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Development of short duration mungbean cultivars for cereal-based cropping systems in Bangladesh

M.M. Haque[1], A, Hamid[1], M. A. Afzal[2], M.A. Bakr[2], M. Alimur Rahman[3], N.A. Mondal[4] , M.J. Ali[4], and A.Z. Sarker[5]

[1]Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur 1706; [2]Pulses Research Center, Bangladesh Agricultural Research Institute, Joydebpur Gazipur 1701; [3]Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Rahmatpur, Barisal; [4]Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jessore; [5]Wheat Research Center, Dinajpur, Bangladesh

Abstract

Two experiments were conducted in two growing seasons to develop short duration mungbean cultivar for rice-based cropping systems. In the first experiment, 48 mungbean genotypes were evaluated in *Kharif* I season, 2002 to characterize and explore the promising entries. Genotypes with shorter maturity duration (as low as 43 days), larger number of pods per plant (36.8), bolder seeds (78.84 mg), and resistance to MYMV were screened. Genotypes varied widely in seed yield, several entries had a yield potential over 1,500 kg ha^{-1}. The second experiment was conducted at four different locations using four genotypes selected from the first experiment to compare their performance with three standard varieties during *Kharif* I, 2003. All the four genotypes performed well in all the locations but some of the entries performed better in specific locations. The line IPK-1040-94 yielded the best (1,456 kg ha^{-1}) having the shortest field duration.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse crop in Bangladesh that is grown mostly in rotation with cereals such as rice and wheat. It is principally cultivated for human consumption for its edible seeds which are high in protein. Its straw is also used as livestock feed. Further, cultivation of mungbean improves soil productivity (Agboola and Fayemi, 1972). In Bangladesh, most of the mungbean area (~65%) is located in the southern part of the country where mungbean is fitted in T. aman rice – mungbean – Fallow or Aus rice – T. Aman rice – mungbean cropping systems.

The common varieties of mungbean used in the cropping systems are low-yielding (about 600 kg ha^{-1}), small seeded, longer duration with non-synchronous maturity and susceptible to Mungbean Yellow Mosaic Virus (MYMV), *Cercospora* leaf spot (CLS), and powdery mildew (Sarker *et al.*, 1996). In recent years, however, cultivation of mungbean has been expanded to southwestern districts, mostly in rice-rice or rice-vegetables cropping systems. Possibility of growing mungbean in rice-rice or rice-wheat systems also exists in northern districts. However, expansion of mungbean cultivation in such non-traditional areas depends largely on its competitive ability with other crops (Hamid, 1996) as well as its adaptability over a wide range of environmental conditions (Popalghat *et al.*, 2001). Among the environmental factors, excess rain at the time of reproductive period causes enormous loss of both seed yield and seed quality of mungbean (Williams *et al.*, 1995). Long term climatic survey in Bangladesh (UNDP, 1988) suggests high probability of rainfall during the monsoon season synchronizing with flowering and pod development phases of mungbean if planted later than March after harvesting winter (or *Rabi*) crops. Therefore, development of short duration mungbean cultivars with synchronous pod maturity may be the best option to avoid excess rain and its consequential damages to mungbean. The present study was undertaken to evaluate mungbean germplasm for the development of short duration, high-yielding variety for cereal-based cropping system.

Materials and Methods

Two field experiments were carried out in successive mungbean growing seasons and at different agro-ecological regions of Bangladesh. The first experiment was conducted at the experimental farm of BSMR Agricultural University during *Kharif* II of 2002 with 48 mungbean genotypes. The mungbean genotypes were ML- 267, ML-613, CO-3, PUSA-9072, Basanti, VC-6153B20G, VC-6135B20P, VC-3960-A-89, VC-6173 B-6, NM-54, NIMB-101, VC-6960-88, PDM-11, SML-32, SML-134, PDM-54, VC-6368 (46-40-4), VC-6369 (53-97), VC-6173 B-10, IPK-1038-94, IPK 2558-97, IPK-1040-94, NM-94, GK-05, GK-07, GK-48, GK-65, VC-3945A, VC-1163 A, Vo 1982 A-G, GK- 06, GK-35, GK-36, IPK-2590-97, IPK-1074-94, VC-6173 B-11, VC- 6367 (44-55-2), VC-6173 A, VC-6371-94, VC-6141-96, BUmug 1, BUmug 2, BARImung 2, BARImung 5, BARImung 4, BINAmung 5 and Barisal local. The crop was sown on September 9, 2002. Each genotype was grown in six lines 4 m long row, 30 cm apart, with an interplant spacing of 10 cm. The crop was managed properly with appropriate dose of fertilizer and other cultural practices. Data were recorded on days to first flowering, days to maturity, pods plant^{-1}, seeds pod^{-1}, 1000 seed weight, grain yield, and resistance to MYMV.

The most promising four genotypes selected from the preceding experiment were used in the second experiment conducted in four regions of Bangladesh during *Kharif* I of 2003. The selected genotypes were IPK- 1038-94, IPK- 2558-97, IPK- 1040-94, and VC6173-B-10. The selected genotypes were compared with three popular varieties, viz. BUmug 1, BARImung 5, and BINAmung 5 released by Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Research Institute (BARI), and Bangladesh Institute of Nuclear Agriculture (BINA), respectively. The four locations were Regional Agricultural Research Station in Barisal, Regional Agricultural Research Station in Jessore, Wheat Research Center in Dinajpur, and Bangabandhu Sheikh Mujibur Rahman Agricultural University in Gazipur. In each location, genotypes were planted using a randomized complete block design with four replications. Each unit plot had six rows of mungbean planted 30 cm apart. Row length was 4 m with plant to plant distance of 10 cm in all the locations. Fertilizer application, irrigation, weeding, and pest control measures were taken as needed. At maturity, the grain yield was determined by harvesting the plants from middle four rows after leaving two rows as border. The grain yield of mungbean was adjusted at 12 % moisture content. From each plot, ten plants were selected randomly to determine yield attributes. Data on seed yield and yield components were subjected to analysis of variance and means were compared by least significant difference test.

Results and Discussion

Characterization of germplasm presents opportunity to identify genotypes suited for adaptation and commercial production or to use as parent materials in breeding research. The variation in the agronomic characters of 48 mungbean genotypes used in the experiment is given in Table 1. The genotypes differed in days to flowering and days to pod maturity by 10 - 12 days. Similarly, differences were observed for the number of pods per plant, seed size, and seed yield. Among the agronomic characters, reducing maturity duration by 10-12 days will enable the crop to fit well in many cropping systems, accommodating winter (*Rabi*) crops and helping avoid hazards like rain damage to yield and quality of mungbean. Pods per plant is a useful agronomic character contributing to higher yield in grain legumes (Islam, 1983). In the present study, pods per plant of mungbean genotypes varied from 11.2 to 36.8 and such variability may be utilized in yield improvement programs. There was significantly positive correlation between the number of pods per plant and yield per plant (Figure 1). Such interrelationship in mungbean was also reported by Giriraj and Kumar (1974). There was also wide variation among the genotypes in seed size that ranged between 31.75 and 78.84 mg suggesting a good source of yield improvement of mungbean. The yield of mungbean is the function of pods per plant, seeds per pod, and seed size (Nag *et al.*, 2000). Larger seed size is considered to be a major contributor to higher yield in modern mungbean.

Table 1. Variability in agronomic characters of 48 mungbean genotypes

Agronomic character	Minimum	Maximum	Mean	Range	Standard Deviation
Days to flowering	23.0	33.0	28.7	10.0	2.2
Days to maturity	43.0	54.0	48.7	11.0	2.6
Pods plant^{-1} (no.)	11.0	36.8	19.4	25.6	6.8
Seeds pod^{-1} (no.)	9.9	13.3	11.6	3.4	0.9
1000 Seed weight (g)	31.8	78.8	48.6	47.1	10.9
Yield (g plant^{-1})	0.5	6.6	4.1	6.1	1.2

The yield of mungbean per plant, however, does not always reflect to its yield in plant community. The yield of plants in community depends largely on crops canopy structure (Hamid *et al.*, 1990). Canopy structure of crop in community is modified by different growing conditions which in turn regulates the efficiency of light utilization in crop productivity (Gifford, *et al.*, 1984). Figure 2 illustrates the frequency distribution of seed yield of 48 mungbean genotypes that ranged from 128 to 1,589 kg ha^{-1}.

