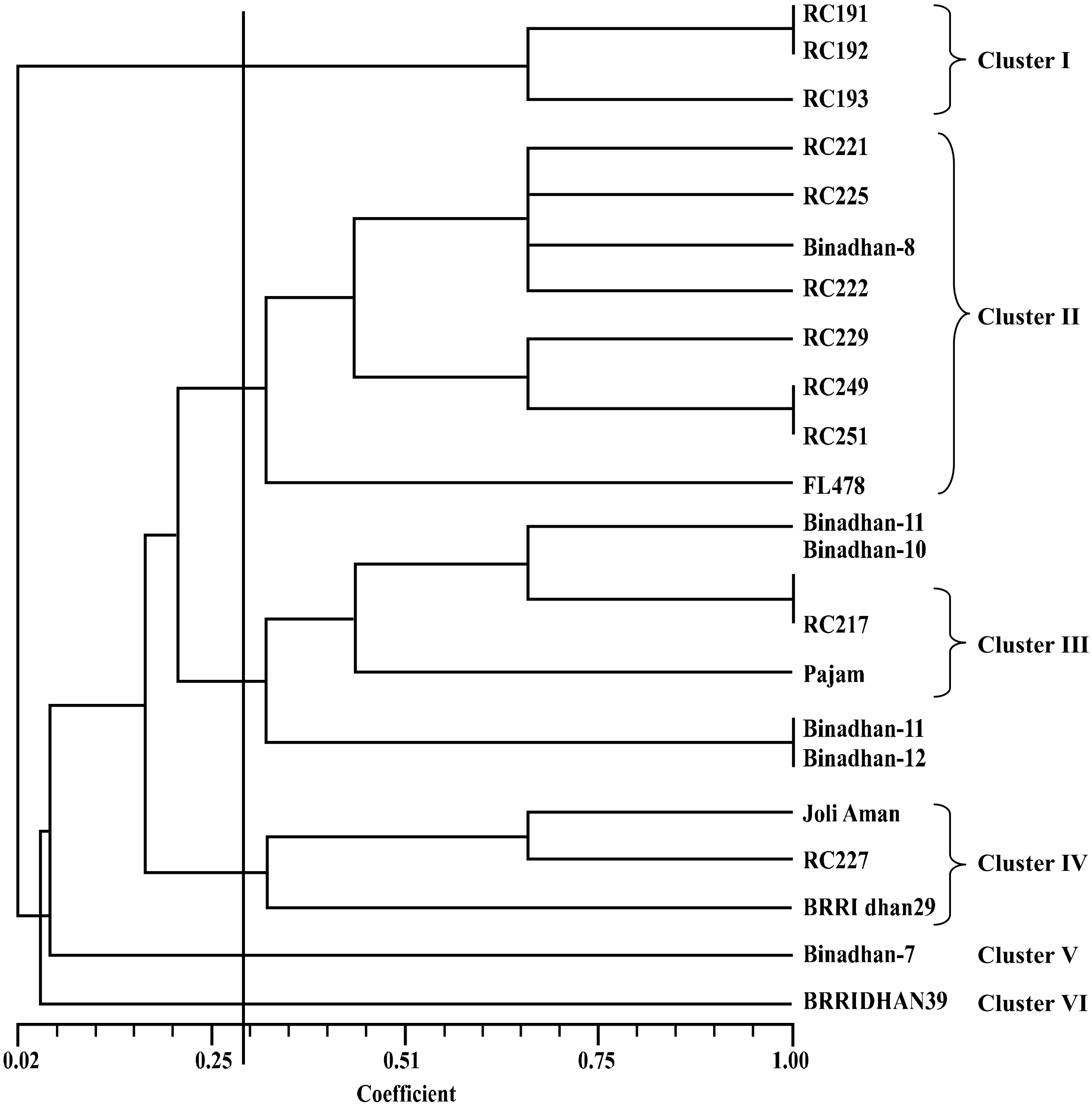


Fig. 7. UPGMA dendrogram based on Nei's (1973) genetic distance differentiation among 22 rice lines. Arrow line indicates the scale of genetic distance (0.00-1.00)

GENETIC DIVERSITY ANALYSIS OF DROUGHT TOLERANT NERICA-4 MUTANT LINES USING SSR AND RAPD MARKERS

Twenty nine early maturing mutant lines of drought tolerant varriety NERICA-4 were selected and investigated for molecular analysis. The experiment was carried out to select high yielding different mutant lines that would be drought tolerant and early maturing. Three selected SSR markers (RM215, RM351 and RM510) were used to study the genetic variation in 29 mutant lines of NERICA-4(Fig. 8 and Fig. 9). A total of 26 alleles were detected among 29 rice lines. The average number of allele per locus was 8.6667. The PIC values in this experiment varied from 0.6324 (RM351) to 0.8512 (RM510) (Table 10). The same lines were analyzed using three (OPB06, OPB10 and OPC01) RAPD markers and a total of 24 RAPD bands were scored (Fig. 11). A total of 24 polymorphic amplification products were obtained by using these primers. The highest number of bands were generated by primer OPB06 whereas, the least number of bands were produced by the both primer PAB10 and OPC01. The polymorphic amplification bands ranged from 7-10 and were computed to be 100% on average. The present study addressed the utilization of SSR and RAPD markers to determine genetic diversity and relationship among mutant lines at molecular level. The genetic diversity determined in this study will help in selection of mutant lines. Mutant lines N_4/250/p-5(5)-6-2, N_4/250/p-1(10)-26-16, N_4/250/p-1(2)-24-19, N_4/350/p-2(1)-32-15, N_4/250/p-2-24-22, N_4/350/p-2(1)-32-11, N_4/250/p-(2)-24-18 and N_4/250/p-1(1)-1 would be selected as desired mutants and could be recommended for further evaluation for drought tolerance.

Table 8. Different morphological parameters related to yield of 29 NERICA-4 mutant lines along with their parents

Mutant lines	Days to 1st flowering	Days to 50% flowering	Days to 80% flowering	Days to maturity	Plant height (cm)	Tillers plant^{-1} (no.)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	100 seed weight (g)	Grain yield plant^{-1} (g)
N_4/250/p-2(6)-30-6-4	65	70	77	99	100	6	6	23	66	42	2.9	11.3
N_4/250/p-5(5)-4-8-1	70	76	84	99	110	5	4	22	51	66	2.8	5.7
N_4/350/p-4(5)-13-10-2	67	72	80	100	110	4	4	21	52	89	3.0	6.2
N_4/350/p-3(3)-11-7-7	65	70	79	101	122	20	18	28	56	59	2.8	48.7
N_4/350/p-6(1)-4-1	73	79	85	99	107	5	4	23	99	58	2.9	11.3
N_4/350/p-31-3-3	75	82	88	99	106	8	5	23	76	41	2.8	10.6
N_4/350/p-4-5-35-11	72	78	85	102	108	14	12	24	156	14	2.3	43.7
N_4/350/p-1(1)-3-3	68	74	82	100	112	13	9	22	170	33	2.8	43.3
N_4/350/p-6-1-8-1	69	75	82	98	107	6	6	26	94	14	3.1	17.2
N_4/350/p-6(1)-6-2	66	71	77	98	101	11	10	26	104	40	2.8	29.4
N_4/350/p-2(8)-5-2	74	80	88	97	90	4	3	24	117	26	3.1	10.9
N_4/250/p-5(5)-6-2	75	81	87	100	95	9	8	19	64	18	3.2	16.2
N_4/250/p-5(3)-4-12-1	72	77	84	99	96	12	7	21	76	20	2.6	13.9
N_4/350/p-1(1)- 19-14-4	75	80	87	98	99	7	7	22	62	23	2.9	12.8
N_4/350/p-3-12-8-5	66	72	83	97	110	5	5	24	110	42	2.8	17.1
N_4/250/p-2(3)-2-10-7	76	81	86	98	108	7	6	25	92	35	2.8	15.4
N_4/250/p-5(5)-4-8-6	68	73	80	96	106	8	7	24	55	107	3.2	12.4
N_4/250/p-2(6)-26-39-10	70	75	81	100	111	15	14	27	128	55	1.9	35.3
N_4/250/p-1(2)-24-19	75	80	86	99	108	20	17	26	157	32	1.9	51.7
N_4/250/p-1(1)-1	64	70	76	99	106	4	4	25	56	25	2.8	6.2
N_4/350/p-4(5)-14-2-2	66	71	77	98	114	3	3	24	99	103	2.7	8.0
N_4/250/p-1(10)-26-16	72	78	85	105	96	6	6	23	104	25	3.2	19.7
N_4/250/p-2-24-22	73	78	86	106	124	11	11	24	218	27	2.1	50.7
N_4/250/p-(2)-24-18	75	80	85	104	126	8	8	23	160	37	2.7	34.3
N_4/350/p-2(1)-32-15	76	82	87	103	148	13	12	24	57	24	2.4	16.2
N_4/250/p-2(6)-26-13	67	72	80	104	135	25	20	25	110	39	2.1	66.7
N_4/350/p-2(1)-32-11	72	77	84	103	138	18	17	28	155	24	2.2	57.2
N_4/250/p-2(5)-11-13	75	81	86	105	135	19	18	27	119	35	2.5	54.4
NERICA-4 (check)	76	83	88	113	100	9	5	22	96	20	3.2	31.5
Mean	70	76.5	82	104.5	121.5	14	11.5	23.5	110.5	60.5	2.55	36.2
Range	64-76	70-83	76-88	96-113	95-148	3-25	3-20	19-28	51-170	14-107	1.9-3.2	5.7-66.7
LSD (0.05)	3.42	3.42	2.14	2.96	4.34	28	3.50	1.96	6.2	5.42	2.1	4.0

Table 9. Coefficient of genotypic correlation among different yield components of 29 NERICA-4 mutant lines

Characters	Days to 1st flowering	Days to 50% flowering	Days to 80% flowering	Days to maturity	Plant height (cm)	Tillers plant^{-1} (no.)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	100 seed weight (g)
Days to 1st flowering	0.990**	0.932**	0.362	0.051	-0.062	-0.105	-0.199	0.227	-0.452*	-0.088	0.083
Days to 50% flowering	1	0.948**	0.383*	0.021	-0.100	-0.150	-0.232	0.196	-0.477**	-0.027	0.045
Days to 80% flowering		1	0.334	-0.009	-0.072	-0.121	-0.271	0.235	-0.491**	-0.004	0.069
Days to maturity			1	0.361	0.305	0.276	0.019	0.335	-0.349*	-0.184	0.510**
Plant height (cm)				1	0.541**	0.588**	0.503**	0.256	0.040	-0.597**	0.561**
Total number of tillers hill-^{1}					1	0.982**	0.534**	0.208	-0.128	-0.570**	0.830**
Effective number of tillers hill^{-1}						1	0.608**	0.200	-0.091	-0.567**	0.822**
Panicle length (cm)							1	0.286	-0.001	-0.510**	0.559**
Filled grains panicle^{-1}								1	-0.310	-0.551**	0.667**
No. of unfilled grains panicle^{-1}									1	0.144	-0.278
100 seed weight (g)										1	-0.656**

** = Significant at 1% and * = Significant at 5% level

Table 10. Summary statistics of 3 SSR markers used to study molecular diversity of 29 NERICA-4 mutant lines

Marker	Major Allele Frequency	Genotype No.	Sample No.	No. of obs.	Allele No.	Availability	Gene Diversity	Heterozygosity	PIC
RM215	0.2414	11.0000	29	29	11	1	0.8585	0	84370.
RM351	0.4828	5.0000	29	29	5	1	0.6778	0	0.6321
RM510	0.2069	10.0000	29	29	10	1	0.8656	0	0.8512
Mean	0.3103	8.6667	29	29	8.666	1	0.8006	0	0.7757

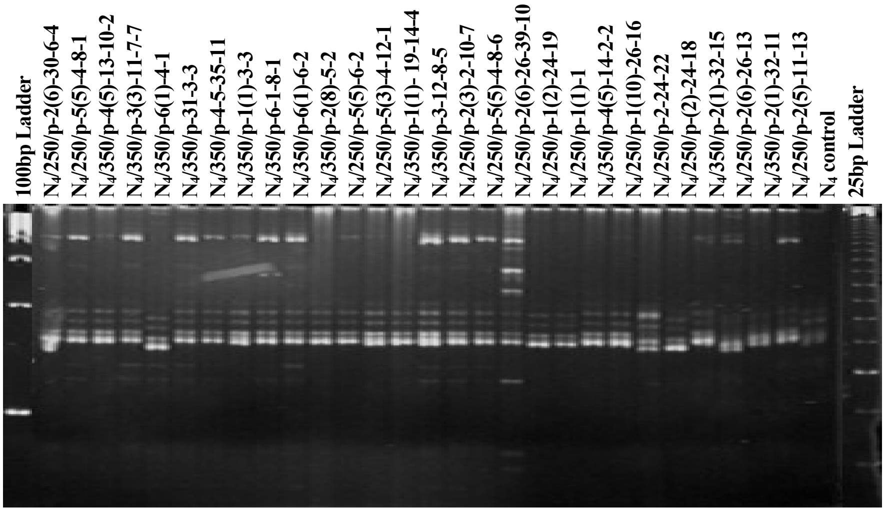


Fig. 8. SSR profile of 29 NERICA-4 mutant lines using primer RM215

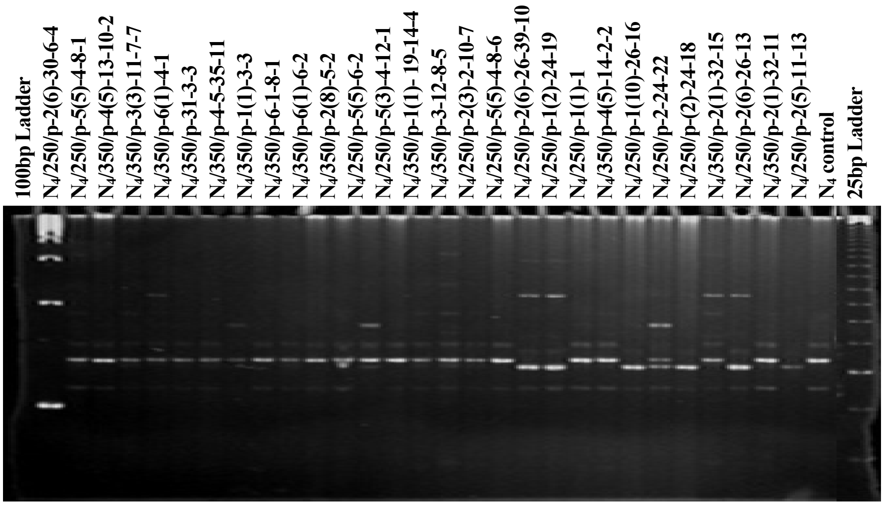


Fig. 9. SSR profile of 29 NERICA-4 mutant lines using primer RM351

Table 11. RAPD primers with corresponding bands score and their size range together with polymorphic bands observed in 29 NERACA-4 mutant lines

Primer code	Sequences (5′-3′)	No. of bands scored	Size ranged (bp)	No. of polymorphic bands	Polymorphic loci (%)
OPB06	TGCTCTGCCC	10	200-850	10	100
OPB10	CTGCTGGGAC	7	120-900	7	100
OPC01	TTCGAGCCAG	7	350-900	7	100
Total		24		24	300
Average		8		8	100

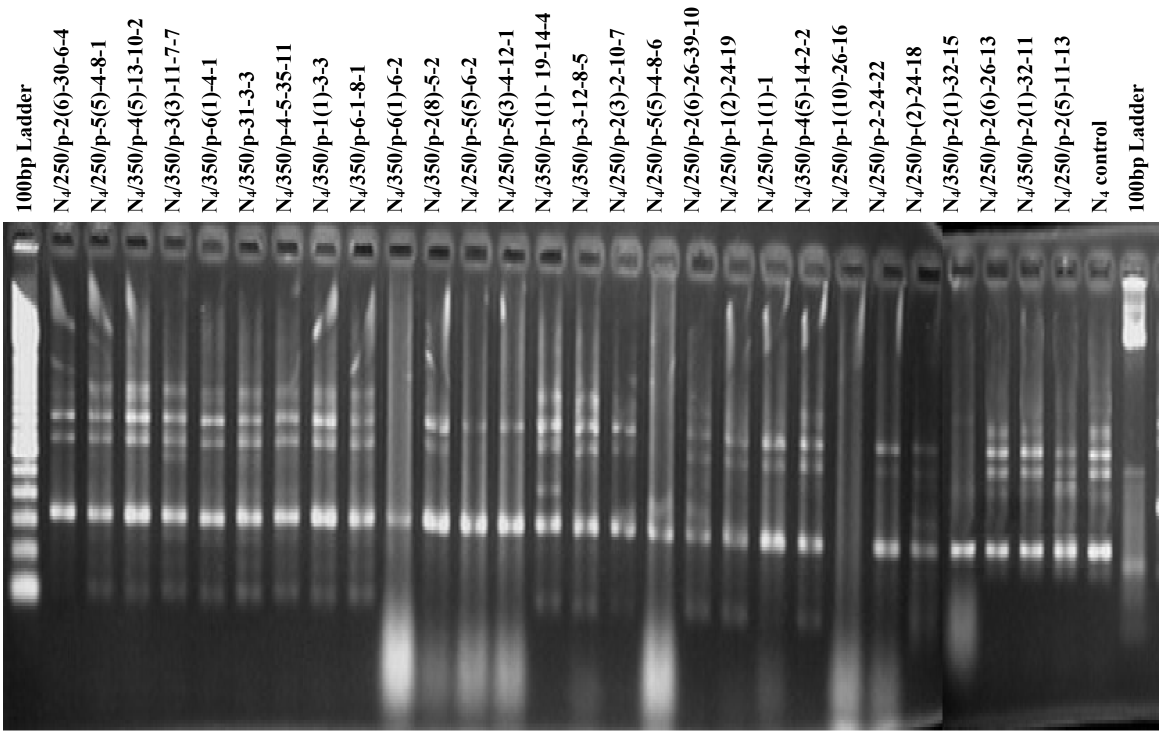


Fig. 10. RAPD profile of 29 NERICA-4 mutant lines including using primer OPB10

Table 12. Summary of the band sharing based on percentage similarity indices within and between individuals of 29 NERICA-4 mutant lines. Similarity (s_i) between individuals of the same variety

Mutant lines	Band sharing values (%)			
	OPB06	OPB10	OPC01	Average S_i (%)
N_4/250/p-2(6)-30-6-4	70.00	57.14	57.14	61.43
N_4/250/p-5(5)-4-8-1	70.00	71.43	57.14	66.19
N_4/350/p-4(5)-13-10-2	70.00	71.43	57.14	66.19
N_4/350/p-3(3)-11-7-7	80.00	85.71	42.86	69.52
N_4/350/p-6(1)-4-1	70.00	71.43	57.14	66.19
N_4/350/p-31-3-3	70.00	71.43	57.14	66.19
N_4/350/p-4-5-35-11	60.00	71.43	42.86	58.10
N_4/350/p-1(1)-3-3	70.00	71.43	57.14	66.19
N_4/350/p-6-1-8-1	70.00	71.43	57.14	66.19
N_4/350/p-6(1)-6-2	80.00	14.29	57.14	50.48
N_4/350/p-2(8)-5-2	60.00	57.14	57.14	58.10
N_4/250/p-5(5)-6-2	0.00	28.57	42.86	23.81
N_4/250/p-5(3)-4-12-1	70.00	28.57	71.43	56.67
N_4/350/p-1(1)- 19-14-4	100.00	85.71	42.86	76.19
N_4/350/p-3-12-8-5	80.00	71.43	57.14	69.52
N_4/250/p-2(3)-2-10-7	80.00	71.43	28.57	60.00
N_4/250/p-5(5)-4-8-6	90.00	28.57	0.00	39.52
N_4/250/p-2(6)-26-39-10	70.00	85.71	71.43	75.71
N_4/250/p-1(2)-24-19	70.00	57.14	71.43	66.19
N_4/250/p-1(1)-1	70.00	42.86	57.14	56.67
N_4/350/p-4(5)-14-2-2	60.00	71.43	28.57	53.33
N_4/250/p-1(10)-26-16	0.00	0.00	42.86	14.29
N_4/250/p-2-24-22	10.00	42.86	71.43	41.43
N_4/250/p-(2)-24-18	10.00	57.14	28.57	31.90
N_4/350/p-2(1)-32-15	70.00	57.14	85.71	70.95
N_4/250/p-2(6)-26-13	70.00	71.43	85.71	75.71
N_4/350/p-2(1)-32-11	70.00	71.43	71.43	70.95
N_4/250/p-2(5)-11-13	70.00	71.43	42.86	61.43
N_4 control	100.00	71.43	57.14	76.19
Average	64.14	59.61	53.69	59.15

DNA FINGERPRINTING AND MORPHO MOLECULAR SCREENING OF SELECTED RICE GERMPLASMS FOR SALT TOLERACE USING SSR AND RAPD MARKERS

Thirty five rice germplasms including traditional landraces, advance lines and modern varieties were used to conduct this experiment for screening salinity tolerant genotypes by DNA fingerprinting and morpho-molecular analysis. Salinity screening was performed at seedling and reproductive stage using modified hydroponic method and sustained water bath following IRRI standard protocol respectively. For phenotypic study of the germplasms, saline water having EC 12 dSm^{-1} and 8 dSm^{-1} were used at seedling and reproductive stage respectively. Biochemical analysis of Na^+-K^+ content in leaf tissue after salinity treatment at harvesting stage was also conducted.