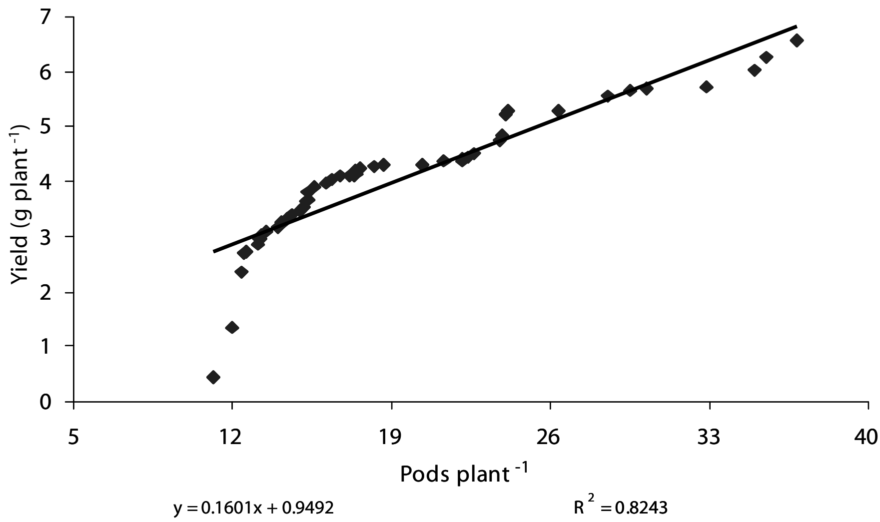

Figure 1. Relationship between pods plant^{-1} and yield plant^{-1} on mungbean genotypes

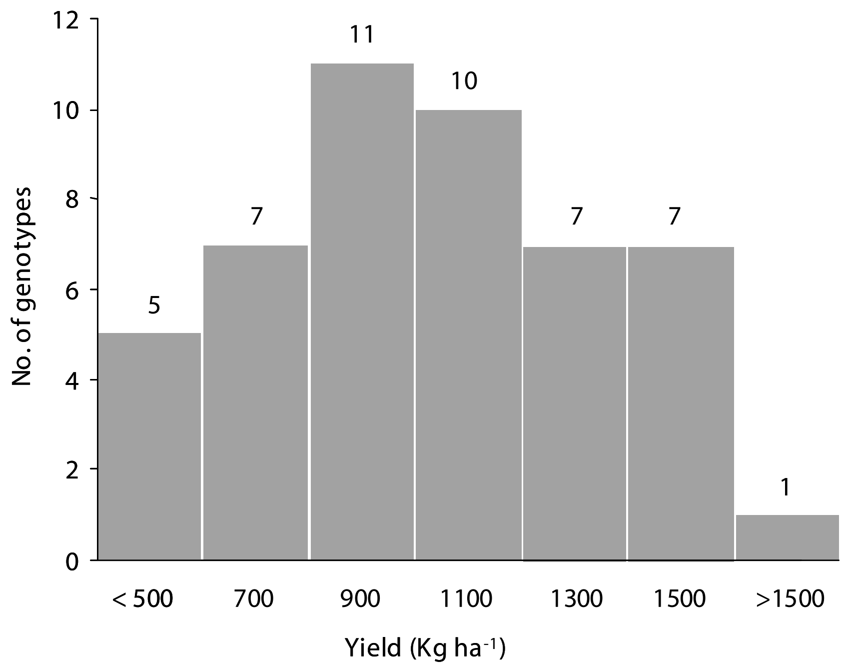

Figure 2. Frequency distribution of seed yield of 48 mungbean genotypes

One of the major constraints in improving or sustaining mungbean yield and production in the South Asian region is the widespread incidence of MYMV (Green *et al.*, 1996). Modern varieties adaptable under Bangladesh conditions need to be resistant/tolerant to MYMV. In the present experiment, incidence of MYMV disease was scored on a 0-9 scale (Malik, 1991) based on visual symptoms. MYMV score of 0 (zero) means the plant is free from the disease, 1 - highly resistant, 3 - moderately resistant, 5 - moderately susceptible, 7 - susceptible, and 9 - highly susceptible. Majority of the genotypes had a high degree of resistance to MYMV. One genotype remained free from disease infection throughout the growing season.

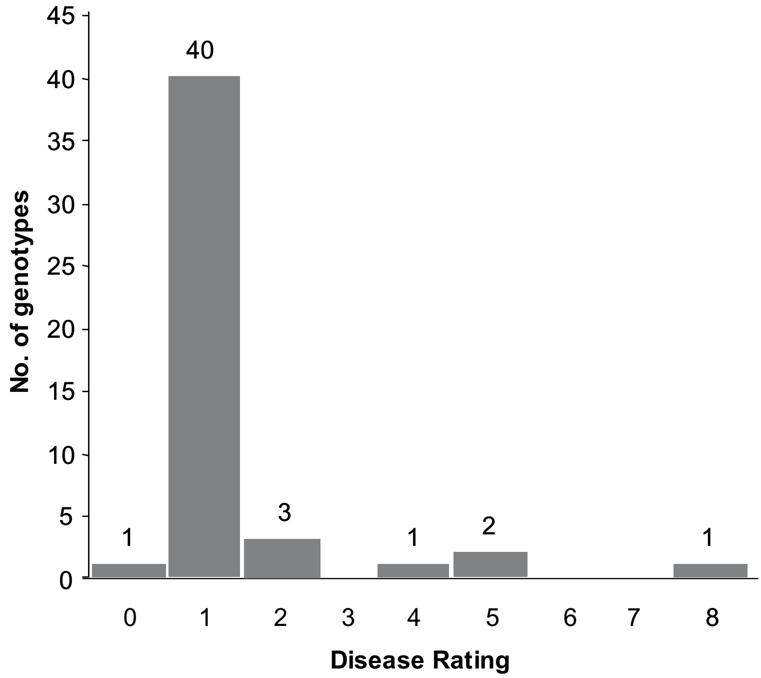

Figure 3. Frequency distribution for visual MYMV disease score

The four promising mungbean genotypes selected from an earlier study were evaluated in four regions of Bangladesh. Planting time and environmental conditions during the mungbean growing seasons across locations differed appreciably. Mungbean was planted earlier in Barisal and latest in Dinajpur. Table 2 shows the mean genotypic differences in mungbean seed yield at four locations. Genotype IPK 1040-94 produced consistently higher yield than other varieties/genotypes in all the four locations. Averaged over the genotypes, significantly higher yield was obtained in Jessore while the lowest yield was obtained in Dinajpur. The interaction effect of genotype x environment on yield or yield attributes was not statistically significant suggesting that none of the genotypes has specific adaptation for any location. All the genotypes were found to have wider adaptability.

Table 2. Mean yield of mungbean genotypes grown at four different locations

Mungbean genotype	Yield (kg ha^{-1})			
	Jessore	Barisal	Gazipur	Dinajpur
IPK1038–94	1751	1431	1206	530
IPK2558–97	1751	1476	1338	517
IPK1040–94	1893	1646	1517	769
VC6173 B–10	1565	1050	1297	609
BUmug 1	1679	1361	1431	854
BARImung 5	1565	1382	1352	90
BINAmung 5	1486	1349	1121	701
LSD $_{(0.05)}$	245	222	317	207
CV (%)	9.60	11.3	15.42	14.95

It was apparent that productivity of mungbean was better in the Jessore region than other locations. Adequate rainfall and better soil conditions might have favored a good stand of the crop in Jessore. In contrast, when planted after March in Dinajpur, high rainfall caused damage to flowering and pod-filling, and encouraged vegetative growth of mungbean resulting in poor seed yield (Williams, 1995). Seed size of IPK 1040-94 was 59.2 mg (Table 3) which was much larger than that of other genotypes. Larger seed size alone might have enhanced seed yield of IPK 1040-94. The genotypes IPK-1040-94 also flowered and matured earlier than the other genotypes. Our results are in agreement with Sandhu *et al.*, (1988) who observed that early maturing genotypes had bolder seeds compared to late flowering ones.

Table 3. Phenology, yield attributes, and yield of promising mungbean lines

Line/variety	Days to flowering	Days to maturity	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seed weight (g)	Yield (kg ha^{-1})
IPK-1038-94	30	45	20.62	10.26	49.0	1229
IPK –2558-97	31	45	20.48	10.53	48.1	1270
IPK-1040-94	29	43	20.15	9.76	59.2	1456
VC6173-B-10	30	44	18.36	10.39	55.3	1130
BUmug 1	30	44	18.72	10.29	53.3	1332
BARImung 5	30	44	20.98	10.7	43.63	1272
BINAmung 5	30	44	20.83	10.13	43.5	1164
LSD $_{(0.05)}$	0.8	1.0	NS	NS	2.7	130.1
CV (%)	3.95	3.22	16.05	9.41	7.71	14.62

NS not significant at 5% level.