Table 14. Phenotypic performance of 35 rice genotypes at seedling stage using modified hydroponic system at EC 12 dSm^{-1}

Genotype	Shoot length (cm)			Root length (cm)			Total dry matter (g)		
	Non-salanized	Salinized	% reduction	Non-salanized	Salinized	% reduction	Non-salanized	salinized	% reduction
Kajol Shail	25.70	18.74	27.08	7.80	5.80	25.60	0.48	0.33	30.61
Hogla	27.60	15.48	43.91	7.90	6.50	18.00	0.49	0.45	8.16
Jamai Naru	19.33	15.00	22.40	8.20	7.80	4.88	0.46	0.42	8.69
Dakh Shail	19.90	15.20	24.00	8.20	6.60	19.51	0.61	0.37	39.34
Patnai	22.30	17.80	22.18	8.80	7.10	19.32	0.56	0.51	8.92
Bhute Shalot	27.20	17.75	34.74	5.80	5.10	12.07	0.67	0.48	28.36
Kute Patnai	19.20	13.62	28.02	7.80	7.40	5.13	0.57	0.51	10.90
Khak Shail	41.40	19.60	52.66	9.90	8.60	13.13	0.68	0.50	26.47
Holde Gotal	25.20	16.08	36.19	6.60	5.20	21.21	0.71	0.63	11.26
Jota Balam	20.70	15.04	27.34	6.70	11.40	10.45	0.53	0.49	7.54
Bazra Muri	20.70	16.56	20.00	6.20	6.60	16.13	0.57	0.53	7.02
Ghunshi	18.80	15.16	19.36	11.38	6.20	45.52	0.76	0.64	15.79
Hamai	12.40	10.00	19.35	8.30	5.10	39.00	0.62	0.50	19.35
Karengal	24.90	10.90	56.22	8.30	6.50	21.69	0.49	0.35	28.57
Kalo Mota	24.20	18.35	24.17	7.50	6.20	17.00	0.47	0.31	34.04
Mondeshor	26.20	19.48	25.65	9.30	7.90	15.05	0.50	0.36	28.00
Nona Kochi	16.50	09.61	41.76	8.00	6.90	13.75	0.45	0.30	33.33
Tal Mugur	33.70	20.91	37.95	9.60	8.30	13.54	0.44	0.39	11.36
Nona Bokhra	24.50	21.51	12.20	8.50	7.20	15.29	0.55	0.43	21.82
Binadhan-8	16.00	13.00	18.75	5.50	4.80	12.73	0.54	0.46	14.81
FL-478	11.90	10.00	15.96	5.10	4.90	3.92	0.64	0.60	6.25
Kashrail	23.70	17.34	26.84	8.70	7.50	13.79	0.42	0.37	11.90
Jolkumri	19.70	09.64	51.07	7.00	5.70	18.57	0.48	0.32	33.33
Pokkali	24.80	18.60	25.00	5.90	5.10	13.56	0.53	0.43	18.86
Fl-378	17.10	14.48	15.32	5.10	4.70	7.84	0.65	0.60	7.69
Dudh Kalam	21.50	15.50	27.29	10.40	7.00	32.69	0.71	0.40	43.66
Hati Bajore	24.80	12.13	42.06	9.30	6.40	31.18	0.70	0.40	42.86
Kalmilata	24.80	17.00	31.45	9.80	5.00	48.97	0.68	0.38	44.12
Rupessor	22.60	12.30	45.58	6.70	3.90	41.79	0.75	0.45	40.00
Mota Aman	26.20	16.02	38.85	7.70	6.30	18.18	0.80	0.41	48.75
Chap Shail	23.30	18.03	22.62	8.90	7.60	14.61	0.78	0.39	50.00
Kali Boro	28.80	15.12	47.50	8.00	5.20	34.00	0.79	0.48	39.24
Kali Boro138	20.10	14.00	30.35	6.50	1.00	84.62	0.44	0.25	43.18
BRRI Dhan-29	14.70	8.00	45.58	4.90	2.00	59.18	0.53	0.30	43.39
IR-29	16.00	6.00	62.50	7.50	2.00	73.33	0.53	0.28	47.17

Table 15. Average Na^+, K^+ and Na^+-K^+ ratio in shoot and salinity tolerance of selected germplasms of rice grown under salinized and non-salinized conditions

Germplasm	Shoot conc. (%) of Na^+		Shoot conc. (%) of K^+		Shoot Na/K ratio		Reaction to Salinity
	Non salanized	Salinized	Non salanized	Salinized	Non salanized	Salinized	
Hogla	0.0262	0.3910	1.3912	2.5523	0.0188	0.1531	Tolerant
Jamai Naru	0.0206	0.3425	1.5390	2.3012	0.0133	0.1488	Tolerant
Dakh Shail	0.0206	0.3625	1.5930	2.3635	0.0129	0.1533	Tolerant
Patnai	0.0224	0.3651	1.7735	2.3512	0.0126	0.1553	Tolerant
Pokkali	0.0150	0.3991	1.2850	2.5200	0.0116	0.1583	Tolerant
FL-378	0.0206	0.4352	1.2107	2.6850	0.0170	0.1620	Tolerant
Khak Shail	0.0299	0.3552	1.1363	2.5012	0.0263	0.1420	Tolerant
Tal Mugur	0.0262	0.3670	2.4107	2.4210	0.0108	0.1516	Tolerant
Nona Bokhra	0.0150	0.4561	1.2532	2.5500	0.0119	0.1788	Tolerant
Ghunshi	0.0299	0.3500	1.3806	2.5215	0.0216	0.1388	Tolerant
Binadhan-8	0.0150	0.4012	1.8373	2.4901	0.0081	0.1611	Tolerant
FL-478	0.0205	0.4204	1.2107	2.4512	0.0169	0.1715	Tolerant
Kashrail	0.0226	0.4012	1.3806	2.4902	0.0163	0.1610	Tolerant
Kajol Shail	0.0505	0.5025	2.2408	2.2952	0.0225	0.2189	Moderately Tolerant
Bazra Muri	0.0187	0.5691	1.1363	2.5012	0.0164	0.2275	Moderately Tolerant
Hamai	0.0262	0.5933	1.2956	2.5048	0.0202	0.2368	Moderately Tolerant
Karengal	0.0262	0.5869	1.6461	2.5126	0.0159	0.2335	Moderately Tolerant
Kalo Mota	0.0112	0.5721	1.5293	2.5612	0.0073	0.2233	Moderately Tolerant
Holde Gotal	0.0617	0.5312	1.4974	2.5122	0.0412	0.2114	Moderately Tolerant
Jota Balam	0.0281	0.5812	1.4974	2.5365	0.0187	0.2291	Moderately Tolerant
Mondeshor	0.0318	0.5377	1.3487	2.5126	0.0235	0.2140	Moderately Tolerant
Nona Kochi	0.0337	0.5562	1.1576	2.5423	0.0291	0.2187	Moderately Tolerant
Jolkumri	0.0224	0.5820	1.3169	2.5512	0.0170	0.2281	Moderately Tolerant
Bhute Shalot	0.0299	0.5525	1.8266	2.2510	0.0163	0.2454	Moderately Tolerant
Kute Patnai	0.0468	0.5836	0.8815	2.1256	0.0530	0.2745	Moderately Tolerant
Dudh Kalam	0.0306	0.6525	1.3212	1.9350	0.0232	0.3372	Susceptible
Hati Bajore	0.0263	0.6312	2.4109	1.9012	0.0124	0.3320	Susceptible
Kalmilata	0.0164	0.8203	1.3125	2.4039	0.0125	0.3412	Susceptible
Chap Shail	0.0148	0.7689	1.3026	2.4861	0.0113	0.3092	Susceptible
Kali Boro	0.0150	0.7500	1.3526	2.4501	0.0110	0.3061	Susceptible
KaliBoro138/2	0.0163	0.7891	1.5692	2.4132	0.0103	0.3269	Susceptible
BRRI dhan29	0.0189	0.8203	1.5986	2.4210	0.0118	0.3387	Susceptible
Rupessor	0.0198	0.8150	1.6236	2.4269	0.0121	0.3358	Susceptible
Mota Aman	0.0159	0.6523	1.2896	1.9350	0.0123	0.3590	Highly susceptible
IR 29	0.0193	0.8352	1.6936	2.4101	0.0113	0.3500	Highly susceptible
LSD (0.05)							

For DNA fingerprinting of rice germplasm, DNA was extracted from leaf samples using IRRI standard method. In this study 8 selected SSR markers viz. RM585, RM336, AP3206, AP3206f, RM8094, SalT1, RM7075 and RM493 were used to screen the germplasm for salt tolerance and 7 RAPD markers viz. OPA04, OPB04, OPB08, OPB10, OPC02, OPC04 and OPC05 were used to analyze genetic diversity. From the SSR analysis, it was found that an average number of 17.75 alleles per locus were detected with PIC values ranged from 0.8779 (SalT1) to 0.9515 (RM336). The highest gene diversity (0.9029) was observed in loci RM336 and the lowest gene diversity (0.757) was observed in loci AP3206 with a mean diversity of 0.8604 (Table 16). Besides RAPD analysis showed 53 loci, where the highest value of gene frequency was obtained 1 among 5 loci viz. OPA04-5, OPB10-5, OPC02-8, OPC05-4 and OPC02-8 while the lowest gene frequency was obtained 0.0571 among 2 loci viz. OPB10-4 and OPC02-9. In general, thirteen genotypes were selected as salinity tolerant, twelve were moderately tolerant and ten were susceptible based on modified standard evaluation score for visual salt injury as well as molecular (SSR) screening. Both SSR and RAPD analysis showed a significantly correlated result. This information could be used for selection of suitable parents for development of salt tolerant rice varieties. Both SSR and RAPD analysis showed a significantly correlated result.

Table 16. Allele variation, PIC values and gene diversity for SSR markers identified in 35 rice germplasms

Primer/Locus	RM	Ta (^{0}C)	NA	EPV	SR (bp)	PIC values	Rare allele	FMA	Gene diversity
RM336	$(CTT)_{18}$	55	17	154	129-165	0.8957	3	0.2000	0.9029
RM585	$(TC)_{45}$	55	16	233	225-240	0.8915	2	0.1714	0.8996
AP3206	$(GAA)_8$	55	9	375	354-374	0.7334	1	0.4286	0.7576
AP3206f	$(AC)_{18}$	55	8	167	154-161	0.7487	1	0.3714	0.7771
RM493	$(CTT)_9$	59	14	211	200-216	0.8874	1	0.1714	0.8963
RM7075	$(ACAT)_{13}$	50	13	155	150-169	0.8594	2	0.2286	0.8718
Sal T1	$(ACAA)_{15}$	55	12	159	141-159	0.8908	1	0.1429	0.8996
RM8094	$(CT)_{18}$	48	11	209	201-215	0.8664	1	0.2000	0.8784
Mean			12.5			0.8466	1.5	0.2393	0.8604

Ta = Annealing Temperature, RM = Repeat Motif, NA = Number of allele, EP = Expected PCR value, SR = size ranges and FMA = Frequency of major allele

Table 17. RAPD primers with corresponding polymorphic bands scored in 35 rice genotypes

Primer codes	Sequence (5$^/$-3$^/$)	Total bands scored (no.)	Polymorphic bands (no.)	Percentage of polymorphic loci (%)
OPA04	AATCGGGCTG	9	8	88.89
OPB04	GGACTGGAGT	6	6	100
OPB08	GTCCACACGG	9	9	100
OPB10	CTGCTGGGAC.	5	4	80.00
OPC02	GTGAGGCGTC	9	8	88.89
OPC04	CCGCATCTAC	7	7	100.00
OPC05	GATGACCGCC	8	6	75.00
Total		53	48	632.78
Average		7.57	6.87	90.39

CHARACTERIZATION OF NERICA-1 MUTANTS THROUGH RAPD MARKERS

This experiment was carried out to evaluate the performance of 31 advanced NERICA-1 mutant rice lines. Among these lines 10 mutant from 250 Gy radiation; 10 from 300 Gy and 10 from 350 Gy radiations including a control were used in the experiment to study their relationship and diversity among the NERICA-1 mutant lines and characterize the NERICA-1 mutant lines at molecular level through RAPD (OPB06, OPB10 and OPC01) markers (Fig. 11). For molecular characterization, in total 22 reproducible DNA bands were generated by 3 arbitrary selected primers (OPB06, OPB10 and OPC01) of which 15 (66.57%) bands were proved to be polymorphic. The highest proportion of polymorphic loci was found in OPC01 (100%) (Table 18).

Table 18. RAPD primers with corresponding bands score and their size range together with polymorphic bands observed in NERICA-1 mutants

Primer	Sequences (5′-3′)	No. of bands scored	Size range (bp)	No. of polymorphic bands	Polymorphic loci (%)
OPB06	TGCTCTGCCC	7	220-950	2	28.57
OPB10	CTGCTGGGAC	7	310-890	5	71.43
OPC01	TTCGAGCCAG	8	450-950	8	100.00
Total		22		15	200.00
Average		7.33		5.00	66.67

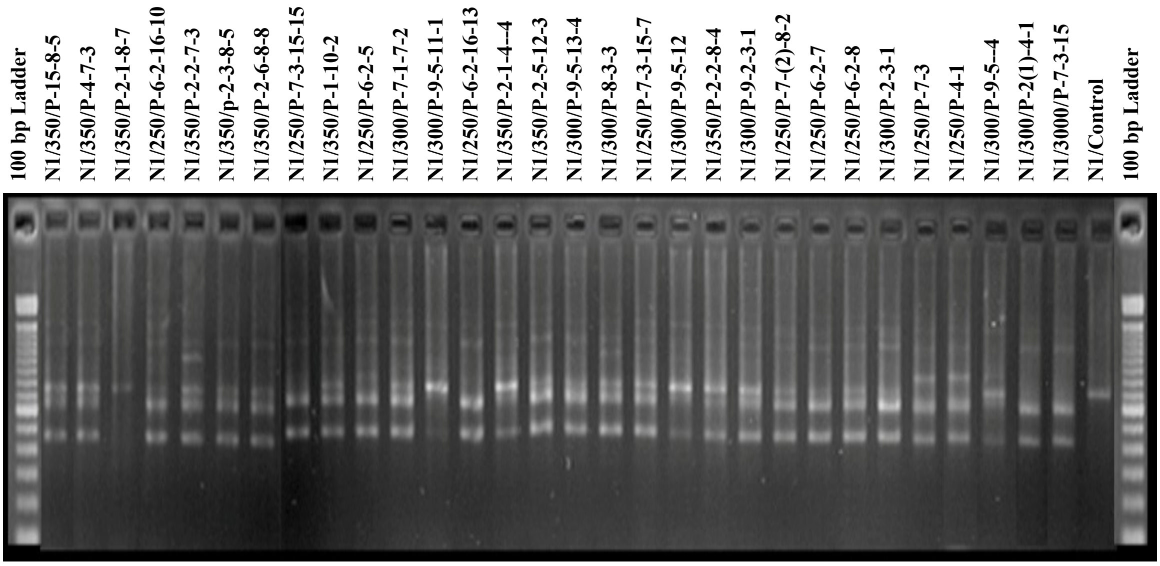


Fig. 11. RAPD profiles of 31 NERICA-1 mutant lines using primer OPC01

Table 19. Summary of the band sharing based on percentage similarity indices within and between individuals of NERICA-1 mutant lines

Genotypes	Band sharing values (%)			
	OPB06	OPB10	OPC01	Average S_i (%)
N_1/350/P-15-8-5	100.00	85.71	62.50	82.74
N_1/350/P-4-7-3	71.43	85.71	62.50	73.21
N_1/350/P-2-1-8-7	85.71	85.71	12.50	61.31
N_1/250/P-6-2-16-10	85.71	100.00	87.50	91.07
N_1/350/P-2-2-7-3	100.00	71.43	75.00	82.14
N_1/350/p-2-3-8-5	71.43	71.43	50.00	64.29
N_1/350/P-2-6-8-8	100.00	85.71	62.50	82.74
N_1/250/P-7-3-15-15	71.43	100.00	75.00	82.14
N_1/350/P-1-10-2	100.00	100.00	75.00	**91.67**
N_1/250/P-6-2-5	100.00	85.71	75.00	86.90
N_1/300/P-7-1-7-2	85.71	71.43	75.00	77.38
N_1/300/P-9-5-11-1	100.00	71.43	37.50	69.64
N_1/250/P-6-2-16-13	100.00	100.00	75.00	**91.67**
N_1/350/P-2-1-4-4	85.71	85.71	50.00	73.81
N_1/350/P-2-5-12-3	100.00	57.14	75.00	77.38
N_1/300/P-9-5-13-4	85.71	28.57	87.50	67.26
N_1/300/P-8-3-3	100.00	28.57	75.00	67.86
N_1/250/P-7-3-15-7	85.71	28.57	87.50	67.26
N_1/300/P-9-5-12	85.71	28.57	75.00	63.10
N_1/350/P-2-2-8-4	85.71	42.86	62.50	63.69
N_1/300/P-9-2-3-1	71.43	57.14	75.00	67.86
N_1/250/P-7-(2)-8-2	71.43	42.86	75.00	63.10
N_1/250/P-6-2-7	71.43	57.14	62.50	63.69
N_1/250/P-6-2-8	71.43	42.86	75.00	63.10
N_1/300/P-2-3-1	100.00	42.86	62.50	68.45
N_1/250/P-7-3	100.00	42.86	75.00	72.62
N_1/250/P-4-1	100.00	42.86	75.00	72.62
N_1/300/P-9-5-4	85.71	42.86	62.50	63.69
N_1/300/P-2(1)-4-1	85.71	57.14	37.50	60.12
N_1/300/P-7-3-15	100.00	57.14	37.50	64.88
N_1/Control	100.00	57.14	12.50	56.55
Average	88.94	63.13	64.11	72.06

Expression Analysis of *Saltol* and *Sub1* Genes in Rice Genotypes by Restriction Digestion of cDNA

Salinity and submergence are very complex trait. Plant adapt to salinity and submergence stress by coordinated functioning of various complex mechanisms which is controlled by a number of genes. Among them *SOS* (salt overly sensitive) and *SKC* gene family high-affinity K^+ transporters (*HKT*) pathway has been established as a major player in ion homeostasis and salt tolerance. The major candidates for transporters that could withdraw Na^+ from the xylem are nonselective cation channels and high-affinity K^+ transporters *(HKT1)* that function as Na^+ uniporters.

On the other hand, submergence tolerance is managed by a single major quantitative trait locus (QTL) on chromosome 9 along with a number of minor QTLs. The major QTL/*Sub1* provides tolerance to complete submergence for up to 2-3 weeks. Sequencing the *Sub1* region in an FR13A-derived line revealed the presence of three genes encoding putative ethylene responsive factors (*ERF*); *Sub1A*, *Sub1B* and *Sub1C* were subsequently identified as the major determinant of submergence tolerance.

In the present study, The *HKT1/SKC1* and *Sub1A* full length cDNA from 16 rice genotypes was isolated and characterized using salinity and submergence tolerant gene specific primer RM7075 and ART5. Three restriction enzymes (*PstI, DraI* and *HinfI*) were used for digesting PCR product of *HKT1* cDNA sequence and *EcoRI, BamHI* and *HindIII* for digesting PCR product of *Sub1A* cDNA sequence. At the end, the image of agarose gel electrophoresis was used to observe the expression pattern of *HKT1* and *Sub1* gene.

Expression analysis of *HKT1* and *SUB1A* gene using restriction digestion of cDNA

It is observed that *HKT1* gene specific primer RM7075 showed average 155 bp PCR products and *Sub1A* gene specific primer ART5 gave average 217 bp PCR product. But in this restriction digestion system, PCR product of *HKT1* genes was amplified against RM7075 gave bands less than 155 bp for all restriction digestion (*PstI, DraI* and *HinfI)*, where undigested cDNA PCR product gave 155 bp banding patterns for all rice genotypes (Fig. 11) except Binadhan-7 (null band) .

On the other hand, PCR product of *Sub1* genes which was amplified using ART5 gave bands 217bp for restriction digestion *(EcoRI* and *BamHI),* which are equal to the bands of undigested cDNA PCR product (217 bp). Digestion of PCR product by *HindIII* gave the banding patterns less than undigested cDNA PCR product (217 bp). Same type of banding patterns was observed for all rice genotypes except Binadhan-7 (Fig. 12).

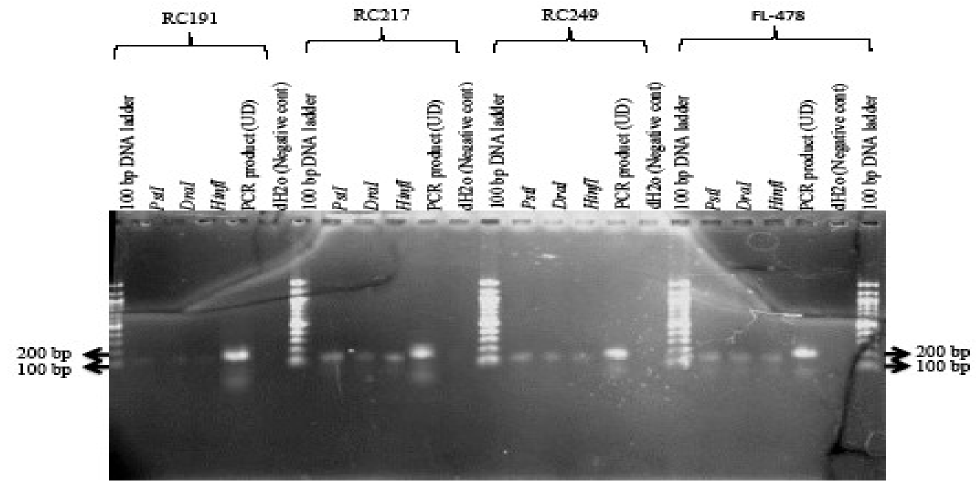


Fig. 12. Restriction digested first strand cDNA PCR product of *HKT1* gene sequence. Here, PCR product 'UD' means undigested PCR product

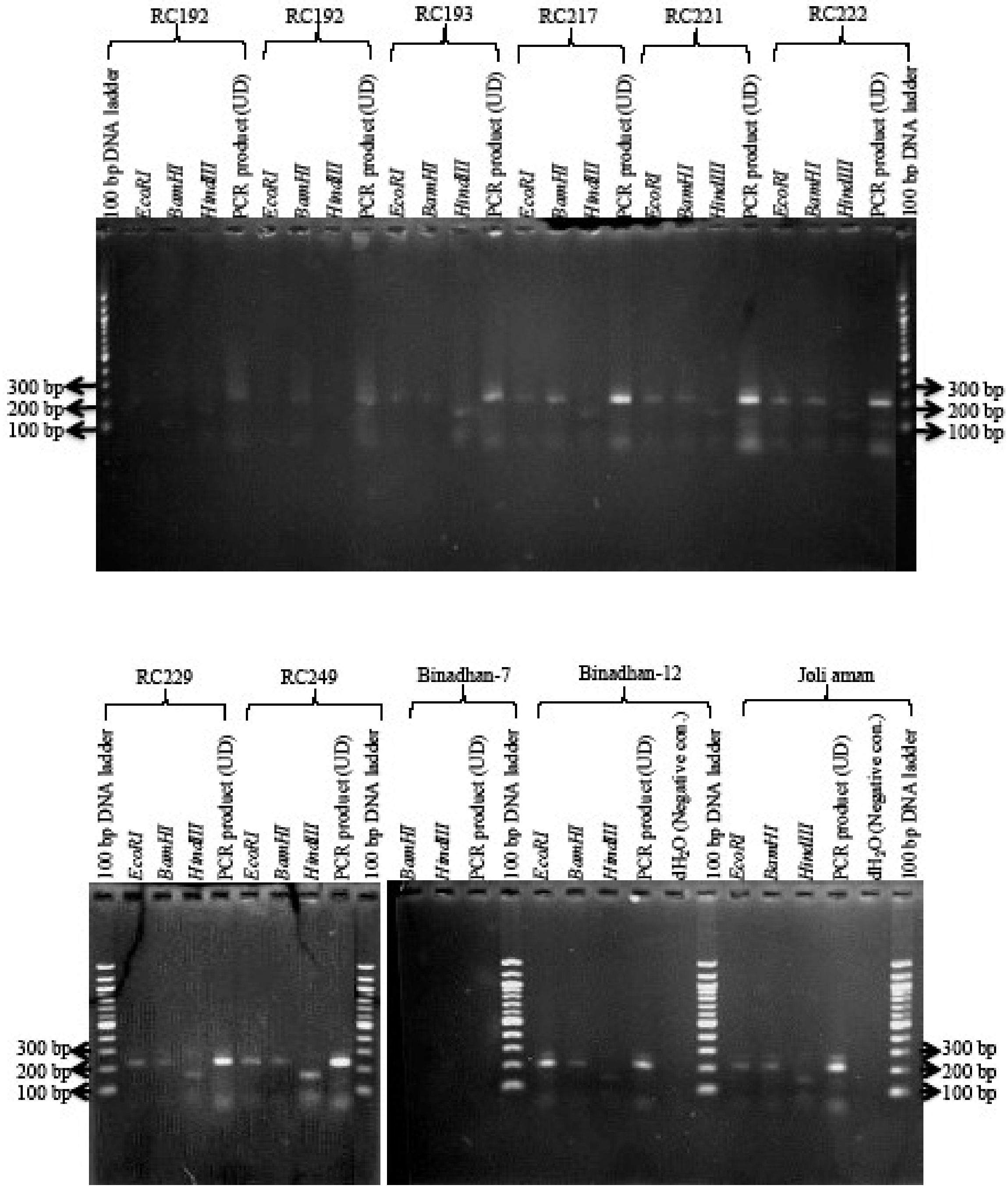


Fig. 13. Restriction digested first strand cDNA PCR product of *Sub1A* gene sequence. Here, PCR product 'UD' means undigested PCR product

Determination of expression level of *HKT1* and *Sub1A* gene by half cycle PCR of cDNA product from restriction digestion

To conform and determine the level of gene expression, half cycle PCR of previously restriction digestion product was done and molecular weight of each allele of individual rice genotype against specific restriction enzyme were measured using alpha view image analysis software. In this case, molecular weight of the PCR product of *HKT1* genes and *Sub1* genes were compared with undigested PCR product. The rice genotypes that gave the similar size allele pattern compared with the allele size of undigested PCR product were counted as proper expression of specific gene. The rice genotype that gave the larger allelic pattern (higher molecular weight) than undigested PCR product was counted as overexpression of specific gene. Finally, the rice genotypes that gave the smaller allelic pattern (higher molecular weight) than undigested PCR product were counted as incomplete expression of specific gene (Fig. 13 and 14).

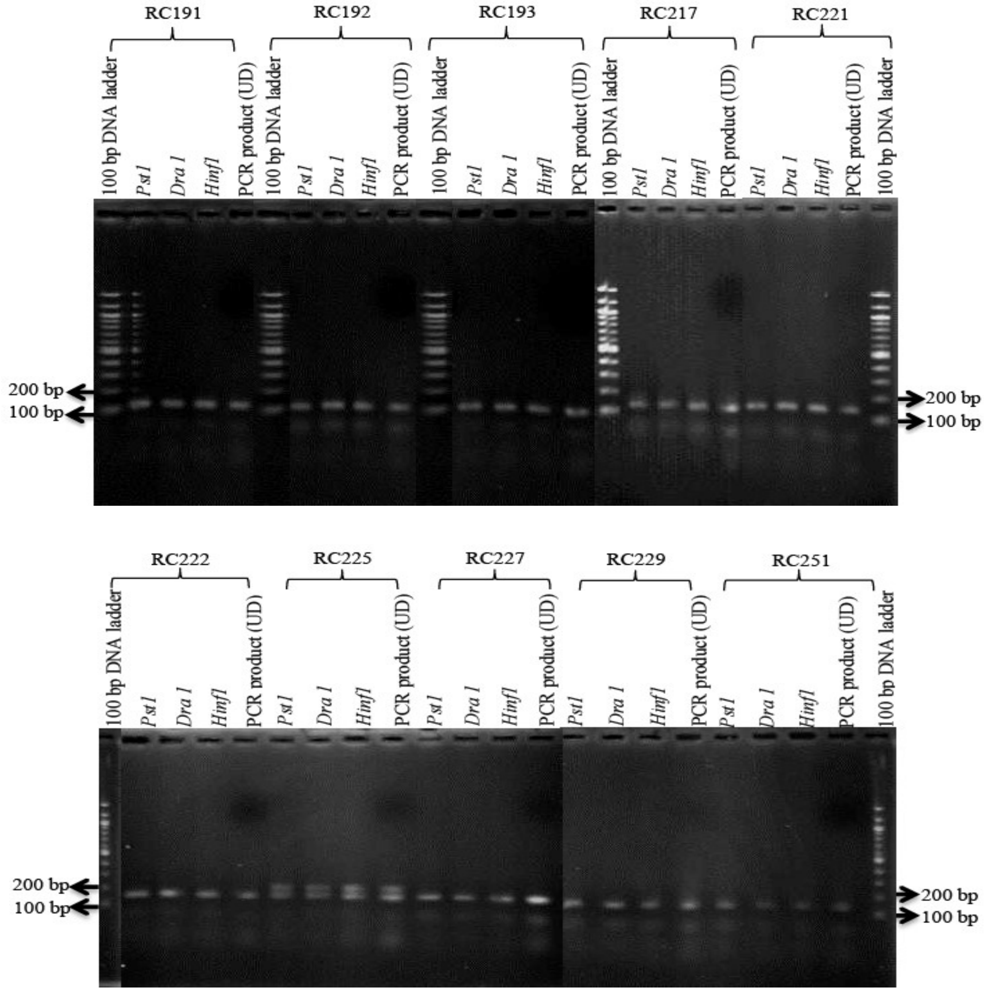
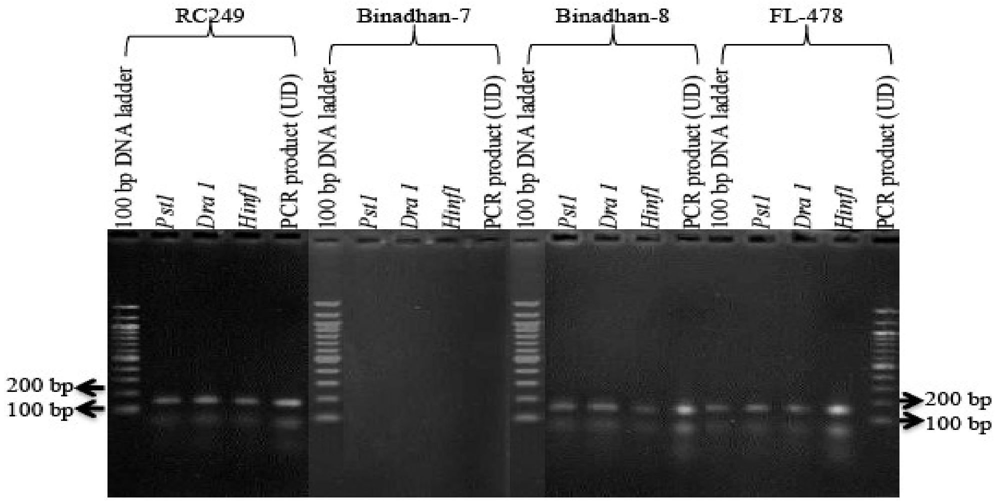
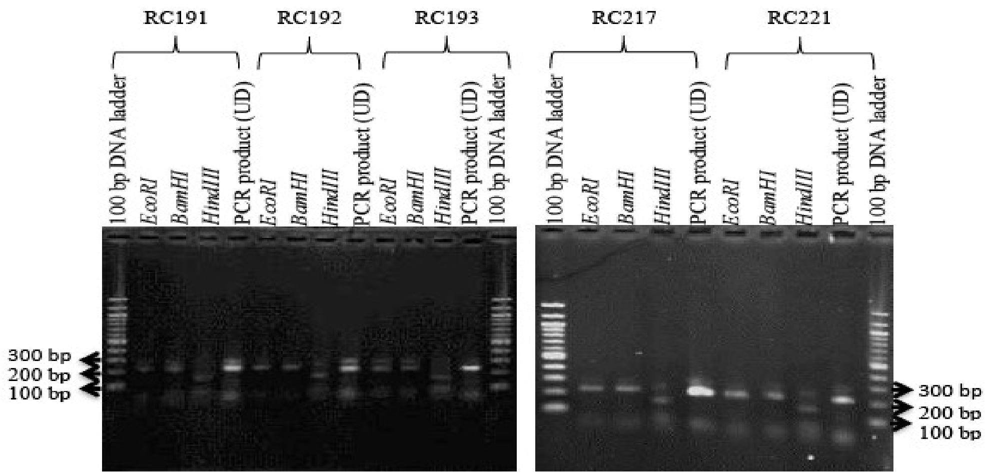


Fig. 14. *HKT1* genes expression profile for restriction digested half cycle PCR product of 22 rice genotypes

Allele size of all rice genotypes for *HKT1* gene was similar compared with their undigested PCR product (Fig. 18). Same type of allele pattern was found for two salinity tolerant Check genotypes Binadhan-8 and FL-478. But salinity sensitive rice variety Binadhan-7 showed null allele for against restriction enzyme. So there was no *HKT1* gene expression occurs in these genotypes. Overexpression of *HKT1* gene was occurred in RC225, RC229, and Binadhan-8. But other genotypes showed also proper *HKT1* gene expression without Binadhan-7 (inexpression). Restriction digestion of *Sub1A* gene by *EcoRI* and *BamHI* was similar with undigested PCR product (217 bp) for all genotypes except Binadhan-7. But the product of *HindIII* restriction enzyme was few base pair smaller (165-170 bp) than the undigested PCR product (217 bp) due to double restriction site exist in *Sub1A* gene for *HindIII* which was confirmed by dry lab NEB Cutter 2.0 with similar 1.5% agarose gel (Fig. 19). The overexpression of *Sub1A* gene was occurred for RC193, RC251, and Joli aman genotypes. The proper level of expression was occurred for RC191, RC192, RC249, RC217, RC227 and Binadhan-12. Incomplete expression was occurred for RC221, RC225 and RC229. But *Sub1* gene expression was not noticed in Binadhan-7.





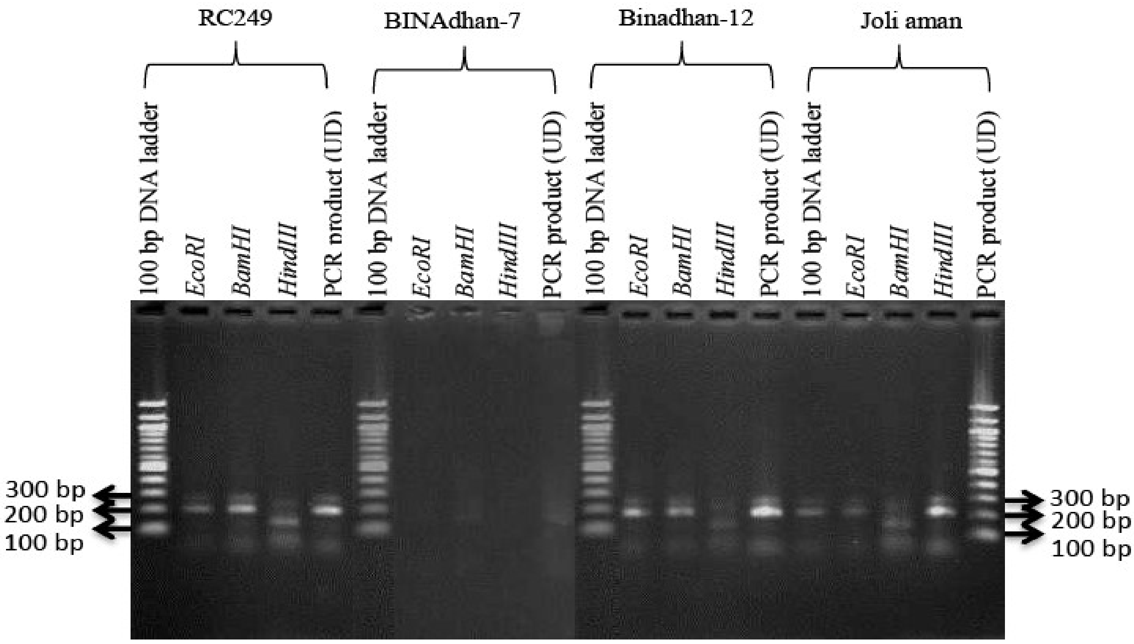


Fig. 15. ***Sub1A*** **genes expression profile for restriction digested half cycle PCR product of 22 rice genotypes**

Growing of M_4 Population of NERICA-1, NERICA-4 and NERICA- 10 mutant lines during Aman season, 2013

Seeds of NERICA-1, NERICA-4 and NERICA-10 were irradiated with different doses of gamma rays (200, 250, 300 and 350 Gy). Total 86 M_4 lines of NERICA-1, NERICA-4 and NERICA-10 were grown in plant progeny rows for selecting true breeding lines of desirable characters like high yield, early maturity, fine grain, drought tolerant, disease and insect resistant etc. During aman season at BINA HQ, Mymensingh and Godagari, Rajshahi; seedlings of mutant population were transplanted in two locations. Therefore, at BINA HQ experiment population was more the Rajshahi for getting the mutant population data properly. Spacing between hills and rows were respectively 15 cm and 20 cm. Recommended fertilizer doses were applied. Cultural and intercultural practices were followed as and when necessary. Data on days to maturity, plant height, no. of effective tillers $hill^{-1}$, Panicle length, no. of filled grains $panicle^{-1}$, 1000 seed weight and grain yield $panicle^{-1}$ were recorded from five randomly selected plants. At BINA HQ, range of maturity date 105-150 days, plant height 94-185 cm, no. of effective tillers $plant^{-1}$ 6-34, panicle length 22-43cm, no. of filled grains $panicle^{-1}$ 50-337, 1000 seed weight 16-37 gm and grain yield $plant^{-1}$ 11.7-150 gm (Table 21). At Godagari, Rajshahi, range of maturity date 103-113, plant height 89.5-135 cm, no. of effective tillers $plant^{-1}$ 4-24, panicle length 19.5-36.3 cm, no. of filled grains $panicle^{-1}$ 50-239, 1000 seed weight 18.4-30 gm and grain yield plant $^{-1}$ 14.16-86 gm (Table 22). All these mutant lines will be evaluated in the next growing season.

Table 20. Performance of M_4 mutants of NERICA-1, NERICA-4 and NERICA-10 grown in Aman season, 2013 at BINA HQ, Mymensingh

Mutants	Days to maturity	Plant height (cm)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grain plants^{-1} (no.)	1000-seed weight (g)	Grain yield plant^{-1} (g)
N1/300/P-6-3-5	117	110	11	25	132	31.2	34.32
N10/300/P-2(1)-6-6	117	121	18	28	122	20.3	36.54
N1/300/P-9-5-9	117	106	23	29	104	23.5	54.05
N4/350/P-3(3)-11-8	117	144	20	22	314	25.5	51.0
N10/300/P-2(1)-6-2	117	124	12	26	180	22.4	26.88
N10/300/P-2(1)-3-6	117	140	8	34	290	21.6	17.28
N1/300/P-9-5-8	117	123	13	31	205	24.1	31.33
N1/250/P-7-6-3	117	105	16	25	97	27.6	44.16
N1/350/P-2-2-6	117	124	13	27	260	31.6	41.08
N1/300/P-9-6-3	117	121	17	29	337	33.2	56.44
N4/300/P-3(4)-10-9	118	130	11	28	266	27.3	30.03
N1/300/P-9-9-13	118	109	18	30	142	23.8	42.84
N1/300/P-9-4-11	118	127	10	29	270	25.7	25.7
N1/250/P-7-2-1	118	94	16	22	175	28.9	46.24
N1/250/P-7-3-(1)-2	118	110	32	27	234	27.6	88.32
N1/250/P-7-3-5	118	168	13	31	142	28.2	36.66
N10/300/P-2-3-5	118	133	11	31	290	25.9	28.49
N1/250/P-7-3	118	157	17	30	180	31.3	53.21
N1/250/P-7-3-13	118	139	23	32	160	27.5	63.25
N1/250/P-9-5-3	118	116	14	28	107	24.6	34.44
N1/250/P-7-3-11	118	125	20	32	192	26.3	52.6
N1/250/P-7-3-4	118	99	16	29	157	25.8	41.28
N1/250/P-7-3-12	118	114	18	29	122	27.2	48.96
N10/300/P-2-(1)-6-13	118	146	9	30.	295	22.2	19.98
N10/300/P-7-1	118	167	13	30	293	21	34.7
N1/300/P-8-3-1	118	120	8	28	207	24.8	19.84
N1/300/P-9-4	118	128	11	27	245	27.4	30.14
N1/300/P-9-5-12	118	119	8	30	147	29.2	23.39
N4/350/P-2(1)-32-13	118	156	19	28	280	26.4	50.16
N10/300/P-2(1)-3-1	118	140	19	36	235	21.8	41.42
N4/350/P-2(1)-32-19	118	135	10	25	175	30.3	30.3
N1/250/P—7(2)-8	118	136	24	27	190	27.4	65.76
N10/300/P-2(1)-6-5	118	125	13	28	153	21	27.3
N10/300/P-2(1)-6-14	118	124	16	27	180	23.4	37.44
N1/300/P-9-5(A)	118	110	25	30	107	24.8	49.6
N10/300/P-2(1)-6-17	118	128	18	28	210	24.7	44.46
N1/350/P-1-10-2	105	125	8	32	325	23.2	18.56
N1/250/P-6-2-8	108	130	9	27	180	26.9	24.21
N1/250/P-6-2-7	108	133	10	31	233	24.9	24.9
N1/300/P-8-3-3	113	122	8	34	312	30.8	24.64
N10/300/P-2(1)-3-5	108	149	6	43	142	24.8	14.88
N4/250/P-1-10-11	105	126	11	35	289	25.1	27.61
N1/250/P-7-3	105	133	27	31	145	24.7	66.69
N4/250/P-2(5)-11-19	105	137	15	29	140	26.3	39.45

Table 20. Contd.