Since IPK 1040-94 is high-yielding, widely adaptable, and with high degree of resistance to MYMV, it may be released for commercial cultivation in cereal-based cropping system of Bangladesh.

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Research on agronomic practices for mungbean in rice-based cropping systems in Bangladesh

A. Hamid[1], M.M. Haque[1], N.A. Mondal[2], M. Alimur Rahman[3], and A.Z. Sarker[4]

[1]Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur 1706; [2]Regional Station, Bangladesh Agricultural Research Institute, Jessore; [3]Regional Station, Bangladesh Agricultural Research Institute, Rahmatpur, Barisal; and [4]Wheat Research Center, Bangladesh Agricultural Research Institute, Dinajpur, Bangladesh

Abstract

To develop a package of agronomic practices for mungbean in different cropping systems with the aim of increasing mungbean yield under variable agro climatic conditions, a set of experiments was conducted at four locations in Bangladesh. Variables included in the experiments were varieties, sowing time, planting density, planting arrangement, seed priming, and fertilizer rates. BARImung 2, BARImung 5, BUmug 1 and BUmug 2 were tested; but all the varieties were not planted in all locations. Sowing time was different for different locations. For Barisal, sowing date was 15 February; for Jessore, 26 March; and for Dinajpur, 20 March. BUmug 1 at Barisal and BUmug 2 at Jessore outyielded other varieties. Planting on 15 February at Barisal, and in March or April at Jessore and Dinajpur produced higher yield. Late planting generally reduced mungbean seed yield; but the reduction was less in BUmug 1 and BUmug 2. Varieties differed significantly in the effect of planting arrangement on mungbean yield. BUmug 2 produced the highest yield at 30 cm x 5 cm and BARImung 2 at 20 cm x 10 cm planting configurations. Seed priming enhanced mungbean yield at Barisal but did not have any yield advantage over non-priming at Jessore and Dinajpur. Primed seeds planted under conventional tillage and non-primed seeds dibbled under no-tillage conditions produced higher yield. Priming of aged seeds also improved plant stand and increased seed yield in mungbean. Mungbean did not respond to applied N fertilizer but application of P fertilizer had pronounced influence on seed yield.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is an important and integral component of cereal-based cropping systems in South and South-Western districts of Bangladesh. The crop is important for both human food nutrition and enrichment of soil fertility (Norman *et al*., 1984). Bangladesh has a rice-based farming system, where the major cropping system consists of two crops of rice. More than 61% of total cropped land is devoted to two to three crops of mono-crop rice or rice and wheat in sequence. Intensive production systems present a severe problem of land degradation and reduced system productivity (Zia *et al*., 1992).

In general, productivity of legumes is very low compared with cereals (Rachie and Roberts, 1974). Yield of legumes in farmers' fields is usually less than 1 t ha^{-1} against the potential yield of 2 to 4 t ha^{-1} (Ramakrishna *et al*., 2000), suggesting a large yield gap. Much of the yield gap may be narrowed down by adopting improved agronomic practices at farm level. Therefore, a set of experiments was conducted at different agro-ecological regions of Bangladesh to develop standard package of agronomic practices for mungbean to increase its productivity in rice-based cropping systems.

Materials and Methods

The experiments were conducted during successive growing seasons in 2003 in different agro-climatic zones of Bangladesh. The experimental variables included were varieties, sowing time, population density, planting arrangement, seed priming, and fertilizer requirement of mungbean. Sowing time of mungbean differs widely depending on the agro-climatic conditions in different locations. Because of its short duration mungbean fits well in a wide range of cropping systems. Hence, the time of harvest of the preceding crop has a large bearing on the planting time of mungbean. The varietal performance differs a great deal depending on location and sowing time. Three varieties, viz. BUmug 1, BARImung 4, and BARImung 5, were planted on three dates - February 1, February 15, and March 2 of 2003 in Barisal region. Four varieties, viz. BARImung 2, BARImung 5, BUmug 1 and BUmug 2 were sown on March 26, April 6, and April 16 at Jessore; and on March 20, April 1, and April 11 at Dinajpur. A RCB factorial design was used.

In a separate experiment, mungbean was grown at four population densities in two planting configurations (30 cm x 10 cm and 30 cm x 5 cm) and by broadcast seeding at 30 kg ha^{-1} and 40 kg ha^{-1}. Seeds were sown at four different times - January 30, February 10, February 20, and March 2. The experiment was conducted at the Regional Agricultural Research Station in Rahmatpur, Barisal. The effect of planting arrangement on the yield of two mungbean varieties was evaluated.

Another experiment was conducted at the Wheat Research Center in Dinajpur where BUmug 2 and BARImung 2 were planted at 20 cm x 10 cm, 30 cm x 5 cm, and 30 cm x 10 cm configurations. Some were also planted through broadcast sowing.

Seed priming effect on the productivity of mungbean was evaluated under different tillage and planting systems. The priming conditions were: (i) no priming and (ii) priming by soaking seeds in water for 8 hrs. The tillage systems were (i) no tillage, (ii) dibbling, and (iii) conventional tillage. The experiment was arranged in a RCB factorial design and conducted at Rahmatpur, Barisal. In a separate experiment, mungbean seeds were broadcast at two seeding rates - 30 kg ha^{-1}, 40 kg ha^{-1}, and planted at two planting configurations (30 cm x 10 cm and 30 cm x 5 cm). All four treatments were superimposed over no-priming (control) and priming (by 8 hrs soaking). The effect of priming on aged mungbean seed was also evaluated in a separate study conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural Experiment Farm. Response of nitrogen and phosphorus fertilizers on the yield of mungbean was determined both at two locations (Jessore and Dinajpur) with N levels of 0, 20, 40 and 60 kg ha^{-1} and the P levels of 0, 30, 60 and 90 kg P_2O_5 ha^{-1}.

In all the experiments, crop was managed properly by doing the necessary cultural practice. Adequate measures were also taken to protect the crop from pests and diseases. During harvest, yield and yield attributing characters were recorded. All data were subjected to analysis of variance and the means were compared by either LSD test or by DMRT (Gomez and Gomez, 1984).

Results and Discussion

Effect of sowing time

Influence of sowing time on the yield of mungbean was evaluated in the three locations. Pronounced effect of sowing time on yield and yield attributes was observed in all three locations. Varieties also differed significantly in yield (Table 1). But the interaction between sowing time and varieties on mungbean was not significant. Varieties BUmug 1 gave higher yield than BARImung 5 (Table 1).

Irrespective of genotypic differences, planting on February 15 produced the highest (1,733 kg ha^{-1}) seed yield but was not significantly different from that obtained from the March 2 planting. Mungbean planted earlier performed poorly mainly because of uneven germination and, consequently, poor plant stand. In contrast, timely and adequate amount of rainfall helped establish the later-sown crop that eventually resulted in better yield. Sufficient soil moisture also favored prolonged growth and repeated flushes of flowering that increased the number of pod pickings which enhanced the grain yield.

Table 1. Yield and yield attributes of mungbean varieties at different sowing times in Barisal

Treatment	Population (m^{-2})	Plant height (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	Seed size (mg)	Yield (kg ha^{-1})
Variety						
BUmug 1	39.84	57.89	24.27	10.77	48.57	1717
BARImung 4	40.82	60.56	28.8	10.41	32.57	1541
BARImung 5	45.76	56.51	25.42	11.08	38.70	1306
LSD	NS	NS	NS	NS	3.92	260
Sowing times						
1 Feb	36.75	47.82	31.51	11.12	41.94	1270
15 Feb	42.18	58.39	25.24	10.80	40.63	1733
2 Mar	47.48	68.76	21.73	10.33	37.26	1562
$LSD_{(0.05)}$	6.48	6.00	4.18	NS	NS	260
CV (%)	15.41	10.31	16.00	29.90	9.82	17.08

NS= significant at 5% level.

In the Jessore region, mungbean is generally sown after the harvest of winter crops and therefore, the experiment was started one month later compared to Barisal. Four varieties namely BARImung 2, BARImung 5, BUmug 1 and BUmug 2 were sown on March 26, April 6, and April 16 of 2003. Varieties and sowing times interacted significantly on the yield of mungbean. Unlike in Barisal region, planting in March or early April (April 6) in Jessore produced significantly higher yield of mungbean than the crop planted later (Table 2). The cultivar BUmug 2, sown on April 6, produced consistently higher yield in all plantings compared with the other three cultivars. BUmug 1 and BARImung 5 also produced high yields when planted on March 26. However, planting of mungbean later than April 6 generally tended to give lower yield. Both BUmug 2 and BARImung 5 registered high yield when planted on April 16.

Table 2. Varieties and planting time effects on the yield (kg ha^{-1}) of Mungbean at Jessore

Planting time	Variety			
	BARImung 2	BARImung 5	BUmug 1	BUmug 2
26 March	1078 c	1320 b	1296 b	1983 a
6 April	1019 d	1467 b	1196 c	2003 a
16 April	665 d	1137 b	943 c	1255 a

Means in rows with same letter are not significantly different at 0.05 level of significance. LSD value for column is 112.

At Dinajpur, mungbean was planted after the harvest of winter wheat in rice-wheat cropping system. The same set of varieties, i.e. BARImung 2, BARImung 5, BUmug 1 and BUmug 2, used in Jessore was planted in Dinajpur but the planting time differed. The experiment was planted on March 20, April 1, and April 11, 2003. Varieties differed a little but the sowing time influenced significantly on the yield performance of mungbean. However, irrespective of treatment differences, mungbean yield was generally low. It was highest (1,082 kg ha^{-1}) when planted on March 20. Planting at later dates reduced the yield drastically. When planted on March 20, mungbean plants had higher number of pods (Table 3). On the contrary, number of pods per plant was much less in late-sown plants which might be attributed to lower number pod droppings due to excessive rainfall during the flowering phase. Variety x planting time interaction was insignificant.

Table 3. Yield attributes and yield of mungbean cultivars planted at different times at Dinajpur during *Kharif* I season of 2003

Planting time	Days to first flowering (days)	Days to first pod maturity (days)	Plants m^{-2}	Plant height (cm)	Pods $plant^{-1}$	Seeds pod^{-1}	Seed size (mg)	Yield (kg ha^{-1})
March 20	27.42	48.08	32.50	43.31	17.99	9.80	39.95	1082
April 1	30.25	44.83	32.50	47.08	13.66	10.33	39.53	528
April 11	26.67	44.42	31.67	41.36	14.28	9.93	41.70	573
$LSD_{(0.05)}$	1.07	1.49	NS	2.83	1.25	NS	NS	174
CV (%)	4.50	3.85	6.23	7.62	9.62	7.82	10.02	28.27

NS not significant at 5% level.

Effect of planting density

Maintaining optimum population density has been critical for higher yield in mungbean. Crop stand and crop productivity further depend on interactive effect of population density and sowing time. Since the yield of legumes differs profoundly to varying densities (Nienhuis and Singh, 1985), it is important to determine optimum density for yield enhancement. The present experiment was conducted at the Regional Agricultural Research Station, Rahmatpur, Barisal to evaluate the effect of sowing time and population density on the productivity of mungbean. Mungbean variety BARImung 5 was sown on January 30, February 10, February 20, and March 2, 2003, each batch with plant spacing of 30 cm x 10 cm, 30 cm x 5 cm, and at seed rates of 30 kg ha^{-1} and 40 kg ha^{-1}. Sowing time and population density interacted significantly on the yield of BARImung 5. The result presented in Table 4 revealed that BARImung 5 seeds broadcast at the rate of 40 kg ha^{-1} produced the highest yield (2,028 kg ha^{-1}) in January 30 sowing. Mungbean planted in rows on March 2 at 30 cm x 10 cm and 30 cm x 5 cm configurations produced better seed yield compared with that of other planting arrangements. Mungbean broadcast at 30 kg or 40 kg ha^{-1}on February 20 had opposite results. However, broadcast sowing using a seed rate of 30 instead of 40 kg ha^{-1} would be cost effective.

Table 4. Yield (kg ha^{-1}) performance of mungbean at different sowing times and population densities during late winter season of 2003 at Barisal

Sowing time	Population density			
	30 cm x 10 cm	30 cm x 5 cm	30 kg ha^{-1}	40 kg ha^{-1}
30 January	1985.63 Aa	1738.18 Ab	1964.50 Aa	2027.87 Aa
10 February	1551.08 Ab	1563.15 A	1261.38 Cb	1267.42 Cb
20 February	1312.68 Cb	1080.33 Cc	1907.17 Aa	1834.74 Ba
2 March	1502.80 Ab	1786.46 Aa	1376.06 Bb	1279.49 Cb

Means in column with same letter (capital) and in rows (small) are not significantly different at 0.05 by DMRT.

Effect of planting arrangement

In Bangladesh, mungbean is generally broadcast although some progressive farmers follow line sowing method. Planting arrangement contributes remarkably in yield enhancement of legumes (James *et al.*, 1996). This is particularly true if the cultivars differ in their morphological characters. Cultivars having lesser branching have greater yield increase in narrow compared with wide rows than do cultivars with profuse branching. Line sowing of mungbean is advocated to reduce seed rate and for better crop management. In this experiment, two mungbean varieties, viz. BUmug 2 and BARImung 2, were sown at Dinajpur in rows at 20 cm x 10 cm, 30 cm x 5 cm, 30 x 10 cm configurations and compared with broadcast method. The experiment was laid out in a randomized complete block design. Each treatment was replicated three times. The crop was harvested at maturity and yield was recorded adjusting at 12% moisture content. The data were subjected to statistical analysis and LSD test was employed to compare the means.

The interaction between varieties and planting method was not statistically significant. The results presented in Figure 1 show that the two varieties differed considerably in producing seed yield at different planting arrangements. BUmug 2 produced the highest yield at 30 cm x 5 cm spacing while optimum planting configuration for BARImung 2 was found to be 20 cm x 10 cm suggesting that BUmug 2 needed a bit closer spacing than that of BARImung 2. BARImung 2 also performed well under broadcast sowing.

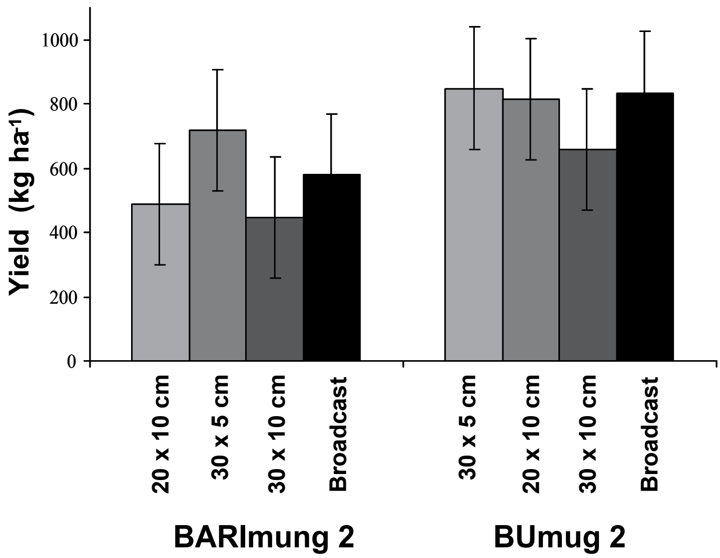

Figure 1. Planting arrangement effects on the yield of two mungbean varieties. (Bar indicates LSD value at 0.05 level of significance)

Effect of seed priming

Seed priming improves seed germination and increases competitive ability of the seedlings, promotes plant and root growth, and increases crop survival under water stress conditions (Musa *et al.*, 2001; Harris *et al.*, 1999; Rashid *et al.*, 2002). The benefit of seed priming, however, depends on the type of crops, growing condition, and physical environment of the soil. In our study, we observed the effect of seed priming on the productivity of mungbean under different tillage conditions and planting systems at three different agro-ecological regions of Bangladesh. In Gazipur, the response of aged mungbean seeds subjected to different degrees of seed priming was also evaluated.

Seed priming did not bring any yield advantage in mungbean over non-priming in Jessore and Dinajpur where wheat was the preceding crop. Frequent rain or irrigation prior to wheat harvest and after the planting of mungbean seeds might have maintained an optimal soil moisture that offset the benefits of seed priming. But in Barisal, seed priming significantly influenced the yield of mungbean grown after the harvest of wetland rice.

In Barisal, mungbean seeds were primed for eight hours, and both primed and non-primed seeds were sown under no tillage, dibbling, and conventional tillage conditions. Mungbean was planted on well-prepared land. The soil is mostly heavy clay and moisture on the top soil was almost lost during land preparation. The results presented in Table 5 indicate that planting primed seeds using conventional tillage produced the highest seed yield. However, non-primed seeds planted by dibbling gave statistically similar yield with seeds primed for 8h planted using conventional tillage.

Table 5. Seed priming and tillage effect on the yield of mungbean

Priming	Tillage	Pods plant^{-1}	Pod length (cm)	Seeds pod^{-1}	1000-grain weight (g)	Yield (kg ha^{-1})
8 hours priming	No tillage	20.20	16.26	10.43	43.13	647
	Dibbling	14.93	16.03	10.77	43.10	737
	Conv. tillage	21.13	17.03	12.00	46.17	1,095
No priming	No tillage	18.13	16.09	10.77	42.50	620
	Dibbling	18.13	16.81	11.77	43.00	807
	Conv. tillage	21.87	17.76	10.67	49.20	775
$LSD_{(0.05)}$		2.22	NS	0.90	NS	201
CV (%)		6.39	5.03	4.47	8.17	14.2

NS not significant at 5% level.