Mutants	Days to maturity	Plant height (cm)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grain plants^{-1} (no.)	1000-seed weight (g)	Grain yield plant^{-1} (g)
N4/250/P-2(5)-11-13	105	135	18	27	155	29	52.2
N4/250/P-2(5)-11-1	108	157	7	30	106	25.9	18.13
N1/300/P-9-5(4&5)	105	123	14	32	127	24	33.6
N10/300/P-2(1)-3-8-6	108	118	9	27	131	20.5	18.45
N4/250/P-2(5)-11-2	105	157	15	28	142	27.2	76.16
N4/350/P-2(1)-32-11	108	138	17	28	204	29.5	50.15
N4/250/P-2(5)-11-3	108	156	14	28	110	26.6	37.24
N10/300/P-2(1)-8	108	132	14	34	200	22	30.1
N10/300/P-2(1)-6-11	108	113	22	27	135	20.8	45.76
N1/300/P-9-2-1	108	137	20	26	180	24.5	49
N1/350/P-2-3	105	129	23	27	173	25.7	59.11
N1/300/P-9-5-6	105	124	14	29	183	30	42
N1/300/P-9-5-12	108	142	14	26	180	31.1	43.54
N1/250/P-7-3	108	150	13	23	160	25.2	32.76
N10/300/P-3-7-6	108	127	15	29	65	16	24
N10/300/P-3-7-3	108	120	9	29	160	19.9	17.91
N10/300/P-3-7-1	108	117	12	27	121	21.7	26.04
N10/300/P-2(1)-4-1	105	120	15	27	226	18.6	27.9
N1/250/P-4-1	108	143	15	29	104	25.2	37.8
N1/250/P-7-3-8	105	185	19	36	240	23.7	45.03
N1/250/P-6-2-6	105	136	13	32	165	27	35.1
N10/300/P-5-7-5	105	158	20	32	185	24.4	48.8
N1/350/P-2(1)-32-15	108	148	12	24	95	24.8	29.76
N4/250/P-2(5)-11-10	105	138	12	24	124	25.9	31.08
N1/350/P-2-2-4	108	158	13	37	164	35.1	45.63
N1/300/P-9-5-(13)	113	132	15	29	167	30.9	46.35
N10/300/P-2(1)-6-4	105	108	14	26	220	18.5	25.9
N1/250/P-7-3-7	105	131	13	33	128	27	35.1
N4/250/P2(6)2(13&14)	108	135	29	25	160	21.1	61.19
N10/300/P-5-7-2	105	129	12	34	240	24	28.8
N1/250/P-7(2)-1	113	119	13	27	225	27.8	36.14
N1/350/P-2-2-8	150	142	19	34	225	34.9	66.31
N10/300/P-2(1)-2-1	150	127	27	29	247	25.7	69.39
N10/300/P-3-7-5	150	115	6	31	190	19.5	11.7
N10/300/P-2(1)-6-7	150	129	15	33	280	18.6	27.9
N1/250/P-7-6-4	113	114	26	23	149	24.8	64.48
N1/300/P-2(1)-6-10	150	111	11	25	50	21.3	23.43
N10/300/P-2(1)-6-16	150	136	21	32	155	24.3	51.03
N1/300/P-9-4-5	150	124	10	24	211	27.8	27.8
N1/250/P-3-2	150	108	34	24	146	37	65
N4/250/P-1(2)	150	110	16	26	156	19.1	76
Minimum	105	94	6	22	50	16	11.7
Maximum	150	185	34	43	337	37	150
Average	116.89	130.35	15.49	29.19	185.44	25.54	42.19

Table 21. Perfomance of M_4 mutants NERICA-1, NERICA-4 and NERICA-10 during Aman season, 2013 at Godagari, Rajshahi

Mutant	Variety	Days to maturity	Plant height (cm)	Effective tillers plant^{-1} (no.)	Panicle length (cm)	Filled grain plant^{-1} (no.)	Grain yield plant^{-1} (g)
N1/250/p-7-6-4	113	125	7	23.80	130	22.1	29.26
N1/250/p-7-3-9	113	110.00	4	24.50	121	27.8	17.24
N1/250/p-7-3-7	113	104.00	11	27.40	120	21	36.74
N1/250/p-7-3-3	113	89.50	11	27.50	164	23.2	62.26
N1/250/p-7-3-19	113	135.00	16	27.20	140	25.3	82.88
N1/250/p-7-3-11	113	105.00	11	27.00	169	27	55.44
N4/350/p-2(1)-32-5	113	118.50	10	20.50	83	25.2	33.50
N 10/300/P-2(1)-3-4	113	129.00	13	36.30	148	22.6	87.49
N10/300/P-2(1)-6-14	113	104.00	13	26.50	197	20.1	61.88
N10/300/P-2(1)-4-1	103	95.00	13	29.00	141	18.4	42.12
N10/300/P-5-1-1	108	116.00	5	35.50	205	22	24.20
N1/250/P-7-6-5	113	121.00	8	25.00	184	28.7	45.68
N1/300/p-9-5-12	113	119.00	12	22.50	132	27	52.44
N1/300/p-9-5-3	113	115.00	8	28.00	160	27.6	43.04
N1/250/p-6-2-5	113	93.00	14	23.50	133	22.5	60.76
N1/300/p-9-5-10	113	97.00	15	23.50	92	27.7	47.25
N1/250/p-7-3-22	113	120.00	24	24.00	160	29.5	42.00
N1/250/p-7-3-1	113	110.00	12	26.50	180	25.6	69.55
N1/250/p-7-6-6	113	103.00	12	25.00	179	26	63.00
N1/300/p-7-1-8	113	116.00	14	30.00	225	27.7	86.00
N1/300/p-6-4-3	113	102.00	13	29.00	239	30	72.00
N1/300/p-8-3-12	113	110.50	7	28.50	143	22.7	27.79
N1/300/p-9-2-6	113	112.50	5	30.00	203	23.8	26.05
N1/300/p-9-5-16	113	120.00	10	30.50	50	24.4	23.1
N1/300/p-9-5-11	113	107.00	8	23.50	120	23.4	31.76
N1/300/p-6-4-1	103	97.50	8	27.40	163	25.7	35.52
N1/250/p-7-3-18	103	120.50	6	28.50	110	30	25.56
N1/300/p-9-5-21	108	113.50	11	27.00	131	20.9	34.87
N1/250/p-7-3-2	113	109.00	10	27.50	117	20.8	35.70
N1/250/p-7-3-5	103	111.00	8	24.00	71	19.8	15.84
N1/250/p-6-2-3	108	117.50	6	19.50	122	23.6	14.16
N1/350/p-1-2(1)	108	100.00	14	22.30	118	23.6	30.94
Minimum	103	89.50	4	19.50	50	18.4	14.16
Maximum	113	135.00	24	36.30	239	30	86.00
Average	110.94	110.90	10.79	26.67	145.26	24.53	49.43

Growing of M_5 population of NERICA-1, NERICA-4 and NERICA-10 mutants grown in Boro season, 2013

Seeds of NERICA-1, NERICA-4 and NERICA-10 were irradiated with different doses of gamma rays (200, 250, 300 and 350 Gy). A total of 67 M_5 lines of NERICA-1, NERICA-4 and NERICA-10 were grown in plant progeny rows for selecting true breeding lines of desirable characters like high yield, early maturity, fine grain, drought tolerant, disease and insect resistant etc during boro season at BINA HQ, Mymensingh. Spacing between hills and rows were respectively 15 cm and 20 cm. Recommended fertilizer doses were applied. Cultural and intercultural practices were followed as and when necessary. At BINA HQ, range of maturity date 130-141 days, plant height 70.1-124 cm, no. of effective tillers plant-^{1} 4-25, panicle length 4.67-32.4cm, no. of filled grains panicle-^{1} 14-251, 1000 seed weight 15.7-37 gm and grain yield plant-^{1} 4.3-41.22 gm (Table 22). All these mutant lines will be evaluated in the next growing season.

Table 22. Performance of of NERICA-1, NERICA- 4 and NERICA-10 in M_5 generation grown in Boro season, 2013 at BINA HQ, Mymensingh

Mutants/checks	Days to maturity	Plant height (cm)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	1000-seed weight (g)	Grain yield plant^{-1} (g)
N1/250/P-6-2	141	100.00	6	23.70	74.80	27.00	12.27
N1/250/P-7-3	141	88.50	9	17.50	40.40	27.00	11.86
N1/300/P-9-5-12	133	90.50	9	23.00	134.50	23.50	29.12
N1/300/P-9-5-12-5	133	86.00	5	23.60	111.50	23.50	14.63
N10/300/P-7-1	133	92.00	9	24.80	121.20	20.40	20.99
N1/300/P-9-9-13	133	92.88	8	22.92	95.00	27.40	19.56
N4/300/P-3(4)-10-9-5(1)	133	96.70	9	24.46	251.00	27.30	20.55
N10/300/P-2-3-5(1)	133	104.90	13	27.16	134.00	25.90	15.03
N10/300/P-2(1)-3-6	133	112.00	4	26.86	176.67	21.60	5.08
N4/300/P-3(4)-10-9-5(7)	133	116.00	9	25.40	167.00	27.30	18.18
N10/300/P-2(1)-6-5-5(7)	133	98.00	10	25.13	143.33	21.00	10.09
N10/300/P-2(1)-3-1	133	110.00	8	30.20	143.50	21.80	8.34
N1/250/P-7-3-15-5(2)	133	106.00	5	25.50	104.66	24.70	4.30
N4/250/P-2(5)-11-1	141	108.40	7	27.34	108.20	25.90	19.93
N10/300/P-2(1)-8	141	99.44	6	31.88	138.80	21.50	22.02
N10/300/P-2(1)-6-11	141	86.88	8	23.75	83.83	20.80	13.63
N10/300/P-5-7-2	141	101.30	5	28.46	113.40	24.00	11.47
N4/250/P-2(6)-26-13(14)	141	102.90	13	24.04	101.80	21.10	13.77
N10/300/P-2(1)-6-7	141	95.20	10	26.40	117.80	18.60	22.20
N10/300/P-2(1)-6-17-5(3)	141	101.00	8	27.20	114.33	24.70	22.59
N1/300/P-9-5-12-5(3)	141	104.00	6	23.83	106.66	29.20	18.68
N4/300/P-3(4)-10-9-5(9)	141	117.00	10	28.43	117.66	27.30	16.16
N1/250/P-7-3-5-5(4)	141	116.00	4	27.50	113.00	28.20	12.77
N1/250/P-7-3-5-5(2)	141	118.00	6	26.83	124.33	28.20	21.03
N10/300/P-2(1)-3-6-5(1)	141	114.00	6	32.40	123.00	21.60	15.94
N1/250/P-7-3-5-5(8)	141	121.00	5	29.30	101.00	28.20	14.24

Table 22 Contd.

Mutants/checks	Days to maturity	Plant height (cm)	Effective tillers hill-1 (no.)	Panicle length (cm)	Filled grains panicle-1 (no.)	1000-seed weight (g)	Grain yield plant-1 (g)
N10/300/P-2 (1)-3-6-5 (7)	141	111.00	5	26.30	127.30	21.60	13.74
N10/300/P-2 (1)-6-6-5 (6)	141	92.00	7	23.30	114.00	20.30	15.85
N10/300/P-2 (1)-3-6-5 (9)	141	105.00	6	27.50	116.60	21.60	15.11
N10/300/P-2 (1)-3-6-5 (8)	141	107.00	8	27.20	164.00	23.20	27.75
N10/250/P-7 -3-7-5 (3)	141	123.00	5	25.40	136.30	27.00	18.40
N1/350/P-1 -10-2-5 (12)	141	100.00	6	23.30	125.00	23.20	17.30
N10/300/P -3-7-1-5 (2)	141	111.00	11	27.30	86.00	21.70	20.52
N1/300/P-9-5-(A)-5(8)	141	97.00	6	24.40	112.30	30.00	20.21
N1/250/P-7 -6-4-5 (7)	141	105.00	9	23.30	95.60	24.80	21.33
N1/300/P-2 (1) -6-10-(5,7,8)	141	103.00	9	25.30	121.00	21.30	28.96
N1/300/P-9-4-5-5 (1,2)	141	108.00	5	4.67	26.50	27.40	16.39
N10/300/P-2 (1)-4-(1)	141	99.20	8	25.26	106.00	18.60	15.96
N1/300/P-9-5-9	141	70.10	4	22.76	111.40	23.50	32.59
N1/300/P-9-5-9 (1)	141	74.00	8	28.30	105.60	18.70	22.93
N10/300/P-2(1)-6-4	141	74.00	8	19.30	69.00	23.40	15.60
N4/350/P-2(1)-32-11-5 (10)	141	104.00	8	20.30	62.00	29.50	38.33
N1/350/P-2-3-5 (9,11)	141	96.25	6	22.50	64.00	25.70	22.62
N1/250/P-6-2-8-5 (13)	141	101.00	9	26.00	198.00	26.90	21.36
N1/250/P-6-2-7-5 (7, 8)	141	109.00	6	25.80	111.00	24.90	18.96
N1/250/P-6-2-7-5 (9)	141	110.00	4	25.40	127.00	24.90	12.64
N10/300/P-2(1)-6-17-5(10)	141	92.40	12	24.60	95.30	24.70	28.24
N4/350/P-2(1)-32-11-5 (6)	141	109.00	6	23.20	101.00	29.50	17.87
N4/350/P-2(1)-32-11-5 (8)	141	102.00	8	21.00	116.60	29.50	27.51
N10/300/P-2(1)-6-5-5-(13)	141	100.00	13	25.40	151.00	21.00	41.22
N10/300/P-2(1)-3-5	141	105.40	7	31.40	109.00	24.80	20.24
N1/250/P-7-3-8-5 (3)	141	113.00	9	28.00	109.60	23.70	23.37
N1/250/P-7-3-8-5 (10)	141	122.00	8	30.50	92.50	23.70	17.50
N10/300/P-2(1)-2-1-5 (5)	141	103.00	14	28.30	176.00	25.70	31.36
N1/300/P-2 (1)-6-10-5 (9)	141	112.00	19	26.60	19.60	21.30	16.13
N1/250/P-3-2-5 (1)	141	99.00	7	26.00	136.00	37.00	35.22
N10/300/P-2(1)-2-1-5 (10)	141	96.00	6	26.30	151.30	25.70	23.33
N1/250/P-7-3-8-5 (12)	141	108.00	5	28.00	139.60	23.70	16.44
N10/300/P-2(1)-4-5 (14)	141	95.00	7	25.00	153.00	18.60	19.92
N10/300/P-2(1)-2-1-5 (2)	141	99.00	6	25.60	146.30	25.70	23.74
N10/300/P-2(1)-3-6-5 (13)	141	124.00	8	31.30	83.00	18.60	12.35
N10/300/P-2(1)-3-6-5 (7)	141	95.00	7	29.00	131.60	23.70	21.81
N1/250/P-7-6-4-5 (13)	141	80.00	22	25.00	121.00	25.70	22.80
N1/250/P-7-6-4-5 (9)	141	91.00	25	26.00	14.00	18.60	6.51
NERICA-1 (check)	130	99.00	6	24.50	119.40	15.70	12.45
NERICA-4 (check)	130	96.50	9	23.96	126.40	25.60	15.50
NERICA-10 (check)	130	90.20	9	23.36	124.00	28.70	16.09
Minimum	130	70.10	4	4.67	14.00	15.70	4.30
Maximum	141	124.00	25	32.40	251.00	37.00	41.22
Average	139	123.32	8	25.24	116.25	24.34	19.22

Preliminary yield trial of some selected NERICA rice mutants during Boro season, 2014

Four NERICA rice lines along with two check variety NERICA-4 and NERICA-10 were tested in Boro 2013-14 at BINA HQ (Mymensingh). The experiment was laid out in RCBD with three replications. Unit plot size was 1m x 1.8m and spacing between hills and rows were respectively 15 cm and 20 cm. Data on days to maturity, plant height, no. of effective tillers hill-[1], Panicle length, no. of filled grains panicle-[1], 1000 grain weight and grain yield plot-[1] were recorded from five randomly selected plants from each plot. Plot yield was converted to t/ha. From the Table-23, it is observed that the highest no. of filled grains panicle-[1] and highest panicle length (cm) was found in N_{10}/350/P-5-4. Grain yield was found the highest in N_{10}/350/P-5-4 followed by N_4/250/P-2 (6)-26 (Table 24).

Table 23. Preliminary yield trial of some selected NERICA rice mutants during Boro season, 2013-14 at HQ, Mymensingh

Location	Mutants/checks	Days to maturity	Plant height (cm)	Effective tillers hill^{-1} (no.)	Filled grains panicle^{-1} (no.)	Panicle length (cm)	1000 grain weight (g)	Grain yield (t/ha)
BINA HQ (Mymensingh)	N4/250/P-1 (2)	134	97.56	14	129.133	23.447	19.30	6.31
	N4/250/P-2 (6)-26	135	100.98	14	128.00	22.093	18.70	6.85
	N10/350/P-5-4	136	86.287	15	142.867	24.08	23.30	7.50
	N10/350/P-4 (5)	137	97.62	14	114.13	22.28	20.20	6.19
	NERICA-4 (check)	131	95.71	8	124.13	23.12	28.20	2.78
	NERICA-10 (check)	131	92.26	9	106.80	23.54	28.03	3.24
	CV %	0.53	7.00	8.09	9.48	4.64	10.18	15.28
	LSD (0.05)	0.4973	4.683	0.7203	0.7542	8.282	1.643	0.5884

On-farm trial of Green Super Rice (GSR) in different locations in Boro season 2013-14

On-farm trial was carried out with one selected green super rice (GSR), BINA-GSR-3 during Boro 2013-14 season at two locations viz., BINA HQ, Mymensingh and Godagari, Rajshahi. The experiment was laid out in RCBD with three replications. Unit plot size was 5m x 6m and spacing between hills and rows were 15c m × 20 cm. The results showed that BINA-GSR-3 produced the highest no. of effective tillers hill-[1], no. of filled grains plant-[1], panicle length, 1000 seed weight and grain yield compared to BRRI dhan28 at all locations (Table 24).

Table 24. On-farm trial of some promising green super rice in Boro season 2013

Location	Variety	Days to maturity	Plant height (cm)	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	1000 grain weight (g)	Grain yield (t/ha)
BINA HQ (Mymensingh)	BINA-GSR-3	148	88	14	23.53	254.70	20.53	7.20
	BRRI dhan28 (chk)	141	93	11	21.53	180.93	20.30	6.30
	CV %	1.32	1.3	18.85	4.54	14.06	2.12	2.74
	LSD (0.05)	3.927	2.59	6.025	13.65	6.466	0.9889	0.331
Rajshahi	BINA-GSR-3	147	85	16	23.43	248.33	22.26	6.93
	BRRI dhan28 (chk)	137	103	14	20.37	168.23	22.17	5.80
	CV %	0.75	2.7	8.82	3.37	4.69	2.09	4.64
	LSD (0.05)	2.267	5.14	2.356	14.35	1.593	0.8954	0.586
Combined means over locations								
Combined	BINA-GSR-3	148	86	15	21.95	269.5	21.23	7.06
	BRRI dhan28 (chk)	139	98	12	22.48	174..58	21.35	6.05
	CV (%)	1.07	2.1	15.59	10.10	4.62	2.11	3.86
	LSD (0.05)	1.941	2.46	2.77	8.479	2.850	0.5711	0.287

Evaluation of promising submergence tolerant rice germplasm in multi location trials (STRASA Project)

Fifteen rice lines were tested for submergence tolerant through participatory variety selection (PVS) at Dhobaura (Mymensingh), Nokla and Nalitabari (Sherpur) in Aman season during 2013. The experiment was laid out in RCBD with three replications (Tables 25-28). Unit plot size was 4 m × 1.2 m and spacing between hill and row was 15 cm × 20 cm. PVS results of mother trials have shown in the following tables. Two genotypes RC-217 and BR11 were selected based on farmer's preference and the characters viz., good yield, long panicle, more number of tillers in a hill, attractive colour of grain and fine and slender grain at three locations.

Table 25. Preference analysis of Mother Trial of salinity and submergence tolerant rice lines at Dhobaura (Mymensingh) during T. Aman, 2013

Entry		Total farmers (n = 30)		Preference score	Yield (t/ha)
Code	Name	(+)ve	(-)ve		
PVS1	RC-191	0	4	-0.03	0.92
PVS2	RC-192	0	0	0.00	1.76
PVS3	RC-193	1	1	0.00	2.06
PVS4	Binadhan-12	6	0	0.04	1.93
PVS5	RC-217	33	1	0.24	2.73
PVS6	RC-251	0	0	0.00	1.28
PVS7	Binadhan-11	0	0	0.00	1.18
PVS8	RC-222	1	26	-0.18	0.75
PVS9	Binadhan-7	2	3	-0.01	1.06
PVS10	RC-225	0	2	-0.01	0.97
PVS11	RC-227	0	4	-0.03	2.12
PVS12	BR11	24	1	0.17	
PVS13	RC-229	0	2	-0.01	1.67
PVS14	RC-249	0	3	-0.02	1.23
PVS15	RC-221	0	26	-0.19	0.95

Male (n = 20) and Female (n = 10) and Researcher (n = 4); total 34

Table. 26. Preference analysis of Mother Trial of salinity and submergence tolerant rice lines at Nokla (Sherpur) during T. Aman, 2013

Variety Code	Entry Name	Total farmers (n = 30)		Preference score	Yield (t/ha)
		(+)ve	(-)ve		
PVS1	RC-191	0	12	-0.08	1.23
PVS2	RC-192	1	2	-0.01	2.36
PVS3	RC-193	0	3	-0.02	2.33
PVS4	Binadhan--12	11	2	0.06	3.44
PVS5	RC-217	14	1	0.09	2.66
PVS6	RC-251	0	12	-0.08	0.81
PVS7	Binadhan--11	1	0	0.01	0.95
PVS8	RC-222	1	15	-0.10	0.32
PVS9	Binadhan-7	1	3	-0.01	1.53
PVS10	RC-225	1	1	0.00	1.96
PVS11	RC-227	7	2	0.03	2.57
PVS12	BR11	30	0	0.21	3.43
PVS13	RC-229	0	4	-0.03	1.39
PVS14	RC-249	3	1	0.01	2.20
PVS15	RC-221	0	12	-0.08	0.28

Male (n = 20) and Female (n = 10) and Researcher (n = 6); Total 36

Table 27. Preference analysis of Mother Trial of salinity and submergence tolerant rice lines at Nalitabari (Sherpur) during T. Aman, 2013

Entry		Farmer				Breeder		Total farmers (n = 30)		Preference score	Yield (t/ha)
Variety Code	Line/Variety	Male		Female		Other		(+)ve	(-)ve		
		(+)ve	(-)ve	(+)ve	(-)ve	(+)ve	(-)ve				
PVS1	RC-191	0	7	0	2	0	3	0	12	-0.08	1.10
PVS2	RC-192	0	0	0	2	0	5	0	7	-0.05	2.40
PVS3	RC-193	0	0	0	2	0	1	0	3	-0.02	2.38
PVS4	Binadhan--12	0	0	0	1	0	0	0	1	-0.01	3.46
PVS5	RC-217	0	1	1	1	0	2	1	4	-0.02	2.70
PVS6	RC-251	4	0	10	0	0	4	14	4	0.07	0.95
PVS7	Binadhan--11	0	0	4	0	0	0	4	0	0.03	0.98
PVS8	RC-222	0	0	1	4	0	4	1	8	-0.05	0.38
PVS9	Binadhan-7	8	0	7	1	10	0	25	1	0.17	1.65
PVS10	RC-225	5	0	9	1	2	0	16	1	0.10	1.92
PVS11	RC-227	1	0	8	1	9	0	18	1	0.12	2.60
PVS12	BR11	0	2	0	9	0	2	0	13	-0.09	3.41
PVS13	RC-229	0	0	0	3	0	0	0	3	-0.02	1.42
PVS14	RC-249	0	0	0	2	1	0	1	2	-0.01	2.28
PVS15	RC-221	0	8	0	11	0	9	0	28	-0.19	0.35

Male (n = 20) and Female (n = 10) and Researcher (n = 6), total 36

Three baby trials were set in Nokla, Sherpur district i.e. research manage trial, with B-10, B-11, Binadhan-8, Binadhan-11 and Binadhan-12 for field evaluation of salinity and submergence tolerant rice lines. On an average 3.5 kg seeds was collected from each entry in two baby trials.

Table. 28. Baby Trial (Research managed trial) of salinity and submergence tolerant rice lines at Nokla (Sherpur) during T. Aman, 2013

Line/Variety	Baby Trial-1 (kg)	Baby Trial-2
B-10	3.4	7.0
B-11	3.5	4.4
Binadhan-8	4.5	8.0
Binadhan-11	3.5	-
Binadhan-12	-	8.3

Screening of high yielding breeding rice lines possessing both salinity and submergence tolerance (with *Sub1*) (STRASA Project)

Eighteen rice lines were tested for salinity and submergence tolerant at Khoribila (Satkhira district) and Kaliganj (Satkhira district) in aman season during 2013. The experiment laid out in RCBD with three replications. Seed was sown in 08 July, 2013 at Kharibila, sadar; Satkhira district.

Table 29. Preference analysis of Mother Trial of salinity submergence tolerant rice lines/germplasms at Khoribila Sadar, Satkhira Bangladesh during T. Aman, 2013

Entry		Total farmers (n = 30)		Preference score	Yield (t/ha)
Variety Code	Name	(+)ve	(-)ve		
PVS1	RC-191	3	0	0.021	4.50
PVS2	RC-192	4	2	0.014	3.50
PVS3	RC-193	0	1	-0.007	2.50
PVS4	RC-195	10	1	0.063	5.50
PVS5	RC-197	0	15	-0.104	3.50
PVS6	RC-221	0	4	-0.028	2.86
PVS7	RC-225	2	0	0.014	4.26
PVS8	RC-226	7	5	0.014	4.50
PVS9	RC-229	0	1	-0.007	5.25
PVS10	RC-247	1	4	-0.021	4.19
PVS11	RC-248	0	7	-0.049	4.74
PVS12	RC-250	3	2	0.007	5.77
PVS13	RC-251	3	21	-0.125	4.74
PVS14	RC-252	13	1	0.083	3.23
PVS15	RC-259 (CK)	3	0	0.021	3.65
PVS16	RC-260 (CK)	22	2	0.139	5.00
PVS17	Binadhan-10 (CK)	1	5	-0.028	4.68
PVS18	Binadhan-8 (CK)	1	2	-0.007	3.73

Male (n = 20) and Female (n = 10) and Researcher (n= 6)

Moddhokalikapur, Kaliganj:

Unit plot size was 5m x 2m and spacing between hill and row was 15cm x 20cm, transplanted in 03 august, 2013 and harvested in 14 November, 2013. The salinity level of the field was 0.91 µs. The experimental lines were submerged for 5 days at kaliganj in September, 2013.

PVS results of mother trials:

Moddhokalikapur, Kaliganj, Satkhira: RC-225 and Binadhan-8 were selected based on farmer's preference and the characters viz., good yield, long panicle, salinity and submergence tolerance more number of tillers in a hill, attractive colour of grain and fine slender grain. Khoribila, Sadar, Shatkhira: RC-260 (check) and RC-252 were selected based on farmer's preference and the characters viz., good yield, long panicle, more number of tillers in a hill, attractive colour of grain and fine, slender grain. In Shamnagar, Unit plot size was 5m x 2m and spacings between hill and row was 15cm x 20cm, transplanted in 07 August, 2013 and harvested in 12 November, 2013. Data collection is running.

Screening of high yielding breeding rice lines possessing both salinity and submergence tolerance (with *Sub1*) (STRASA Project)

Experiments were conducted to select desirable rice lines for Zn deficiency and salt tolerance during boro 2013-14 from 6 elite breeding lines with standard checks for salinity and submergence tolerance. The experiment was laid out in RCBD design with 3 replications. Data on different yield contributing characters are presented in Table 30.

Table 30. Performance of salinity and Zn deficiency tolerance elite breeding rice lines

Variety	Plant height	Days to 50% flowering	Effective tillers plant^{-1} (no.)	Days to maturity	Panicle length (cm)	Filled grains plant^{-1} (no.)	Unfilled grains plant^{-1} (no.)	Grain yield Plant^{-1} (g)
RC 192	76	139.5	8.167	175	20.67	75.67	38.17	11.41
RC 251	98	123.7	13	150.2	21	72.83	34.5	15.74
RC 221	91	132.7	10.83	155	21.67	107.2	24.33	15.1
RC 227	97	116.5	17.17	152.8	25	58	26.67	17.37
RC 229	90	116.3	15.67	153.3	24	82.83	22	17.75
RC 193	88	112.5	14.33	143.8	26.00	99.83	32	15.11
Binadhan-11	88	127	11.5	159.8	20.67	108.7	27.67	16.02
BRRI dhan 39	100	118.7	13.67	151	24.67	90.83	32.83	18.92
Binadhan-8	97	101.3	16	136.8	25.17	119.8	27.83	21.39
Binadhan-10	99	116.8	14.67	148.8	28.33	130.7	29.17	19.65
Mean	91	121.53	13.12	154.53	23.65	93.96	29.67	16.44
Maximum	100.5	139.5	17.17	175	28.33	130.7	38.17	21.39
Minimum	76.17	101.3	8.17	136.8	20.67	58	22	11.41
SD	8.23	10.78	2.87	11.39	2.49	21.68	4.66	3
CV (%)	4.13%	2.04%	19.94%	1.85%	8.05%	17.49%	32.08%	3.89%

Among the studied elite breeding lines RC192 was dwarf and RC251 was tallest in stature. RC193 was earliest regarding days to flowering. No. of effective tiller ranged from 8 to 17 per plant. The longest panicle was RC193. No. of filled grain was found the highest in RC221. Yield per plant ranged from 11.41 to 21.39 g. Less co efficient of variation was observed for days to 50% flowering, days to maturity and unit yield per plant.

Development of breeding lines combining *Saltol* and one additional QTL for salt tolerance through marker-assisted back crossing (MABC) (STRASA Project)

Selected genotypes carrying major *Saltol-sub1* QTL were used as the donor. Binadhan-10 and Binadhan-11 crossed with selected six donor lines (RC-222, RC-191, RC-251, RC-247, RC-292 and RC-193) to obtain F_1 seeds. F_1 plants were grown and backcrossed with Binadhan-10 and Binadhan-11 to develop BC_1F_1 populations.

An experiment was set to develop breeding lines combining saltol and additional QTL salinity tolerance. Salinity and submergence tolerant rice lines (Introduced from IRRI) were sowing at 3 seeding dates i.e. 23/06/2013, 27/06/2013 & 01/07/2013; crossing started from 05/09/2013 to 02/10/2013 and harvested on 14/10/2013, 20/10/2013 to 22/10/2013. The crossing combination of recurrent and donor parent are given below in Table 31.

Table 31. Crossing combination of recurrent and donor parent for salinity and submergence tolerant rice lines

Recurrent parent	Donor parent	Seeds harvested (no.)
Binadhan-10	RC-191	700
	RC-251	479
	RC-247	439
	RC-292	85
	RC-193	305
	RC-222	1030
Binadhan-11	RC-191	308
	RC-251	581
	RC-247	309
	RC-292	448
	RC-193	607
	RC-222	83
		5374

MARKER BASED SCREENING OF SOME AMAN RICE LANDRACES FOR DEEPWATER TOLERANCE AT SEEDLING STAGE AND VEGETATIVE STAGES

Eighteen rice germplasms including traditional landraces and modern varieties were used to carry out this experiment for screening of deepwater tolerant genotypes using phenotypic and DNA fingerprinting. Deepwater screening was performed at seedling and vegetative stages in plastic drum following IRRI standard protocol. For phenotypic study of the germplasms, water level was increased up to 50 cm for both seedling and vegetative stage. Based on phenotypic study; Badal, Mota. Aman, Pajam, Biroin, Ghotok and Laki were found tolerant. Lal Bagdak, Dhala Bagdak and Samba Mahsuri showed moderate tolerance; while Rajasail, Najirasail, Pokkali and Biroi were susceptible to deepwater.

DNA was extracted from fresh leaf samples using IRRI standard protocol. In this study five selected SSR markers viz. RM3452, RM5493, ARTS, SC3 and RM17 were used to screen the germplasm for deepwater tolerance (Fig. 16 and . From the SSR analysis, it was found that an average number of 9.4 alleles per locus were detected with PIC values ranged from 0.7136 (SC3) to 0.8795 (RM3452). The highest gene diversity (0.8889) was observed in locus RM3452 and the lowest gene diversity (0.7407) was observed in locus SC3 with a mean diversity of 0.8432. The highest genetic distance was 1.00 and lowest genetic distance was 0.20. Comparatively higher genetic distance was found in between Lal Bagdak vs. Biroin, Lal Bagdak vs. Ghotok, Lal Bagdak vs. Biroi, Lal Bagdak vs. Raja Sail, Lal Bagdak vs. Najira sail, Lal Bagdak vs. Laki, Lal Bagdak vs. Badal, Dhala Bagdak vs. Badal, Dhala Bagdak vs. Mota Aman, Dhala Bagdak vs. Najira sail, Raja sail vs. Badal etc. On the other hand, the lowest genetic distance was found in between Najirasail vs. Rajasail. This information could be used for selection of suitable parents with deepwater tolerance gene for development of deepwater tolerant rice varieties.

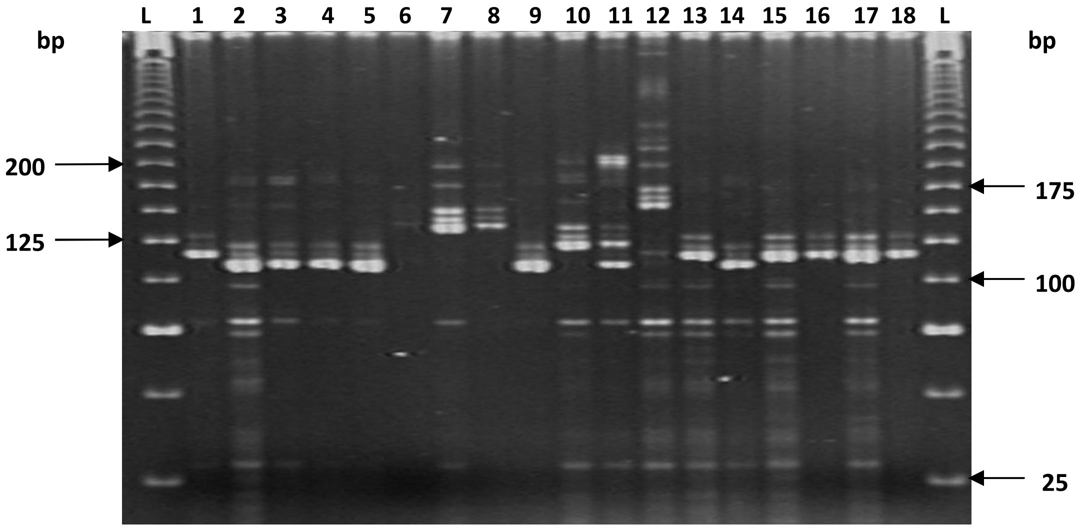


Fig. 16. SSR profile of 18 rice germplasms using RM5493

Here, 1- Lal Bagdak, 2- Pokkali, 3- Biroi, 4- Raja sail, 5- Najira sail, 6- Mota Aman, 7- Dhala Bagdak, 8- Laki, 9- Badal, 10- Biroin, 11- Ghotok, 12- Pajam, 13- BRRI dhan11, 14- Binadhan11, 15- Binadhan-10, 16- Binadhan-8, 17-Binadhan-7 and 18- Samba mhasuri (*Sub1*)

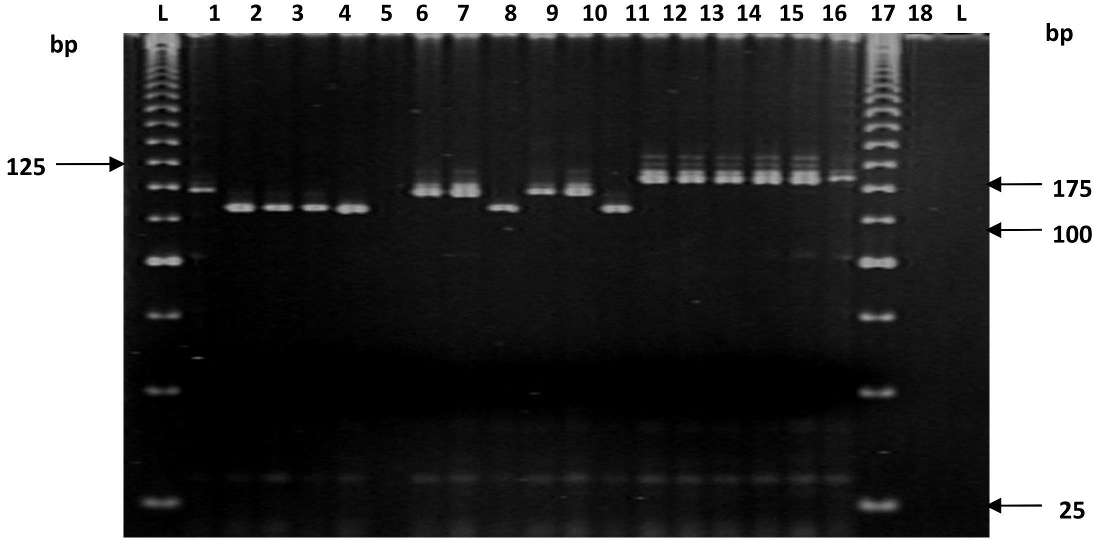


Fig. 17. SSR profile of 18 rice germplasms using RM17

Here, 1- Lal Bagdak, 2- Pokkali, 3- Biroi, 4- Raja sail, 5- Najira sail, 6- Mota Aman, 7- Dhala Bagdak, 8- Laki, 9- Badal, 10- Biroin, 11- Ghotok, 12- Pajam, 13- BRRIDhan11, 14- Binadhan11, 15- Binadhan-10, 16- Binadhan8, 17-Binadhan7 and 18- Samba mahsuri (*Sub1*)

Table 31. Summary statistics of molecular marker information found among 18 rice germplasms for 5 microsatellite (SSR) markers

Marker	Allele size range (bp)	No. of Alleles	Major Allele Frequency	PIC
RM3452	170 - 214	12.0000	0.2222	0.8795
RM5493	180 - 206	10.0000	0.2222	0.8645
ART5	132 - 165	9.0000	0.1667	0.8636
SC3	200 - 225	7.0000	0.4444	0.7136
RM17	180 - 199	9.0000	0.2778	0.8143
Mean	--------	9.4000	0.2667	0.8271

Unweighted Pair Group Method of Arithmetic Means (UPGMA) Dendrogram

The UPGMA cluster analysis led to the grouping of the 18 germplasms in two major clusters (Fig. 18). Cluster 1 (C-1) had two subcluster (S.C.-1 and S.C.-2) and four sub-sub-cluster (S.S.C.-1.1.1, S.S.C.-1.1.2, S.S.C.-1.2.1 and S.S.C.-1.2.2). A part of S.S.C.-1.1.1 comprised of Rajasail and Najirasail. On the other hand S.S.C.-1.1.2 comprised of Pokkali and Biroi- showed susceptibility against deepwater condition at both seedling and vegetative stage. S.S.C.-1.2.1 comprised of Binadhan-7, Binadhan-10 and Binadhan-8 while the other part of S.C.-1.2 comprised of Binadhan-11, BR11 and Samba mahsuri (*Sub1*). These germplasms found as moderately tolerant against deepwater environment. S.C.-2.1 and S.C.-2.2 actually comprised of maximum tolerant and highly tolerant germplasms. The position of well known deepwater tolerant rice germplasms are Lal Bagdak, Dhala Bagdak and Laki in same cluster indicated that those partners must have a deepwater tolerant gene that was also justified from their expression during phenotypic screening.