The effect of seed priming is statistically significant only if planting system of 30 cm x 10 cm is used. It is also clear that with priming, 30 cm x 10 cm has statistically significant advantage over other planting arrangement. Without priming, the planting systems 30 cm x 10 cm and 40 kg ha^{-1} gave comparable yields (Table 6).

Table 6. Seed priming and planting system effects on mungbean yield

Planting system	Yield t ha^{-1}		Difference
	0 hr priming	8 hr priming	(8 hr-0 hr)
30 cm x 10 cm	1,660 a	2,318 a	658**
30 cm x 5 cm	1,265 b	1,562 b	297 ^{NS}
40 kg ha^{-1}	1,605 a	1,636 b	31 ^{NS}
30 kg ha^{-1}	1,265 b	1,420 b	155 ^{NS}

In a colum, means followed by letter are not significantly different at 5% level.

Whether seed priming could improve the quality of aged mungbean seeds was evaluated in a separate experiment conducted at BSMRAU, Gazipur. Seeds of two mungbean varieties, viz. BARImung 2 and BUmug 2, were aged and kept at 42^{O}C with 100% relative humidity for three days. Both aged and non-aged seeds were primed for 0, 4, and 8 hours. The experiment was laid out in a factorial design.

Each treatment was replicated three times. At maturity, the pods were harvested and yield data were recorded. Statistical analysis was performed to compare the means. Interaction between variety and ageing level or varieties, ageing and primary duration on yield and yield attributes were not statistically significant. Table 7 shows that irrespective of seed priming effect, BARImung 2 performed better than that of BUmug 2 in terms of yield. Although BUmug 2 is bold seeded with higher yield potential, prolonged growth duration of BARImung 2 allowed several harvests. Longer growth duration also resulted in larger number of pods per plant of BARImung 2 that eventually raised grain yield. Table 7 also shows superiority of non-aged seeds over the aged seeds and priming could improve the stand establishment and yield of mungbean. Seed priming for four hours increased the yield of mungbean by nearly 11%. Further increase in the duration of priming caused reduction in the grain yield. Improvement of seed germination and stand establishment by priming the aged seeds was also reported by Park *et al.* (1998).

Table 7. Yield and yield attributes of mungbean with and without aging and at different priming levels

Treatment	Population m^{-2}	Pods $plant^{-1}$	Seeds pod^{-1}	Seed size (mg)	Seed yield (kg ha^{-1})
Variety					
BARImung 2	25.72	23.96	9.99	33.11	1599.28
BUmug 2	26.2	11.72	9.79	58.96	1332.83
F test	NS	**	NS	**	**
Aging level					
Normal seed	27.00	18.40	9.93	45.83	1545.89
Aged seed	24.94	17.29	9.86	46.25	1386.22
F test	*	NS	NS	NS	**
Priming duration					
0 hour	25.83	17.58	9.79	46.06	1430.50
4 hour	27.41	19.05	10.08	46.00	1585.42
8 hour	24.67	16.89	9.81	46.06	1382.25
F test	*	NS	NS	NS	**
CV (%)	8.60	14.11	5.07	2.40	9.05

* significant at 1% level, ** significant at 5% level, NS not significant at 5% level.

Effect of Nutrition

Nitrogen and phosphorus are two major elements required for mungbean production. Although mungbean can fix atmospheric nitrogen, a good mungbean crop with high yield potential requires addition of N fertilizer. Moreover, most soils are deficient in nitrogen. Likewise, in many soils, level of available phosphorus is poor. The amount of nutrients to be added to realize a good yield depends largely on nutrient status of the soil and presence of biological nitrogen fixing bacteria. The present experiment was conducted in Jessore and Dinajpur to determine the nitrogen and phosphorus fertilizer requirement for higher yield of mungbean. In Jessore, addition of neither nitrogen nor phosphorus influenced significantly on the yield of mungbean. In Dinajpur, response of mungbean to nitrogen fertilizer was not statistically significant but phosphorus fertilizer enhanced the yield of mungbean significantly. Figure 2 shows that application of 60 kg P_2O_5 ha^{-1} increased mungbean yield by about 56% over control although further increase of P fertilizer dose tended to decrease yield. Our earlier experiments at Dinajpur indicated poor yield performance of mungbean. Inclusion of a legume crop in cereal-cereal cropping systems is advocated in order to avoid further soil degradation. To promote mungbean production in Dinajpur region, it is therefore necessary to determine the nutrient status of the soil and response of mungbean to phosphorous specifically.

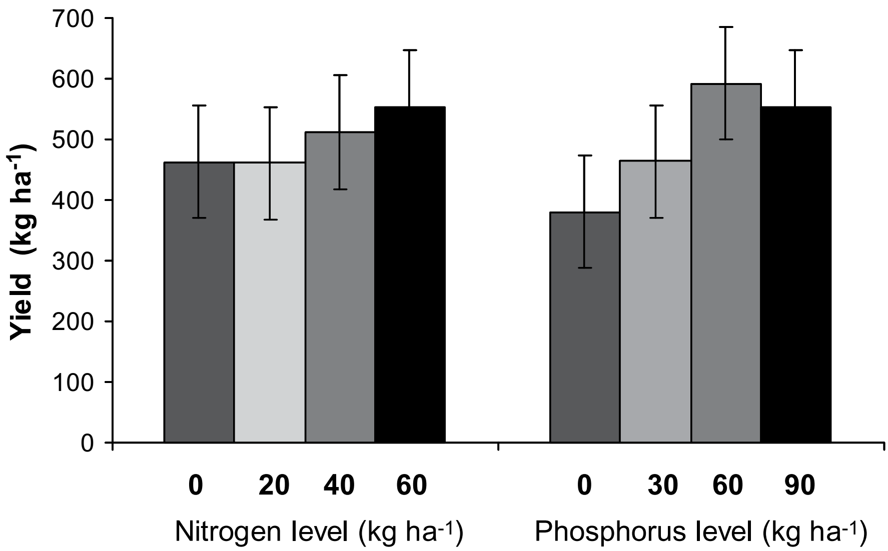

Figure 2. Effect of nitrogen and phosphorus fertilizer on the yield of mungbean (Bar indicates LSD value at 0.05 level of significance)

From the results it was observed that improved agronomic practices may narrow the yield gap, thus enhancing mungbean yield. The yield of mungbean may be increased further by adopting the other important agronomic practices such as soil amendment, weeding, irrigation, and effective pest control.

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The effect of incorporation of mungbean residue on the productivity of rice

A. Hamid[1], M.M. Haque[1], N.A. Mondal[2], A.Z. Sarker[3], and M.S. Aktar[4]

[1]Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur 1706; [2]Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Jessore; [3]Wheat Research Station, Bangladesh Agricultural Research Institute, Dinajpur; and [4]Pulse Research Station, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur 1701, Bangladesh

Abstract

Field experiments were conducted at Jessore and Dinajpur representing two diverse agro-climatic conditions of Bangladesh to evaluate effect of incorporating mungbean residue on the following rice crop in cereal-cereal-legume cropping system. In the system, mungbean was planted after the harvest of wheat. Mungbean pods were harvested by hand pickings and stubbles were plowed down and mixed with the soil before starting the next rice crop. Mungbean biomass was mixed with the soil. Aman rice seedlings (cv. BR 11 in Jessore and BRRIdhan 39 in Dinajpur) were transplanted after the harvest of mungbean. The amount of mungbean stubbles plowed down varied between 2.24 and 2.36 t ha^{-1} in Jessore and 2.70 and 2.86 t ha^{-1} in Dinajpur. In both Dinajpur and Jessore, rice crop received 0, 25, 50, 75 and 100% of the recommended fertilizer level with and without addition of mungbean residue. Benefit of incorporating mungbean stubbles on the growth and productivity of the succeeding rice crop varied greatly between the locations. In Jessore, growing mungbean in rice-wheat system generally tended to increase yield of rice compared to that of rice-wheat system although the difference was not statistically significant. In Dinajpur, application of 75% of recommended N plus mungbean biomass produced the highest yield of rice (4.58 t ha^{-1}). However,integrating mungbean biomass without N fertilizer application resulted in the lowest yield (3.42 t ha^{-1}) of rice. Therefore, both organic and inorganic sources of N are essential in sustaining the yield of modern rice in a multicrop system especially in soils with low fertility.