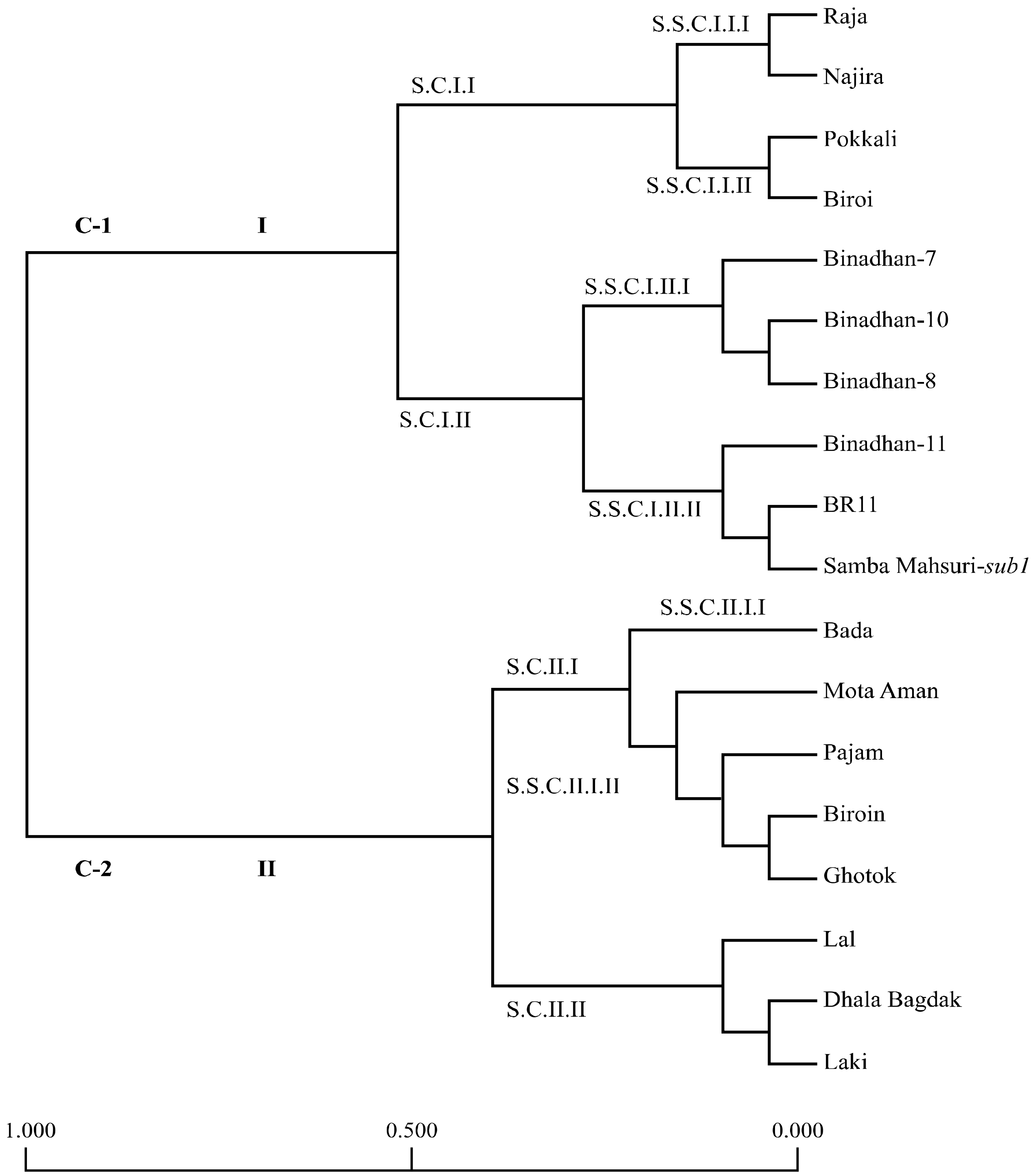


Fig. 18. UPGMA dendogram based on Nei's (1983) genetic distance summarizing the differentiation among 18 rice germplasms according to SSR analysis. (Arrow indicates the scale of genetic distance)

Morpho-molecular characterization of GI, varieties and germplasm of different crops

Morphological Characterization of Local til (GI crop)

Morphological characterization of local til (GI crop) has been done. Passport information and plant and leaf characteristics of the crop have been recorded. This local til is termed as various names in different locations as Dashi til, Boro til, Goji til, Doi shira til, char shira til, Kalo til, Dhanya til. Technical report achieved so far is presented below (Table 32 & Fig. 19).

Table 32. Distinctness of the morphological characters of Local til

State of the characters	Local til
Branching habit	Branched
Leaf position	Alternate
Growth	Indeterminate
Capsule shape	Narrow oblong
Shattering in the field	Shattered
Seed coat colour	Brown
Number of flowers per leaf axil	1
Number of nodes to first flower	5-7
Internode length (cm)	4.5
Capsule length (cm)	1.8-2.0
Seeds per capsule	45-50
Number of pods/plant	50-55
1000 -seed weight (g)	2.1 -2.5
Yield/plant (g)	10-12

Flower **Fruit bearing habit** **Fruit** **Vertical secton of fruit** **Root**

Sesame

Fig. 19. Photograph showing different parts of local til (GI crop)

Soybean (*Glycine max*)

Morphological Characterization of Soybean varieties/germplasm

Two released soybean varieties (Binasoybean-1 and Binasoybean-2) and 12 germplasm (out of 22) were put into experimental field at BINA Head Quarter farm, Mymensingh during Rabi season, 2012. The experiment was laid out in a randomized complete block design with three replications. Spacing between rows was 30 cm, and 5-7 cm between plants in a row. Unit plot size was (3m x 2m). Recommended production packages were followed to ensure normal plant growth and development. Morphological characterization and identification of the traits of documentation for distinctness of the varieties/germplasm were recorded and photograph taken from the field using the approved descriptors of IBPGR and IPGRI. Data recorded from the experiment are presented in Table 33 and Fig. 20. There is not much variation in soybean varieties. Molecular analysis was not done for soybean due to unavailability of primers.

Table 33. Distinctness of the morphological characters of soybean varieties

State of the characters	Binasoybean-1	Binasoybean-2
Stem determination	Determinate	Determinate
Shattering score	No shattering	No shattering
Plant height (cm)	48-57	42-55
Number of primary branches/plant	2-3	3-4
Number of pods/plant	46-52	45-55
Seeds/pod	2-3	2-3
Seed colour	Yellowish	Light yellowish
Days to flowering	40-45	36-40
Days to maturity	105-110	95-100
100 -seed weight (g)	8.0-8.2	8.1-8.3
Oil content (%)	19	18
Protein (%)	44.5	43.0

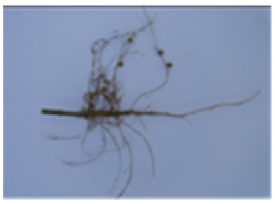

Leaf (ventral side)


Leaf (dorsal side)


Fruit bearinghabit


Fruit


Seed


Root

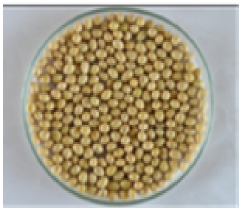
Binasoybean-1

Leaf (ventral side)

Leaf (dorsal side)

Fruit bearinghabit

Fruit



Seed

Root

Binasoybean-2

Fig. 20. Photograph showing different parts of jute varieties

Molecular characterization of six soybean germplasm using RAPD markers

Out of 18, six different soybean germplasm were characterized using RAPD markers. The four primers initially tested among them, one primers (OPB10) produced comparatively higher number of amplification products with high intensity, minimal smearing and good resolutions with clear bands. Banding pattern of RAPD markers is shown in Fig. 21. Molecular analysis of rest of the germplasm was not done due to time constraint.

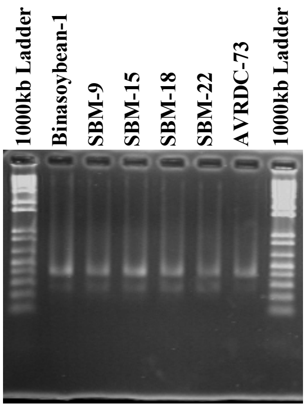


Fig. 21. RAPD profiles of 6 soybean varieties/germplasm using OPB-10

Crop: Jute (*Chorchorus capsularis*)

Morphological Characterization of Jute varieties/germplasm

Three BINA released jute varieties and five germplasm were grown for morphological characterization at BINA Head Quarter farm, Mymensingh during Kharif-1 season, 2013. Plot size was 5 m x 0.3 m. Each row was 5m long. Distances between rows and plants were 30 and 6-8 cm, respectively. Fertilizers and normal cultural practices were done to ensure normal growth and development of plant. Morphological characterization and identification of the traits of documentation for distinctness of the varieties/germplasm were recorded and photograph taken from the field using the approved descriptors of IBPGR and IPGRI and are presented in Table 34 and Fig. 22.

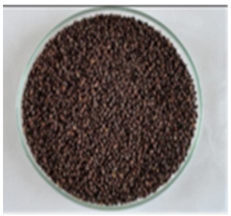
Table 34. Distinctness of the morphological characters of jute varieties

State of the character	Atompat-38	Binadeshipat-2	Binadeshipatshak-1
Stem colour	Green-no sign of any neck pigmentation (G)	Green-no sign of any neck pigmentation (G)	Green-no sign of any neck pigmentation (G)
Petiole colour	Green (G)	Green (G)	Green (G)
Stipule shape	Present, Leaf shaped	Present, Scaly	Present, Scaly
Stipule colour	Green (G)	Green (G)	Green (G)
Leaf shape	Ovate-Lanceolate	Ovate-Lanceolate	Ovate-Lanceolate
Leaf texture	Rough or non-glossy (R)	Rough or non-glossy (R)	Rough or non-glossy (R)
Leaf margin	Wavy (W)	Wavy (W)	Wavy (W)
Pigmentation of flower seed (Calyx)	Green (G)	Green (G)	Green (G)
Pigmentation of fruit	Green (G)	Green (G)	Green (G)
Seed dispersal mechanism	Indehiscent	Indehiscent	Indehiscent
Immature fruit colour	Dull green	Dull green	Dull green
Seed coat colour	Black	Black	Black
1000-seed weight (g)	3.6	3.4	3.2

Leaf (ventral side)

Leaf (dorsal side)

Twig



Seed

Root

Atompat-38

Leaf (ventral side) **Leaf (dorsal side)** **Twig** **Seed** **Root**

Binadeshipat-2

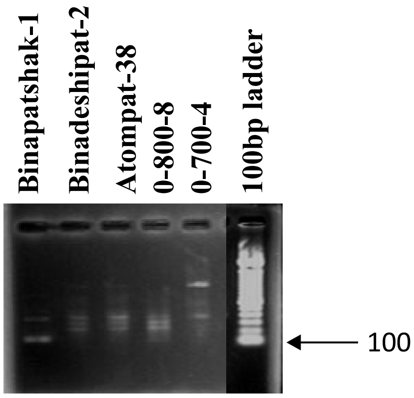
Leaf (ventral side) **Leaf (dorsal side)** **Twig** **Seed** **Root**

Binapatshak-1

Fig. 22. Photograph showing different parts of jute varieties

Molecular characterization of five jute germplasm using RAPD markers

Out of 8, five different jute germplasm were analyzed as a group for RAPD analysis. The five primers initially tested among them, two primers (OPA01 and OPA02) produced comparatively higher number of amplification products with high intensity, minimal smearing and good resolutions with clear bands. Banding pattern of RAPD markers is shown in Fig. 23. Molecular analysis of rest of the germplasm was not done due to time constraint.



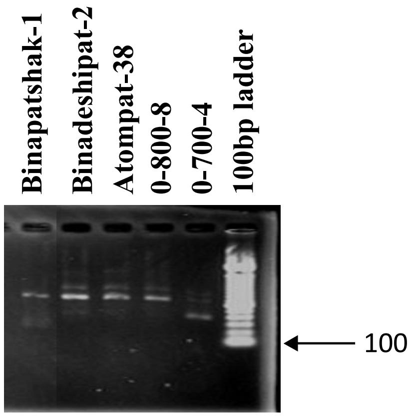


Fig. 23. RAPD profiles of 5 jute varieties/germplasm using OPA01and OPA2

HORTICULTURE DIVISION

RESEARCH HIGHLIGHTS

Tomato

The research work was conducted during rabi season of 2013-14 to develop varieties of tomato with high yield potential. Advanced yield trials with 3 exotic lines (HM-2853, HM-2722 & HM-2671) and 1 (one) exotic genotype (Phili-1) were performed through a pot and 2 field experiments. At the pot experiment, both the HM-2671 and Phili-1 genotypes showed the higher fruit yield (98.79 t ha^{-1} and 94.06 t ha^{-1}, respectively) compared to check variety, Binatomato-7 (91.68 tha^{-1}). In the field experiment of the locations of Mymensingh and Ishurdi, Phili-1 and HM-2671 genotypes also produced significantly higher yield (at Mymemsingh 95.37 t ha^{-1} and 94.54 t ha^{-1}, respectively; at Ishurdi 99.18 t ha^{-1} and 97.73 t ha^{-1}, respectively) compared to check variet, Binatomato-7. Yield trial experiment with these two genotypes will be performed at the farmer's field of four different locations over the country at the following year.

Okra

A pot experiment was conducted at the pot yard of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during Kharif-II season, 2013-2014 to select genotypes for irradiation to develop improved variety. Yield and yield attributes of 2 exotic genotypes of okra were compared with localy available Bankim genotype. Fruit yield was recorded significantly higher in Phili (1908.67 g $plant^{-1}$) and China (1151.33 g $plant^{-1}$) than that of Bankim (982.67 g $plant^{-1}$). For better performance compared to Bankim, two exotic genotypes (China and Phili) were selected for irradiation to get higher yield.

Brinjal

An experiment of brinjal was conducted in the glass house of Bangladesh Institute of Nuclear Agriculture, Mymensingh to observe the effects of gamma radiation on emergence (%) and seedling height of three brinjal genotypes. The control plant of all genotypes showed the highest seedling emergence where as lower percentages of germination were observed at 150 Gy. Seedling height was reduced with the increasing doses of gamma rays which were same for all three genotype of brinjal.

Five brinjal plants of M_1 of Natore local and 8 plants of M_1 of Ind-1 were selected to grow during 2014-15 for getting M_2 generation as only these mutants can bear fruits up to maturation. Other mutants of Natore local, purple long and Ind-1 also produce fruits but all of them were shredded before maturation.

Experiment of brinjal was conducted with sixty five genotypes of brinjal to evaluate for yield potential at BINA farm, Mymensingh during rabi season, 2013-2014. Genotypes which yield more than 2 kg $plant^{-1}$ were selected for further research which are Zhumki, ISD-006, Laffa_B, Laffa_S), Volanath M, Dohazari G, Borka, Islampuri B, Dharala, L-118, Dhundhul, Longla long, Shingnath, Islampuri, Menter, Comilla-L, BARI Begun-5, Magura local, Kansant local, Laffa BAU, Katabegun. Among these genotypes EG-190, L-118 and Dhundhul genotype showed moderately tolerant to shoot and fruit borer of brinjal.

Papaya

An experiment was conducted at BINA Substation, Khagrachari during 2013-2014 to determine improve varieties of papaya through generating variability by gamma irradiation and to screen for variants that have high yield potential. Eight genotypes of papaya were exposed to different doses of gamma rays. Compared to no gamma radiation treated papaya plant, plant height was found different in different mutant plants. The experiments will continue up to harvest to record the data on yield and yield attributes of papaya mutants (M_1) to screen M_1 plant with high yield potential.

Advanced yield trial tomatoes with 4 exotic lines/varieties.

A pot experiment was conducted at the pot yard of BINA, Mymensingh during the rabi season of 2013-14 to develop tomato varieties with high yield potential. Four exotic lines were put into the trial to assess their performance in respect of fruit yield. Field experiments were also conducted at two locations of BINA farm, Mymensingh and Ishurdi substation during rabi season, 2013-14. The pot experiment was laid out in a CRD with five replications. The experiments were laid out in randomized complete block design with three replications. Unit plot size was 2.5 m × 2.0 m and spacing was 75 cm × 60 cm for two locations. Recommended production packages were followed to ensure normal plant growth and development. Data on various characters such as plant height, number of fruits per plant, fruit weight per plant and average fruit weight were taken from three randomly selected plants. Fruit yield of each plant was recorded at final harvests.

Table 1. Performance of tomato genotypes under pot condition at BINA farm, Mymensingh grown during rabi season, 2013-14

Genotype	Plant height (cm)	No. of fruits (no. plant^{-1})	Fruit yield (kg plant^{-1})	Average fruit weight (g fruit^{-1})	Fruit yield (t ha^{-1})
Philli-1	90.00 d	40.67 b	3.24 b	79.76 b	94.06 b
HM-2853	91.67 d	36.00 c	3.02 d	83.95 b	87.62 d
HM-2722	95.67 c	48.00 a	2.80 e	58.49 c	81.24 e
HM-2671	98.67 b	37.00 c	3.41 a	92.20 a	98.79 a
Binatomato-7	103.67 a	34.00 c	3.16 c	93.04 a	91.68 c
CV (%)	1.17	4.40	0.88	3.93	0.83
$LSD_{0.05}$	2.119	3.243	0.05954	6.035	1.419

The common letter in a column did not differ at 5% level of probability as per DMRT.

At the pot experiments, result showed significant variations in all the characters (Table 1). Plant height varied from 90.00 to 103.67 cm. Binatomato-7 showed the tallest plant height (103.67 cm) followed by HM-2671 (98.67 cm). Phili-1 showed the lowest plant height (90.00 cm). Number of fruits per plant was found highest in HM-2722 (48 no. plant^{-1}) followed by Phili-1 (40.67 no. plant^{-1}). The lowest number of fruit was observed in Binatomato-7 (34 no. plant^{-1}) with statistically similar result of HM-2853 (36 no. plant^{-1}) and HM-2671 (37 no. plant^{-1}). In case of fruit yield, HM-2671 produced the highest yield (98.79 t ha^{-1}) having significantly higher yield than all other genotypes. The second highest fruit yield was observed in Phili-1 (94.06 t ha^{-1}) genotype. Both the HM-2671 and Phili-1 genotypes showed the higher fruit yield compared to check variety, Binatomato-7 (91.68 t ha^{-1}). Other two genotypes of HM-2853 (87.62 t ha^{-1}) and HM-2722 (81.24 t ha^{-1}) showed lower yield than that of Binatomato-7. But average fruit size was found highest in Binatomato-7 (93.04 g fruit^{-1}) havng non-significance difference with HM-2671 (92.20 g fruit^{-1}). HM-2722 showed the lowest fruit size (58.49 g fruit^{-1})

Table 2. Performance of tomato genotypes grown under field condition at BINA farm, Mymensingh during rabi season 2013-14.

Genotype	Plant height (cm)	No. of fruits (no. plant^{-1})	Fruit yield (kg plant^{-1})	Average fruit weight (g fruit^{-1})	Fruit yield (t ha^{-1})
Philli-1	100.67 b	36.33 b	3.29 a	90.53 a	95.37 a
HM-2853	95.67 c	29.67 c	2.76 c	93.16 a	80.13 c
HM-2722	86.00 d	47.67 a	2.55 d	53.63 b	74.07 d
HM-2671	104.00 ab	34.67 b	3.26 a	94.13 a	94.54 a
Binatomato-7	104.67 a	31.00 c	2.91 b	93.86 a	84.34 b
CV (%)	2.06	2.88	1.47	3.50	1.48
$LSD_{0.05}$	3.812	1.945	0.0842	5.602	2.390

The common letter in a column did not differ at 5% level of probability as per DMRT.

Table 3. Performance of tomato genotypes grown under field condition at Ishurdi substation, BINA during rabi season 2013-14

Genotypes	Plant height (cm)	No. of fruit (no./plant)	Fruit yield (kg/plant)	Fruit yield (t/ha)	Average fruit weight (g/fruit)
Phili-1	89.80 b	34.00 d	3.42 a	99.18 a	100.60 a
HM2853	79.13 d	48.60 a	3.08 b	89.42 b	63.45 bc
HM2722	81.93 c	29.00 e	1.80 c	52.20 c	62.07 c
HM 2671	90.07 b	46.40 b	3.37 a	97.73 a	72.66 b
Binatomato-7	104.07 a	41.33 c	3.15 b	91.35 b	76.23 b
CV (%)	1.53	2.29	2.06	2.06	2.59
$LSD_{0.05}$	2.569	1.718	0.1191	3.336	3.656

The common letter in a column did not differ at 5% level of probability as per DMRT.

Significant variation was also observed in all characters of tomato grown in the field experiments of two locations (Table 2 & Table 3). The tallest plant was found in Binatomato-7 (104.67 cm) at BINA farm, Mymensungh followed by HM-2671 (104.00 cm) and Phili-1 (100.67 cm). At Ishurdi substation, the tallest plant was also found in Binatomato-7 (104.07 cm) followed by HM-2671 (90.07 cm) and Phili-1 (89.80 cm). The highest number of fruits was recorded in HM-2722 (47.67 no. plant^{-1}) at Mymensingh, but in HM-2853 genotype (48.60 no. plant^{-1}) at Ishurdi. Number of fruit per plant was observed higher in all genotype compared to Binatomato-7 except HM-2722 at Ishurdi and HM-2853 at Mymensingh. Fruit yield was found highest at the locations of Mymensingh and Ishurdi in Phili-1 (95.37 t ha^{-1} and 97.73 t ha^{-1} at Mymnensingh and Ishurdi, respectively). This two genotype showed significantly higher yield compared to check variety Binatomato-7 and showed similar trend in both location of Mymensingh and Ishurdi. No significant variation was observed among different genotypes in case of average fruit size except HM-2722 at Mymensingh. At Ishurdi substation phili-1 (100.60 g fruit^{-1}) showed the highest fruit size followed by Binatomato-7 (76.23 g fruit^{-1}) with statistically similar result to HM-2671 and HM-2853. HM-2722 produced the lowest sized fruit (62.07 g fruit^{-1}).

Preliminary yield trial of elite genotypes of okra (Lady's finger)

A pot experiment was conducted at the pot yard of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during Kharif-II season, 2013-2014 to select suitable genotypes. Three genotypes were used including two exotic genotypes. The experiment was laid out in a randomized complete block design with five replications. Seed was sowed on 2nd week of July, 2013. Recommended production packages were followed to ensure normal plant growth and development. Data on various characters, such as plant height, number of branch per plant, fruits number per plant, fruit weight per plant and average fruit weight were recorded.

The mean values for different characters of the selected genotypes are presented in Table 4. Significant variations were observed among the genotypes for all the characters. Yield and yield attributes of 2 exotic genotypes of okra were compared with localy available Bankim genotype. Shorter plants were observed both in China (111.67 cm) and Phili (113.33 cm) compared to Bankim (137.67 cm). Number branch per plant was found highest in China (5.67 no. plant^{-1}) which was also significantly higher than other two genotypes where as other genotypes produced statistically similar no. of branch. Number of fruits per plant and fruit yield per plant was recorded significantly higher in Phili (35 no. plant^{-1} and 1908.67 g plant^{-1}, respectively) and China (34.67 no. plant^{-1} and 1151.33 g plant^{-1}, respectively) genotypes that Bankim (30.33 no. plant^{-1} and 982.67 g plant^{-1}, respectively). But in case of average fruit size, highest fruit size was observed in Phili (54.56 g fruit^{-1}) and lowest fruit size was recorded in Bankim (32.39 g fruit^{-1}) with statistically similar to China (33.26 g fruit^{-1}). For better performance compared to Bankim, two exotic genotypes (China and Phili) were selected for irradiation to get high yield potential and resistant to fruit borer and YMV okra genotype.

Table 4. Performance of okra genotypes grown under pot condition at BINA farm, Mymensingh during Kharif-II season 2013-14.

Genotype	Plant height (cm)	No. of branch (no. plant^{-1})	No. of fruits (no. plant^{-1})	Average fruit weight (g fruit^{-1})	Fruit yield (g plant^{-1})
China	111.67 b	5.67 a	34.67 a	33.26 b	1151.33 b
Phili	113.33 b	4.33 b	35.00 a	54.56 a	1908.67 a
Bankim	137.67 a	4.00 b	30.33 b	32.39 b	982.67 c
CV (%)	1.57	12.37	2.45	4.60	3.21
$LSD_{0.05}$	3.578	1.087	1.538	3.471	81.57

The common letter in a column did not differ at 5% level of probability as per DMRT.

Evaluation of the effects of gamma radiation on emergence (%) and seedling height of different brinjal genotypes

The experiment was conducted in the glass house of Bangladesh Institute of Nuclear Agriculture, Mymensingh. The well dried seeds of three brinjal genotypes viz. purple long, Nature local, Ind-1 were taken to observe the effects of gamma radiation on emergence (%) and seedling height of different brinjal genotypes. The parameters taken into consideration were seedling emergence percentage, seedling height, seedling height percentage and reduction of seedling height (%) of brinjal. Germination test was performed before irradiation of seed. A number of 15 seeds per genotype were germinated in petri dishes containing water soaked filter paper in normal condition. All of the genotypes responded 100% germination. After that, 100 seeds per genotype were exposed to 2 doses of gamma rays (75, 150 Gy) and a control (0 Gy). Prior to mutagenic treatments the seeds were kept in desiccators over a 60% glycerol/water mixture for three days at room temperature for seed moisture equilibration. The seeds were subjected to gamma rays from ^{60}Co irradiator at Bangladesh Institute of Nuclear Agriculture, Mymensingh. Irradiated 100 seeds per dose and per genotype were sown in trays contained soil mixed with sand and cowdung in the glasshouse. Water was applied as and when necessary. Weed was maintained manually. The germinated seeds were observed daily from 1st day of germination. Germination data was recorded at the 14th day and stem height data were taken at the 21th day after sowing of brinjal seed. The experiment was designed in completely randomized design (CRD) with three replications. Means in each treatment were compared by Duncan Multiple Range Test using Statistical Analysis System MSTAT-C.

Table 5. Effect of gamma irradiation on emergence (%) of brinjal genotypes at 14 days after sowing

Gamma doses	Seedling emergence (%) of brinjal genotypes		
	Purple long	Natore local	Ind-1
0	58.67 a	75.33 a	71.33 a
75	46.33 b	59.33 b	67.00 a
150	23.00 c	33.00 c	45.67 b
CV (%)	6.90	1.40	3.33
$LSD_{0.05}$	6.674	1.772	4.628

The common letter in a column did not differ at 5% level of probability as per DMRT.

The results indicated significant differences for germination percentage of the three genotypes of brinjal exposed to different gamma rays treatment (Table 5 & Table 6). These showed a reduction of germination percentage of all seedlings from irradiated seeds. The control plant of all genotypes showed the highest seedling emergence (58.67%, 75.33%, 71.33% for Purple long, Natore long and Ind-1, respectively) which was statistically similar to 75 Gy for Ind-1 (67.00%) and statistically higher both to 75 and 150 Gy for Purple long and Natore local. Significantly lower percentages of germination were observed at 150 Gy in all three genotypes (23.00%, 33.0% and 45.67% in Purple long, Natore local and Ind-1 genotypes, respectively).

Table 6. Effect of gamma irradiation on seedling height of different brinjal genotypes after 21 days after sowing

Gamma dosages (Gray)	Seedling height (cm)		
	Purple long	Natore local	Ind-1
0	4.51 a	4.59 a	4.65 a
75	3.53 b	3.29 b	4.35 b
150	2.88 c	2.03 c	3.84 c
CV (%)	3.65	6.08	1.11
$LSD_{0.05}$	0.3041	0.4534	0.1014
Seedling height (%) (Relative to control)			
0	100.00 a	100.00 a	100.00 a
75	78.43 b	71.90 b	93.69 b
150	63.96 c	44.28 c	82.64 c
CV (%)	3.35	3.23	1.14
$LSD_{0.05}$	6.139	5.284	2.384
Seedling height reduction (%) (Relative to control)			
0	0.00 c	0.00 c	0.00 c
75	21.77 b	28.10 b	6.31 b
150	36.04 a	55.72 a	17.36 a
CV (%)	14.05	8.34	13.32
$LSD_{0.05}$	6.139	5.284	2.383

The common letter in a column did not differ at 5% level of probability as per DMRT.

The results showed similar sensitivity at different gamma rays in three genotypes of brinjal. The difference among gamma ray treatments were also observed for seedling height of brinjal. The seeds receiving no irradiation produced the highest seedling height (4.51 cm, 4.59 cm & 4.65 cm of Purple long, Natore local and Ind-1, respectively) compared to the treatment receiving 75 and 150 Gy. Lowest seedling height was observed at the 150 Gy (2.88 cm, 2.03 cm & 3.84 cm of Purple long, Natore local and Ind-1, respectively). Seedling height reduction percentage was found highest at 150 Gy doses of gamma radiation (36.04%, 55.72% & 17.36% in Purple long, Natore local and Ind-1, respectively). Seedling height was reduced with the increasing doses of gamma rays which were same for all three genotype of brinjal. As gamma radiation effects significantly on the emergence (%), seedling height of irradiated plant of three brinjal genotype, so it could be expected that there occurred mutation. For this, the survived plants were allowed to grow up to harvest to observe the yield and yield attributes of brinjal genotypes.

Performance of the mutants (M_1) of three genotypes of brinjal

The experiment was conducted to see the performance of the mutants (M1) of three genotypes of brinjal up to fruit harvest time. Seedlings of the three brinjal genotypes were transplanted during 2nd week of November, 2013. The experiment was laid out in RCBD with three replications. Unit plot size was 2 m × 2.5 m and spacing 70 cm × 60 cm. Recommended production packages were followed to ensure normal plant growth and development. Data on various characters, such as plant height, no. of branch/plant, leaf length, leaf width, fruit length, fruit width, date of 1st flowering, no. of fruit, fruit yield per plant and average fruit weight were taken from each mutants.

Results showed that the mutants and the check variety differed for yield and yield attributes (Table 7). Only 5 plants of M_1 of Natore local and 8 plants of M_1 of Ind-1 were taken into consideration for data collection as only these mutants can bear fruits up to maturation. Other mutants of Natore local, purple long and Ind-1 also produce fruits but all of them were shredded before maturation. Two mutant plant of Natore local, ($NLM_1D_{75}P_{24}$ & $NLM_1D_{75}P_{25}$) and two mutant plant of Ind-1 ($IndM_1D_{75}P_{62}$ & $IndM_1D_{75}P_{71}$) took shorter period to flowering compared to non irradiated genotypes (38.33) of each variety. All the mutants produced longer plant than non treated genotypes except $NLM_1D_{75}P_{31}$, $IndM_1D_{75}P_{62}$, $IndM_1D_{75}P_{90}$ and $IndM_1D_{150}P_{102}$. In case of fruit yield per plant, $NLM_1D_{75}P_{18}$ (960 g plant^{-1}) & $NLM_1D_{75}P_{39}$ (1355 g plant^{-1}) of Natore local and $IndM_1D_{75}P_{80}$ ((1670 g plant^{-1}), $IndM_1D_{75}P_{166}$ (910 g plant^{-1}), $IndM_1D_{150}P_{91}$ (1875 g plant^{-1}) & $IndM_1D_{150}P_{114}$ (685 g plant^{-1}) of Ind-1 produced the higher fruit yield compared to non irradiated plant of each genotypes (Natore local 655 g plant^{-1} & Ind-1 618 g plant^{-1}). As only the 13 M_1 plants of brinjal can produce fruit, all 13 plants were selected to grow during 2014-15 for getting M_2 generation.

Table 7. Yield attributes of mutants (M_1) of brinjal with control at BINA farm, Mymensingh during Kharif-II, 2013-14

Mutant	Plant height (cm)	Branch/ Plant (no. plant^{-1})	Leaf length (cm)	Leaf width (cm)	1st flowering (DAT)	Fruit length (cm)	Fruit width (cm)	No. of fruit (no. plant^{-1})	Average fruit wt. (g fruit^{-1})	Fruit yield (g plant^{-1})
$NLM_1D_{75}P_{18}$	93.00	3.00	9.60	10.66	45.00	10.00	7.00	10.00	96.00	960.00
$NLM_1D_{75}P_{24}$	84.00	5.00	13.00	12.00	29.00	9.00	5.80	10.00	55.50	555.00
$NLM_1D_{75}P_{25}$	88.00	6.00	15.66	9.33	35.00	9.50	7.50	25.00	22.00	550.00
$NLM_1D_{75}P_{31}$	71.00	5.00	12.00	8.66	40.00	6.00	4.00	10.00	42.50	425.00
$NLM_1D_{75}P_{39}$	83.00	8.00	14.66	8.66	40.00	10.00	8.50	20.00	67.75	1355.00
Control (NL)	**79.33**	**5.67**	**16.33**	**9.89**	**38.33**	**10.50**	**7.57**	**18.33**	**36.08**	**655.00**
$IndM_1D_{75}P_{62}$	85.00	4.00	12.33	8.00	36.00	6.00	6.80	35.00	17.14	600.00
$IndM_1D_{75}P_{71}$	88.00	5.00	12.33	8.33	35.00	6.00	6.00	40.00	10.25	410.00
$IndM_1D_{75}P_{80}$	105.00	6.00	11.33	7.33	39.00	7.20	6.50	40.00	41.75	1670.00
$IndM_1D_{75}P_{90}$	82.00	6.00	9.00	8.66	47.00	4.50	4.00	20.00	30.00	600.00
$IndM_1D_{75}P_{166}$	94.00	4.00	13.00	10.33	50.00	8.00	7.00	25.00	36.40	910.00
$IndM_1D_{150}P_{91}$	97.00	6.00	17.66	10.66	43.00	11.00	7.50	25.00	75.00	1875.00
$IndM_1D_{150}P_{102}$	67.00	5.00	12.00	8.00	40.00	8.00	6.00	25.00	21.80	545.00
$IndM_1D_{150}P_{114}$	114.00	5.00	11.66	7.66	40.00	13.00	5.00	65.00	10.54	685.00
Control (Ind)	87.80	5.00	12.06	8.73	37.40	7.00	6.02	45.00	16.09	618.00
Control (PL)	89.50	5.67	14.00	9.58	46.25	12.00	6.13	45.00	34.39	1161.25
SD	**11.55**	**1.12**	**2.30**	**1.28**	**5.29**	**2.42**	**1.25**	**15.29**	**24.49**	**445.64**

Note: NL = Natore local, Ind = Ind-1, PL = Purple long, M_1 = M_1 plant, D = Dose, P = Plant

Screening of elite genotypes of eggplant

Sixty five genotypes of eggplant were tested to evaluate the yield potentials at BINA farm, Mymensingh during rabi season, 2013-2014 presented in Table 8. The experiment was laid out in a RCBD with three replications. Unit plot size was 2m×2.5m and spacing was 70cm×60cm. Seedlings were transplanted during 2nd week of November, 2013. Recommended production packages were followed to ensure normal plant growth and development. Data on number of fruits per plant, and fruit yield per plant were taken from three replicated plants.

Table 8. Performance of eggplant genotypes under field condition at BINA farm, Mymensingh during rabi season, 2013-14

Sl. No.	Genotypes	No. of fruit (fruit plant^{-1})	Yield (kg plant^{-1})	SL. No.	Genotypes	No. of fruit (fruit plant^{-1})	Yield (kg plant^{-1})
1.	Zhumki	17	3.00	33.	Menter	14	2.33
2.	ISD-006	14	2.56	34.	Salta	12	1.22
3.	Laffa_M	10	1.29	35.	Iribegun	7	1.29
4.	Laffa_G	9	1.63	36.	Eye-red	13	1.07
5.	Laffa_B	14	2.56	37.	Deembegun	9	1.25
6.	Laffa_S	12	2.52	38.	Comilla-L	11	2.06
7.	Volanath M	14	2.71	39.	Chega	8	1
8.	Thamba	9	1.02	40.	BARI Begun-1	15	1.31
9.	Dohazari Red	6	1.27	41.	BARI Begun-4	13	1.79
10.	Dohazari G	10	2.14	42.	BARI Begun-5	14	2.4
11.	Borka	14	2.76	43.	BARI Begun-6	5	0.9
12.	Khathatia B	14	1.48	44.	BARI Begun-7	12	0.88
13.	Khathatia BAU	15	1.57	45.	BARI Begun-9	12	1.06
14.	Kaikka N	9	1.11	46.	BARI Begun-10	4	0.64
15.	Kaikka G	15	1.48	47.	BAU-1	7	1.53
16.	Islampuri BADC	15	3.27	48.	Indian-1	11	1.73
17.	Jessore L	9	1.74	49.	Pahuza-1	15	1.33
18.	Dharala	11	2.46	50.	Pahuza-2	17	1.66
19.	Uttara	10	1.45	51.	Magura local	18	2.16
20.	Kazla	15	1.52	52.	Long lived high plant	9	1.68
21.	L-118	16	2.22	53.	Purple long	12	1.12
22.	Dhundhul	13	2.08	54.	Kansant local	15	2.31
23.	EG-190	17	1.41	55.	Laffa BAU	10	2.18
24.	China oblong	11	0.95	56.	Katabegun WS	14	3.27
25.	Ishurdi-WS	15	1.88	57.	Marich begun S	17	1.07
26.	Ishurdi-BS	14	1.53	58.	Marich begun E	17	0.71
27.	Putabegun	12	1.53	59.	Natore local (long)	6	1.21
28.	Longla long	16	3.13	60.	Apple begun	9	1.40
29.	Shingnath	15	2.34	61.	Natore local (round)	12	1.76
30.	Longla talbegun	13	1.71	62.	China round	7	0.77
31.	Islampuri	10	2.7	63.	BAU-2	9	1.55
32.	Thapara	9	1.8	64.	Kansant-1	7	1.12
				65.	Kansant-2	6	1.05
	LSD $_{0.05}$	1.534	0.1445		LSD $_{0.05}$	1.534	0.1445

The results of the field experiment of eggplant with 65 genotypes are presented in Table 8. There was found significant differences among different genotypes for no. of fruit per plant and fruit yield per plant. Number of fruits varied from 4 to 18 no. of fruits plant^{-1} and fruit yield varied from 0.64 to 3.27 kg plant^{-1}. On the basis of yield, 21 genotypes were selected among 65 eggplant genotypes for irradiation. Genotypes which yield more than 2 kg/plant were selected for further research which are Zhumki (3.00 kg plant^{-1}), ISD-006 (2.56 kg plant^{-1}), Laffa_B (2.56 kg plant^{-1}), Laffa_S (2.52 kg plant^{-1}), Volanath M(2.71 kg plant^{-1}), Dohazari G (2.14 kg plant^{-1}), Borka (2.76 kg plant^{-1}), Islampuri B (3.27 kg plant^{-1}), Dharala (2.46 kg plant^{-1}), L-118 (2.22 kg plant-1), Dhundhul (2.08 kg plant^{-1}), Longla long (3.13 kg plant^{-1}), Shingnath (2.34 kg plant^{-1}), Islampuri (2.7 kg plant^{-1}), Menter (2.33 kg plant^{-1}), Comilla-L (2.06 kg plant^{-1}), BARI Begun-5 (2.40 kg plant^{-1}), Magura local (2.16 kg plant^{-1}), Kansant local (2.31 kg plant^{-1}), Laffa BAU (2.18 kg plant^{-1}), Katabegun (3.27 kg plant^{-1}). Above these genotypes including EG-190 was selected for further research to study the susceptibility or tolerance to shoot and fruit borer of brinjal. Though the yield performance of EG-190 genotype is low (1.41 kg plant^{-1}), after that it was selected for further research as there was observed moderate tolerance to shoot and fruit borer. Among other genotypes, L-118 and Dhundhul showed tolerant to shoot and fruit borer of brinjal.

Screening and growing of M_1 generation of elite genotypes of papaya

An experiment was conducted at Khagrachari substation, Bangladesh Institute of Nuclear Agriculture (BINA) during 2013-2014 to determine the potential of using irradiation for the production of useful mutants and improve varieties in papaya. The objective of the experiment is to generate variability in papaya variety by gamma irradiation and to screen for variants that have high yield potential, early fruit bearing and resistant to YMV diseases. Eight genotypes were used in this experiment. Uniform seeds of papaya were irradiated at 200 Gy of gamma rays using ^{60}Co gamma source. The treated seeds, along with the control were sown in polybag containing a mixture of sand and soil. Recommended production packages were followed to ensure normal plant growth and development. Data were recorded on plant height and number of leaf.

The results indicated differences for plant height and no. of leaf (Table 9). Eight genotypes of papaya were exposed to different gamma rays treatment. Compared to control papaya plant, plant height was found higher in DebM$_1$ x P$_2$ (27 cm), DebM$_1$ x P$_9$ (30 cm) & DebM$_1$ x P$_{10}$ (29cm) in Debgiri genotype; SHM$_1$ x P$_{17}$ (28 cm), SHM$_1$ x P$_{18}$ (30 cm) & SHM$_1$ x P$_{19}$ (23 cm) in Sweethoney genotype; all plant of Dhudsagor (DSM$_1$ x P$_{41-50}$); HGM$_1$ x P$_{51}$ (30 cm), HGM$_1$ x P$_{53}$ (23 cm), HGM$_1$ x P$_{54}$ (22 cm), HGM$_1$ x P$_{55}$ (22 cm) & HGM$_1$ x P$_{57}$ (21 cm) in Hygrade genotype; PahM$_1$ x P$_{21}$ (26 cm), PahM$_1$ x P$_{23}$ (25 cm), PahM$_1$ x P$_{24}$ (28 cm) & PahM$_1$ x P$_{30}$ (26 cm) in Pahuza; RedM$_1$ x P$_{31}$ (20 cm), RedM$_1$ x P$_{34}$ (23 cm), RedM$_1$ x P$_{36}$ (22 cm), RedM$_1$ x P$_{37}$ (24 cm), RedM$_1$ x P$_{38}$ (22 cm) & RedM$_1$ x P$_{40}$ (21 cm) in Redmaster genotype; SMM$_1$ x P$_{63}$(24 cm) in Sweetmaster genotype and all M$_1$ plants of Indonesia. The experiments will continue up to harvest to record the data on yield and yield attributes of papaya mutants (M$_1$) to screen M$_1$ plant with high yield potential.