Introduction

Bangladesh has a rice-based farming system although the climatic and edaphic conditions support a wide range of production options. The major cropping pattern in Bangladesh consists of two crops of rice (i.e. winter rice–fallow–summer rice) covering 1.8 million ha. Three rice crops in sequence per year is also commonly practiced. Wheat-rice-fallow and wheat-fallow-rice patterns combined account for about 0.44 million ha. Currently, more than 61% of total cropped land is devoted to two to three crops of monocrop rice or rice and wheat in sequence. Growing food demand that parallels population growth called for such intensive cropping systems.

Intensive production systems present a severe problem of land degradation. System productivity stagnation, nutrient and water imbalance, and increased pest and disease incidence in the continuous rice-rice or rice-wheat rotations are apparent and widespread. The ameliorating effect of adding in legumes in such continuous cereal cropping systems has long been known but, because of low-yield potential, area under legumes has generally declined over time. With the introduction of new high-yielding short duration mungbean, cereal-legume system can be revived.

The productivity of rice–wheat system can be sustained partly by inclusion of legumes in the existing cropping systems. Adding of legumes in cereal based cropping system can improve soil structure, improve nutrient exchange, and can maintain healthy sustainable soil system (Becker *et al.*, 1995). The objective of the present study was to evaluate the impact of incorporating mungbean residue on the productivity of rice in a rice–wheat–mungbean cropping system.

Materials and Methods

The experiment was conducted at the Regional Agricultural Research Station in Jessore and Wheat Research Center in Dinajpur. In wheat–rice–mungbean cropping system, wheat and mungbean were grown with recommended fertilizer (RF), while rice was grown after incorporating the biomass of harvested mungbean, plus different levels of nitrogen fertilizer. The treatments were designed to be able to quantify the amount of nitrogen to be saved in rice cultivation due to inclusion of mungbean in cereal-based cropping system. The treatment variables were T_1: Rice (RF) – Wheat (RF) – Fallow, T_2: Rice (RF) – Wheat (RF) – Mungbean (RF), T_3: Rice (75% RF) – Wheat (RF) – Mungbean (RF), T_4: Rice (50% RF) – Wheat (RF) – Mungbean (RF), T_5: Rice (25% RF) – Wheat (RF) – Mungbean (RF), and T_6: Rice (0% RF) – Wheat (RF) – Mungbean (RF). Recommended rates of fertilizer were: (1) for rice 80 – 60 – 40 – 20 – 5 kg N P K S B ha^{-1}, (2) for wheat 100 – 60 – 50 – 20 – 2 kg ha^{-1} N P K S B ha^{-1}, and (3) for mungbean 40 – 60 – 40 – 20 – 10 – 5 – 2 – 0.5 kg N P K S Mg Zn B Mo ha^{-1}.

After the harvest of wheat mungbean was planted on March 29, 2003 in Jessore and on April 6, 2003 in Dinajpur. Variety BUmug 1 was planted in both locations. Pods were harvested at maturity and, immediately after the final harvest, the stubbles of mungbean were plowed down. Before incorporation into the soil the plants were sampled stubbles were measured, and the probable amount of N they could release was estimated. Nitrogen added by mungbean biomass was calculated by multiplying dry matter yield by percent of N content. The experimental plots were not dismantled and after the seedbed preparation, 35 d old rice seedlings were transplanted at a configuration of 25 cm x 15 cm. Variety BR 11 was used in Jessore and BRRIdhan 39 in Dinajpur. The experiment was set up in a factorial RCB design. Unit plot size of the experiment was 7.5 m x 6 m and the treatments were assigned randomly. Prior to transplanting rice seedling, biomass yield of mungbean was recorded and incorporated into the soil. All the inorganic fertilizers and one third of urea was applied as basal dose during transplanting. The remaining two thirds of urea was applied in two equal splits at maximum tillering and panicle initiation stages.

Adequate care was taken to manage the crop by irrigating, weeding, and spraying of insecticides. Upon maturity, crop was harvested from individual plots and the yield was recorded at 14% moisture content. Ten plants were also selected randomly from each plot to determine the yield attributes of rice. Data on yield and yield attributes were subjected to analysis of variance and means were compared by least significant different test (Gomez and Gomez, 1984).

Results and Discussion

Data on the amount of mungbean biomass incorporated into soil and the estimated amount of N added to the soil that the succeeding rice crop can use are presented in Table 1. Above ground biomass of mungbean added to the soil ranged from 2.24 to 2.36 t ha^{-1} in Jessore and 2.70 to 2.86 t ha^{-1} in Dinajpur. The probable nitrogen supply from the mungbean biomass incorporated into the soil thus varied accordingly from 27.64 to 29.12 kg ha^{-1}in Jessore and 33.32 to 35.29 kg ha^{-1} in Dinajpur. Contribution of N through biomass addition is rather underestimation of the amount actually released. Substantial portion of symbiotically fixed N by the mungbean plants remained in the stubbles and roots and were disregarded since only the amount of aboveground biomass was recorded.

Table 1. Quantity of incorporated mungbean biomass and the estimated amount of N added to the soil in rice-wheat cropping system

Mungbean in cereal based cropping system	Jessore		Dinajpur	
	DM ($t\ ha^{-1}$)	N ($kg\ ha^{-1}$)	DM ($t\ ha^{-1}$)	N ($kg\ ha^{-1}$)
T_1: Rice (RF) – Wheat (RF) – Fallow	-	-	-	-
T_2: Rice (RF) – Wheat (RF) – Mungbean (RF)	2.36	29.12	2.86	35.29
T_3: Rice (75% RF) – Wheat (RF) – Mungbean (RF)	2.25	27.77	2.70	33.32
T_4: Rice (50% RF) – Wheat (RF) – Mungbean (RF)	2.24	27.64	2.85	35.17
T_5: Rice (25% RF) – Wheat (RF) – Mungbean (RF)	2.28	28.14	2.83	34.92
T_6: Rice (0% RF) – Wheat (RF) – Mungbean (RF)	2.27	28.10	2.81	34.68

DM: Dry matter yield of mungbean; N: estimated amount of nitrogen added to the soil by mungbean.

In Jessore, rice yield varied between 4.33 t ha^{-1} (T_1) and 5.03 t ha^{-1} (T_5) (Table 2). Irrespective of the amount of N added, inclusion of mungbean in the cropping system generally tended to increase rice yield but the difference in rice yield among the treatments was not statistically significant. Relatively lower yield of rice grown with recommended rate of N indicates that higher rate of N alone is not sufficient to produce high yield in a rice-wheat system in the Jessore region (Prasad *et al.*, 2002). The highest yield (5.03 t ha^{-1}) of rice was recorded for the rice grown with mungbean biomass incorporation plus 25% N of recommended fertilizer. Further reduction of N reduced the yield to 4.92 t ha^{-1}. Grain legumes are believed to add 20 –60 kg N ha^{-1} to the succeeding crop (Kumar *et al.*, 1998). Such addition of N from mungbean along with high soil N status (0.11%) might be able to sustain the productivity of succeeding rice crop in Jessore. Therefore, combined application of both organic and inorganic source of nitrogen is essential in sustaining the productivity of rice in cereal-based cropping system (Bar *et al.*, 2000).

Table 2. Yield and yield attributes of rice grown after mungbean under different levels of nitrogen at Jessore

Treatment	No. of panicle m^{-2}	No. of filled grain / panicle	No. of unfilled grain / panicle	1000 grain weight (g)	Yield ($t\ ha^{-1}$)
T_1	257	100.93	39.13	23.65	4.33
T_2	308	132.53	31.03	25.27	4.95
T_3	331	128.97	25.83	25.12	4.86
T_4	314	122.57	22.87	24.93	4.81
T_5	276	100.13	23.67	25.27	5.03
T_6	280	108.17	20.37	26.01	4.92
$LSD_{(0.05)}$	NS	13.20	11.69	1.10	NS
CV (%)	21.63	6.28	23.66	2.42	8.90

T_1: Rice (RF) – Wheat (RF) – Fallow; T_2: Rice (RF) – Wheat (RF) – Mungbean (RF); T_3: Rice (75% RF) – Wheat (RF) – Mungbean (RF): T_4: Rice (50% RF) – Wheat (RF) – Mungbean (RF): T_5: Rice (25% RF) – Wheat (RF) – Mungbean (RF); T_6: Rice (0% RF) – Wheat (RF) – Mungbean (RF)

Rice yield obtained in Dinajpur was comparatively lower and ranged between 3.42 t ha^{-1} and 4.58 t ha^{-1}. Incorporation of mungbean biomass plus use of recommend N fertilizer gave the highest yield (4.58 t ha^{-1}) of rice. Soil N status was poorer in Dinajpur (0.06%). Variation in yield between Jessore and Dinajpur may be related to differences in soil fertility status in the two locations (Table 3).

Table 3. Yield and yield attributes of rice grown after mungbean under different levels of nitrogen at Dinajpur

Treatment	No. of panicle m^{-2}	No. of filled grains $panicle^{-1}$	No. of unfilled grains $panicle^{-1}$	1000-grain weight (g)	Yield (t ha^{-1})
T_1	245	112.40	37.67	24.54	4.27
T_2	255	116.20	36.63	24.63	4.58
T_3	243	118.70	33.17	24.57	4.53
T_4	233	114.90	35.03	24.48	4.03
T_5	228	105.83	36.07	24.53	3.97
T_6	222	104.13	27.23	24.24	3.42
$LSD_{(0.05)}$	NS	8.11	NS	NS	0.56
CV (%)	6.88	3.98	12.26	1.07	7.50

T_1: Rice (RF) – Wheat (RF) – Fallow; T_2: Rice (RF) – Wheat (RF) – Mungbean (RF); T_3: Rice (75% RF) – Wheat (RF) – Mungbean (RF): T_4: Rice (50% RF) – Wheat (RF) – Mungbean (RF): T_5: Rice (25% RF) – Wheat (RF) – Mungbean (RF); T_6: Rice (0% RF) – Wheat (RF) – Mungbean (RF)

Research conducted elsewhere showed that combined use of organic and inorganic N increased nutrient uptake and grain yield of rice than application of inorganic N alone (Dieknann *et al.*, 1993). Increased nutrient uptake, as well as growth and yield of rice grown in combined organic and inorganic sources of N, could be attributed to improvement in the physical, chemical, and biological properties of soil. Several authors (Mandal *et al.*, 1994; Patra *et al.*, 2000; Yadav *et al.*, 2000) reported that combined application of manures and fertilizers reduces bulk density and nutrient losses, and improves water soluble aggregates, total porosity, hydraulic conductivity, and water holding capacity. Besides, application of organic manure is known to increase micro-nutrient concentration and enhances nutrient absorption capacity of the crop. Thus it increases biological yield at a certain level of applied fertilizer.

Positive impact of inclusion of mungbean in the rice-wheat system has been apparent in the present study in Dinajpur only. Increasing and sustaining high yield of rice in rice-wheat system requires application of organic matter as well as nitrogen fertilizer in Dinajpur, although a substantial amount of N can be saved in Jessore by incorporating mungbean in the system.

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Seasonal variation in seed quality of two improved mungbean varieties

Rina R. Saha[1], A. Hamid and M.M. Haque

Bangabandhu Sheikh Mujibur Rahman Agricultural University,Salna, Gazipur 1706

[1] Present address: Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Hathazari, Chittagong, Bangladesh

Abstract

Two experiments were conducted at the BSMR Agricultural University to assess seasonal variation in seed quality of two improved mungbean varieties. The varieties were BARImung 2 and BUmug 2 which were tested in *Kharif* I (March-May) and in *Kharif* II (August – November) seasons. Seed quality was evaluated based on seed growth and harvest frequency. Irrespective of season and variety, pattern of seed growth indicated a lag phase at the beginning of grain filling and thereafter a linear phase attaining maximum dry weight at around 17 days after flowering. Seed quality in terms of germination paralleled to the pattern of seed growth and it was almost 100% percent at its maximum dry weight. Maximum dry weight and better seed quality was obtained at 17 DAA in BUmug 2 and 19 DAA in BARImung 2. Seasonal variation indicated that better quality mungbean seeds may be harvested in *Kharif* I season from BUmug 2. Harvest frequency indicated that first picking produced the best quality seeds in both the varieties in both the seasons. Deterioration of seed quality at later harvests was associated with the degree of development of hard seeds which had its maximum (33%) in BARImung 2 at third harvest.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse crop in tropical Asia. It is popular because of its short growth duration and adaptation to diverse agro-ecological conditions. Mungbean is very rich in protein and it complements the staple rice in Asian diets (AVRDC, 1998). However, intake of protein by the Asian people is very low compared to WHO recommendation. One of the approaches to increasing protein intake by the Asian people is to increase the production and consumption of mungbean. With the expansive culture of HYV rice and wheat production of food legumes in the South Asian Region mungbean cultivation generally has gone down in recent years. Low yield potentials of grain legumes, including mungbean, makes the crop less competitive with cereals and other high valued crops. To increase production, it is imperative that productivity of mungbean be increased.

Among the many factors that regulate crop productivity, quality seed is the most important (Ahmad, 2001). As quality seeds ensure vigorous stand establishment, the use of healthy and vigorous seeds is a prerequisite to attain optimum plant stand. Quality seed of mungbean may be obtained by selecting appropriate cultivars. Better understanding of the pattern of seed growth is also important as it determines quality of grain legumes (Egli and Legget, 1976; Gupta, 1992). Understanding the pattern of seed growth is useful in overcoming constraints in harvesting better quality mungbean seeds (Hedly and Ambrose, 1980). Seed quality is governed not only by the genetic make-up of the crop but also by environmental factors prevailing in the growing season (Tekrony *et al.*, 1980). Environmental factors vary widely over the years and also from season to season. Since mungbean can be grown almost throughout the year, it encounters great variation in environmental conditions at its different growth stages. The influence of environmental conditions of different growing seasons on seed formation and development that may affect the quality of seed produced. However, information relating to seed growth and seed quality of mungbean cultivars over the growing season is scarce. This present study evaluates seasonal variation in the pattern of seed growth and seed quality of two mungbean cultivars.

Materials and Methods

Two sets of experiments were conducted during two succeeding growing seasons at the BSMR Agricultural University in Gazipur. The location of the experimental site was 24 N latitude and $19^{0}16$ longitude with an elevation of 8.4 m above the mean sea level. In one set of experiment, two mungbean varieties were planted and each was harvested at three different times. The experiment with two varieties and three harvest times made up six treatments. Each treatment was replicated four times. The experiment was laid out in a randomized block design. The second set of experiment comprised of two varieties, each grown in large plots measuring 8 x 4 m. The variety formed the treatment variable and each treatment had four replications. Each set of experiment was planted in *Kharif* I (March – May) and *Kharif* II (August – November) seasons. Two varieties, BARImung 2 and BUmug 2, were used in all the experiments. For both sets of experiment, crop was planted on March 6, 2002 in *Kharif* I and on August 17, 2002 in *Kharif* II seasons. The crop was fertilized with urea, triple super phosphate, and muriate of potash at the rate of 20-60-40 kg NPK ha^{-1}. One third of urea and full dose of other fertilizers were applied as basal during land preparation.The rest of the urea was top-dressed in two equal splits at 20 and 35 days after sowing. Appropriate agronomic management and adequate plant protection measures were taken during the growing season.

In the first set of experiments, mungbean seeds were harvested at different times, cleaned, and sun-dried for assessment of quality. Seeds were placed on petridishes and incubated at 25°C. It was considered germinated when the radicle of the seeds emerged within seven days. Germinated and hard seeds, and decayed seeds were separated and counted at the end of germination test following ISTA (1993). Vigor index was calculated using the formula of Jayaraj and Karivaratharaju (1992). Data pertaining to seed quality were subjected to analysis of variance (ANOVA) and the means were compared by least significant difference test wherever necessary.

When the mungbean plants of the second set of experiments attained were at 50% flowering stage, about 700 flowers were tagged to measure the pattern of seed growth. The tags were tied to pedicels in such a way that individually-tagged pods could be easily identified at later dates. The sample pods were harvested at every alternate day beginning one day after anthesis (DAA). A total of 20 pods per cultivar was harvested each day. The seeds were separated from pods till 25 DAA. The separated seeds were oven-dried at 70 C for 48 hours prior to taking dry weight. A separate set of harvested seeds was used to determine the quality of seed as per standard practices.

Results and Discussion

Both seasons and cultivars had considerable influence on the pattern of seed growth of mungbean. Irrespective of cultivars, seed growth was better in *Kharif* I than in *Kharif* II season. When Figures 1 and 2 are viewed in conjunction, it becomes apparent that seed growth depended almost entirely on the availability of sunlight during the seed developmental phase. More sunny hours prevailed during the reproductive phase because of low rainfall in the *Kharif* I season. The abundance of sunlight has increased leaf photosynthesis and enhanced the seed growth of mungbean in *Kharif* I season (Gifford *et al*., 1984).