Table 9. Yield attributes of some mutants of papaya with control at BINA substation Khagrachari during 2013-14

Genotypes	Plant height (cm)	No. of leaf (no. plant^{-1})
DebM$_1$ x P$_1$	25	3
DebM$_1$ x P$_2$	27	6
DebM$_1$ x P$_3$	19	5
DebM$_1$ x P$_4$	16	4
DebM$_1$ x P$_5$	18	6
DebM$_1$ x P$_6$	15	6
DebM$_1$ x P$_7$	17	5
DebM$_1$ x P$_8$	20	5
DebM$_1$ x P$_9$	30	6
DebM$_1$ x P$_{10}$	29	9
Control	**25.5**	**6.7**
SHM$_1$ x P$_{11}$	20	4
SHM$_1$ x P$_{12}$	17	4
SHM$_1$ x P$_{13}$	21	6
SHM$_1$ x P$_{14}$	21	3
SHM$_1$ x P$_{15}$	16	8
SHM$_1$ x P$_{16}$	16	5
SHM$_1$ x P$_{17}$	28	6
SHM$_1$ x P$_{18}$	30	10
SHM$_1$ x P$_{19}$	23	5
SHM$_1$ x P$_{20}$	21	7
Control	**21.2**	**4.3**
PahM$_1$ x P$_{21}$	26	8
PahM$_1$ x P$_{22}$	12	6
PahM$_1$ x P$_{23}$	25	8
PahM$_1$ x P$_{24}$	28	8
PahM$_1$ x P$_{25}$	21	6
PahM$_1$ x P$_{26}$	22	5
PahM$_1$ x P$_{27}$	20	7
PahM$_1$ x P$_{28}$	23	7
PahM$_1$ x P$_{29}$	16	4
PahM$_1$ x P$_{30}$	26	6
Control	**23.2**	**5.6**
RedM$_1$ x P$_{31}$	20	5
RedM$_1$ x P$_{32}$	18	3
RedM$_1$ x P$_{33}$	12	4
RedM$_1$ x P$_{34}$	23	7
RedM$_1$ x P$_{35}$	16	8
RedM$_1$ x P$_{36}$	22	3
RedM$_1$ x P$_{37}$	24	5
RedM$_1$ x P$_{38}$	22	6
RedM$_1$ x P$_{39}$	16	6
RedM$_1$ x P$_{40}$	21	1
Control	**19.4**	**4.8**

Genotypes	Plant height (cm)	No. of leaf (no. plant^{-1})
DSM$_1$ x P$_{41}$	24	4
DSM$_1$ x P$_{42}$	35	8
DSM$_1$ x P$_{43}$	29	5
DSM$_1$ x P$_{44}$	31	5
DSM$_1$ x P$_{45}$	30	4
DSM$_1$ x P$_{46}$	29	3
DSM$_1$ x P$_{47}$	28	6
DSM$_1$ x P$_{48}$	30	4
DSM$_1$ x P$_{49}$	29	3
DSM$_1$ x P$_{50}$	49	7
Control	**22.1**	**5**
HGM$_1$ x P$_{51}$	30	8
HGM$_1$ x P$_{52}$	14	4
HGM$_1$ x P$_{53}$	23	6
HGM$_1$ x P$_{54}$	22	7
HGM$_1$ x P$_{55}$	22	6
HGM$_1$ x P$_{56}$	12	4
HGM$_1$ x P$_{57}$	21	5
HGM$_1$ x P$_{58}$	18	4
Control	**18.2**	**5.4**
SMM$_1$ x P$_{59}$	11	5
SMM$_1$ x P$_{60}$	17	7
SMM$_1$ x P$_{61}$	15	4
SMM$_1$ x P$_{62}$	14	6
SMM$_1$ x P$_{63}$	24	5
Control	**19.6**	**6.1**
IndoM$_1$ x P$_{64}$	20	5
IndoM$_1$ x P$_{65}$	29	6
IndoM$_1$ x P$_{66}$	20	5
IndoM$_1$ x P$_{67}$	18	3
IndoM$_1$ x P$_{68}$	21	6
IndoM$_1$ x P$_{69}$	30	10
IndoM$_1$ x P$_{70}$	28	6
IndoM$_1$ x P$_{71}$	24	7
IndoM$_1$ x P$_{72}$	30	7
IndoM$_1$ x P$_{73}$	25	9
Control	**17.5**	**5.1**

AGRICULTURAL ECONOMICS DIVISION

RESEARCH HIGHLIGHTS

The study on Cost and Return of Binachinabadam-4 cultivation was undertaken in 3 Groundnut growing areas

The average cost and net return in the production of Binachinabadam-4 were Tk. 50074.32 and Tk. 48304.77 per hectare.

The yield of Binachinabadam-4 was 2.005 ton per hectare

The return to scale was 1.32; indicating farmers are operating at the region of increasing returns to scale.

Analysis of resource use efficiency revealed that higher return can be obtained by appropriate crop management and application of fertilizer.

The study on field level comparative analysis of Binadhan-7 and BRRI dhan33 cultivation was undertaken in northern rice growing areas.

The average yield of Binadhan-7 (4.80 t ha^{-1}) was higher than the average yield of BRRI dhan33 (4.00 t ha^{-1}).

The per hectare net return were Tk. 56392 for Binadhan-7 and Tk. 39247 for BRRI dhan33.

At all locations, the undiscounted benefit cost ratios were 2.45 and 2.00 for Binadhan-7 and BRRI dhan33 respectively.

Farmers can harvest Binadhan-7 within 110-115 days which is earlier than BRRI dhan33 and cultivate robi crops like potato, cabbage, mustard etc, easily

It was observed that non availability of seed at proper time was the first constraint for Binadhan-7 cultivation but for BRRI dhan33 cultivation it was ranked five.

Estimation of Costs and Return of Groundnut Variety Binachinabadam-4

Three districts (Kishorganj, Jhenaidah and Lalmonirhat) were selected for the survey of Binachinabadam-4 production. Under these three districts three upazilla including char lands namely Bhairab of Kishorganj, Kaliganj Upazilla of Lalmonirhat and Moheshpur of Jhenaidah were selected purposively. A total of 90 Binachinabadam-4 growers consisting of 30 from each district were randomly selected as a sample size.

Profit equation was employed to assess the profitability of Binachinabadam-4 production.

Net return/profit, $\Pi = P_{F.}Q_F - (TVC + TFC)$

Cobb-Douglas production function analysis was done to find out the impact of input on production. The function was specified as:

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}X_7^{b7}X_8^{b8}X_9^{b9}X_{10}^{b10}X_{11}^{b11}X11b^{12}e^{ui}$$

The function was linearised by transforming it into double log or log linear form as follows, $LogY = Loga + b_1LogX_1 + b_2LogX_2 + b_3LogX_3 + b_4LogX_4 + b_5LogX_5 + b_6LogX_6 + b_7LogX_7 + b_8LogX_8 + b_9LogX_9 + b_{10}LogX_{10} + b_{11}LogX_{11} + b_{12}LogX_{12} + Ui$

Where,

Y = Gross return (Tk ha^{-1})
X_1 = Human labour cost (Tk ha^{-1})
X_2 = Animal labour cost (Tk ha^{-1})
X_3 = Power tillar cost (Tk ha^{-1})
X_4 = Seed cost (Tk ha^{-1})
X_5 = Urea cost (Tk ha^{-1})
X_6 = TSP cost (Tk ha^{-1})
X_7 = MP cost (Tk ha^{-1})
X_8 = Sulphur cost (Tk ha^{-1})
X_9 = Zypsum cost (Tk ha^{-1})
X_{10} = Organic manure cost (Tk ha^{-1})
X_{11} = Irrigation cost (Tk ha^{-1})
X_{12} = Farm size (Tk ha^{-1})
Ui = Disturbance term, a = intercept and bi = Production co-efficient.

Resources are considered to be efficiently used to result in attaining the maximum profit when the ration of marginal value product (MVP) to marginal factor cost (MFC) approaches one, or MVP and MFC for each input were equal.

The average cost of production of Binachinabadam-4 is Tk. 50074.32 per hectare with an average yield of 2.01 t ha^{-1} which indicates to a production cost of Tk. 24.97 kg^{-1} (Table 2).

Table 1. Cost of production of Binachinabadam-4

Cost component	Kishorganj (n = 30)	Jhenaidah (n = 30)	Lalmonirhat (n = 30)	Average
Human labour (man-days ha^{-1})	17908.18	22106.82	20556.85	20190.61
Animal labour	-	2136.01	688.20	941.00
Power tillar	3612.28	1870.37	2549.74	2677.46
Seed	18169.24	14809.57	17836.97	16938.59
Fertilizer	5882.23	4509.83	5652.74	5348.26
Urea	579.38	44.25 (n=6)	7.90 (n=1)	210.51
TSP	2624.05	2867.80	2308.95	2600.27
MP	1176.63	877.54	971.41	1008.23
Sulphur	180.12 (n=5)	92.92 (n=4)	484.87 (n=20)	252.46
Organic manure	1080.75 (n=18)	627.32 (n=8)	1879.61 (n=20)	1195.69
Irrigation	1685.48	2283.48	2509.85	2159.60
Interest on operating capital	1732.46	1855.16	1989.32	1867.60
Total variable cost	45851.45	48234.24	48555.44	47547.04
Total Fixed cost	3138.42	1337.00	3106.42	2662.72
Total Cost	48989.87	49571.24	51661.86	50074.32

(n = indicates no. of observation)

Table 2. Financial Profitability of Binachinabadam-4 in the study areas

Type of input	Kishorganj (n = 30)	Jhenaidah (n = 30)	Lalmonirhat (n = 30)	Average
Yield (Kg ha^{-1})	2166.49	1769.29	2079.75	2005.18
Yield (Tk ha^{-1})	89591.52	88464.26	107189.43	93215.32
By product (Tk ha^{-1})	7353.95	6922.49	7615.63	7297.36
Gross Return	96945.47	95386.75	114805.06	100512.67
Total variable cost	45851.45	48234.24	48555.44	47547.04
Total Cost	48989.87	49571.24	51661.86	50074.32
Gross Margin	51094.02	47152.51	66249.62	54832.05
Net Return	47955.60	45815.51	63143.20	52304.77
Benefit cost ratio (undiscounted): Full cost basis	1.98	1.92	2.22	2.04

Factors affecting and resource use efficiency in Binachinabadam-4 production

The co-efficient of multiple determination, R^2 is 0.84% this implies that 84% of the total variation in the output of groundnut was accounted for the explanatory variables included in the model, while the remaining 16% variation of the dependent variable was accounted for by disturbance term (Table 3).

Table 3. Estimated values of the coefficients and related statistics of Cobb-Douglas production function of Binachinabadam-4 farmers

Explanatory variables	Values of coefficient	t- value	p-value	MVP/MFC (Resource Use Efficiency)	Description of Efficiency Index
Intercept	5.28***	11.94	0.000	-	-
Human labour (X_1)	0.104***	2.64	0.010	2.47	underutilized
Animal labour (X_2)	0.107***	4.36	0.000	4.61	underutilized
Power Tiller (X_3)	0.393***	6.79	0.000	18.10	underutilized
Seed (X_4)	0.160**	1.89	0.048	3.09	underutilized
Urea (X_5)	0.024*	1.82	0.813	2.87	underutilized
TSP (X_6)	-0.067**	-2.34	0.022	-8.72	Over utilized
MP (X_7)	-0.042	-1.21	0.232	-1.93	Over utilized
Irrigation (X_{11})	0.157***	3.82	0.000	13.10	underutilized
Farm size (X_{12})	0.25***	3.37	0.001	11.53	underutilized
Co-efficient of multiple determination, R^2			0.84		
F-Value			33.68***		
Returns to scale (Σb_i)			1.32		

'***', '**' and '*' represents significant level at 1, 5 and 10 percent respectively.

The return to scale is 1.32 which was the sum of elasticities as shown in Table 3. This value being greater than unity 1 means that the farmers are operating at the region of increasing returns to scale. Analysis of resource use efficiency indicates that higher return can be obtained by appropriate crop management and application of fertilizer.

Field Level Comparative Analysis of Binadhan-7 and BRRI dhan33

The study was conducted at five districts of Bangladesh, namely Rangpur, Kurigram, Lalmonirhat, Nilphamari & Gaibandha. The objectives were i) to compare the productivity of Binadhan-7 and BRRI dhan33; ii) to assess the profitability of Binadhan-7 and BRRI dhan33; and iii) to determine the constraints of Binadhan-7 and BRRI dhan33 cultivation.

The survey covered 150 farmers in the study area 30 from each District. Tabular method using descriptive statistics were used in analyzing the collected data. In the study, costs and return analysis were done to compare the profitability.

Result and Discussion

The average cost of production of Binadhan-7 is Tk. 38968.86 per hectare and for BRRI dhan33 Tk 39213.12 per hectare. The major share of total cost was human labour, power tiller and irrigation. Among the study areas the cost of Binadhan-7 cultivation was found higher in Rangpur (Tk 44372.87 ha^{-1}) followed by Gaibandha (Tk 41939.25 ha^{-1}), Lalmonirhat (Tk. 39759.87 ha^{-1}), Kurigram (Tk. 34451.48 ha^{-1}), and Nilphamari (Tk. 33844.93 ha^{-1}). In case of BRRI dhan33 cost is also higher in Rangpur (Tk. 43699.67 ha^{-1}) followed by Gaibandha (Tk.42470.35 ha^{-1}), Lalmonirhat (Tk. 39300.92 ha^{-1}), Kurigram (Tk.6689.23 ha^{-1}) and Nilphamari Tk. (33884.69 ha^{-1}) (Table 4).

Table 4. Cost component of Binadhan-7 and BRRI dhan33

Cost component	Binadhan-7						BRRI dhan33					
	R	G	L	K	N	Average	R	G	L	K	N	Average
Human-labour (man-days ha^{-1})	18180.33	22827.10	17776.70	15979.34	16233.00	18199.31	17451.30	21930.14	18524.96	16744.47	16271.17	18188.41
Power tillar	7189.18	4407.88	6397.57	5262.61	5059.72	5754.92	6822.18	5838.99	5597.56	5622.83	4736.90	5723.69
Seed	1484.80	925.56	1320.17	832.52	1070.07	1126.62	1569.18	1148.46	1005.48	944.50	965.97	1126.71
Fertilizer	9021.34	5274.44	7361.13	6385.39	5729.3	6754.32	8927.92	6957.66	7012.56	6940.8	6118.37	7191.45
Urea	4100.15	2593.40	3650	3212.07	3388.89	3388.90	4329.17	3467.32	3355.55	3226.67	3144.99	3504.74
TSP	2140.35	1636.66	2538.79	2027.55	1468.47	1962.36	2334.31	2272.03	2380	2563.3	2014.65	2312.86
MP	998.68	818.68	1057.56	974.69	680.83	906.09	988.06	959.40	1092.57	977.5	769.20	957.34
Sulphur	64.327	225.70	114.78	171.08	121.67	139.51	55.55	258.91	184.44	173.33	189.53	172.35
Organic manure	1717.84	-	-	-	69.44	357.46	1220.83	-	-	-	-	244.16
Pesticide	936.77	544.24	825.09	930.94	601.25	767.66	842.63	988.86	779.33	718.31	627.80	791.39
Irrigation	4586.40	1960.67	2509.39	1709.43	2160.69	2585.32	5388.61	2110.64	2575.77	1835.14	2277.72	2837.57
Interest on operating capital	1655.95	2761.30	1447.60	1244.10	1234.16	1672.26	1587.349	1429.466	1334.938	1227.956	1169.648	350.03
Total variable cost	43054.78	38701.19	37637.65	32344.33	32088.19	36860.41	42589.17	40404.22	36830.60	34034.01	32167.58	37209.25
Total Fixed cost	1318.10	3238.06	2122.22	2107.15	1756.74	2108.454	1110.51	2066.14	2470.33	2655.23	1717.12	2003.87
Total Cost	44372.87	41939.25	39759.87	34451.48	33844.93	38968.86	43699.67	42470.35	39300.92	36689.23	33884.69	39213.12

*Ranpur = R, Gaibandha = G, Lalmonirhat = L, Kurigram = K, Nilphamari = N

Table 5. Comparative Profitability of Binadhan-7 and BRRI dhan-33

Type	BIinadhan-7						BRRI dhan 33					
	R	G	L	K	N	Average	R	G	L	K	N	Average
Yield (kg ha^{-1})	5343.10	4288.20	4951.30	4283.33	4893.86	4751.96	4187.86	3942.93	4153.98	4351.81	3489.44	4025.20
Yield (tk ha^{-1})	104020.79	62697.47	88723.48	63195.83	68885.38	77504.59	60712.26	64735.42	63433	85711.22	57591.11	62436.60
By product (kg ha^{-1})	9272.21	7528.09	9295.65	9284.72	8548.98	8785.93	9334.83	8442.30	6844.44	5924.09	5888.89	7286.91
By product (tk ha^{-1})	18412.10	21376.40	18243.48	14156.25	17097.95	17857.24	21842.30	17155.56	13155.56	13444.22	14520.83	16423.69
Gross Return	122432.90	84073.87	106967.00	77352.08	85983.33	95361.83	82554.56	81890.98	76588.56	79155.40	72111.94	78460.29
Total variable cost	43054.78	38701.19	37637.65	32344.33	32088.19	36860.41	42589.17	40404.22	36830.60	34034.01	32167.58	37209.25
Total Cost	44372.87	41939.25	39759.87	34451.48	33844.93	38968.86	43699.67	42470.35	39300.92	36689.23	33884.69	39213.12
Gross Margin	79378.12	45372.68	69329.35	45007.75	53895.14	58501.42	39965.39	41486.76	39757.96	45121.39	39944.36	41255.17
Net Return (Tk ha^{-1})	78060.03	42134.62	76207.13	42900.60	52138.40	56392.97	38854.89	39420.63	37287.64	424466.17	38227.25	39247.04
Benefit cost ratio (Undiscounted)	2.76	2.00	2.69	2.25	2.54	2.45	1.90	1.93	1.95	2.16	2.12	2.00

*Ranpur = R, Gaibandha = G, Lalmonirhat = L, Kurigram = K, Nilphamari = N

The average yield of Binadhan-7 and BRRI dhan33 were 4751.96 kg (4.8 t ha^{-1}) and 4025.20 kg (4.0 t ha^{-1}) per hectare, i.e. the average yield of Binadhan-7 was higher than the average yield of BRRI dhan33. The average paddy price was Tk. 18 for Binadhan-7 and for BRRI dhan33 it was Tk. 16. As Binadhan-7 needs only 110 days for cultivation, farmers can sell their paddy and straw before other competitive variety; therefore they also get higher net return.

The per hectare net return was Tk. 56392.97 for Binadhan-7 and Tk. 39247.04 for BRRI dhan33 respectively. The highest net return (Tk.78060.03 ha^{-1}) comes from Rangpur district followed by Lalmonirhat (Tk. 67207.13 ha^{-1}), Nilphamari (Tk. 52138.40 ha^{-1}), Kurigram (Tk. 42900.60 ha^{-1}), and Gaibandha (Tk. 42135.62 ha^{-1}) for Binadhan-7. In case of BRRI dhan33 the highest net return comes from Kurigram (Tk. 42466.17 ha^{-1}) followed by Gaibandha (Tk. 39420 ha^{-1}), Rangpur (Tk. 38854.89 ha^{-1}), Nilphamari (Tk. 38227.25 ha^{-1}), and Lalmonirhat (Tk. 37287.64 ha^{-1}). The undiscounted benefit cost ratio over full cost basis was 2.45 and 2.00 for Binadhan-7 and BRRI dhan33 respectively (Table 5).

Constraints of Binadhan-7 and BRRI dhan33 cultivation

The respondent farmers were asked about the constraints of Binadhan-7 and BRRI dhan33 cultivation in the study areas. In this regard, more than one answered was given by the respondent. It was observed that non availability of seed at proper time was the first ranked constraint for Binadhan-7 cultivation but it was ranked five for BRRI dhan33 cultivation in Table 6. Infestation with insect and disease was the first ranked constraint for BRRI dhan33 cultivation and it was three for Binadhan-7 cultivation. On the other hand, non availability of seed at proper time was the first constraint for Binadhan-7 and five for BRRI dhan33 cultivation.

Table 6. Constraints of Binadhan-7 and BRRI dhan33 cultivation

Sl. No.	Constraints	Rank Value	
		Binadhan-7	BRRI dhan 33
1.	Non availability of seed at proper time	1	5
2.	Lack of technical knowledge about improved cultivation practices	2	3
3.	Infestation with insect and disease	3	1
4.	Lack of credit facilities	4	4
5.	Low market price	5	2

Conclusion

Binadhan-7 is early maturing variety than BRRI dhan33. Farmers can harvest 110-115 days which is earlier than BRRI dhan33 and can cultivate robi crops like mustard, potato, cabbage, etc. In short, we can say from the result that both of the varieties are profitable but Binadhan-7 is more profitable than BRRI dhan33 and plays a dominant role to ‘Monga’ mitigation in the northern part of Bangladesh.

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