The pattern of seed growth further revealed that there had been a lag phase followed by a linear phase that persisted until the maximum dry weight was attained. Egli and Lagget (1976) also observed almost a similar pattern of seed growth in soybean. The lag phase of seed growth in the early part of reproductive stage might be due to partitioning and transportation of more assimilates towards the development of pod walls. It is possible that as the sink size had been determined and pod wall development completed, seed development took the lead drawing on the current photosynthesis as well as redistribution of stored assimilates towards the developing seeds (Fraser *et al.*, 1982). Cultivar differences in seed growth indicated that BUmug 2 had faster growth rate than that of BARImung 2 in both the growing seasons. Seeds of BUmug 2 attained maximum dry weight 53.63 mg in *Kharif* I and 47.09 mg in *Kharif* II season at 17 DAA compared with 38.51 mg in *Kharif* I and 31.22 mg for BARImung 2 in *Kharif* II season attained at 19 DAA. Attainment of maximum seed dry weight of BUmug 2 and BARImung 2 at 17 and 19 DAA indicated their physiological maturity (Fischer and Palmer, 1984) and point of highest seed quality (Copeland, 1976).

Figure 3 shows the germination pattern of mungbean seeds in two growing seasons. Irrespective of seasonal and cultivar differences, germination percentage of mungbean seeds increased gradually, reached its peak by showing nearly 100%, and then declined a little as the season progressed further. Decline in germination after attaining the peak might be due to development of hardseededness in mungbean seeds (Imrie, 1992; Hazarika and Barua, 2002). Mungbean seeds harvested within one week after anthesis did not germinate at all and eventually decayed wholly. The total decay was perhaps due to high moisture content in the immature seeds. The extent of increase in germination percentage was highest in seeds obtained from 9 to 11 DAA in BUmug 2 in both seasons. The corresponding increase in germination in BARImung 2 however, varied across the growing seasons. The highest germination increase in BARImung 2 occurred at 11 to 13 DAA in *Kharif* I and 9 to 11 DAA in *Kharif* II season. The germination of BUmug 2 was 100% in seeds harvested between 13 to 17 DAA in *Kharif* I and 15 to 19 DAA in *Kharif* II season whereas in BARImung 2, it was at 19 DAA in *Kharif* I and 17 to 19 DAA in *Kharif* II season. Significant and positive correlation between seed dry weight and germination percentage (Table 1) implies that the pattern of dry matter accumulation in seed is an important factor affecting seed quality.

Table 1. Correlation coefficient between seed dry weight and germination

Season and Variety	**Correlation coefficient**
Kharif I: BARImung 2	0.973**
Kharif I: BUmug 2	0.971**
Kharif II: BARImung 2	0.955**
Kharif II: BUmug 2	0.972**

** Significant at 0.01% level.

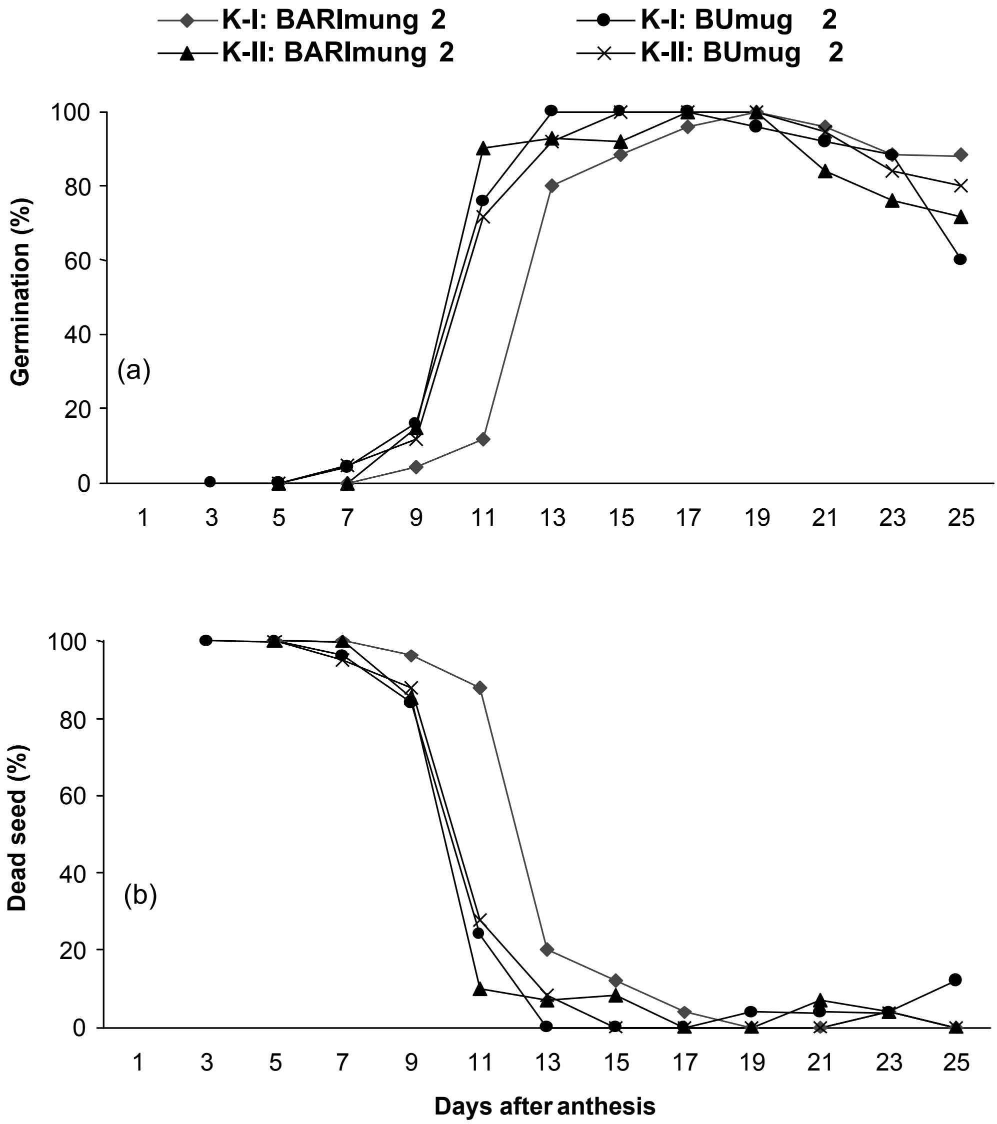

Figure 3. Pattern of seed germination (a) and dead seed (b) of mungbean varieties

Seed quality depends not only on the pattern of dry matter accumulation in seeds but also on the time of seed harvest. As mungbean is an indeterminate crop and its pods mature at different times under different environmental conditions, it is likely that the quality of seeds obtained from different pickings may also differ appreciably. Seeds harvested from the first flush of flowers and pod set produced the best quality seeds in terms of both germination and vigor index (Table 2). Germination percentage was significantly higher in seeds harvested from the first flush of pods than those harvested at later dates. Seed germination percentage decreased progressively over the successive harvests. The trend was similar for the mungbean seeds of both the varieties and in two seasons. Reduction of seed germination percentage at later harvests was associated with increased number of dead seeds and hard seeds (Table 2). In both the varieties and seasons, percentage of hard seeds and dead seeds was higher in seeds harvested at later dates. Increased percentage of hard seeds and dead seeds associated with later dates of harvests might be due to more frequent cloudy days and consequential reduced sunshine hours (Figure 1). In *Kharif* I season, maximum number of cloudy days prevailed at the time of seed maturation. While in *Kharif* II season, maximum cloudy days occurred at the time of seed development period of mungbean.

Table 2. Quality parameters of mungbean cultivars as influenced by variety and harvest time over two growing seasons

Quality parameter	Time of harvest	*Kharif I*		*Kharif II*	
		BUmug 2	BARImung 2	BUmug 2	BARImung 2
Germination (%)	1st	96.5 a	95.0 a	88.0 a	86.0 a
	2nd	77.5 b	90.5 a	82.0 a	78.0 b
	3rd	69.0 c	67.5 c	67.0 c	53.0 d
Hard seed (%)	1st	1.5 c	2.0 c	7.0 c	8.0 c
	2nd	11.0 b	3.0 c	9.0 c	13.0 c
	3rd	11.0 b	16.5 a	27.0 b	33.0 a
Dead seed (%)	1st	2.0 d	3.0 d	5.0 b	6.0 b
	2nd	11.5 bc	6.5 cd	9.0 ab	9.0 ab
	3rd	20.0 a	16.0 ab	6.0 b	14.0 a
Vigor index	1st	2689 a	1671 c	2266 a	1309 cd
	2nd	2232 b	1193 d	1830 b	1214 d
	3rd	1775 c	825 e	1397 c	723 e

Same letter(s) in each parameter in each column do not differ significantly at 0.05 level of significance.

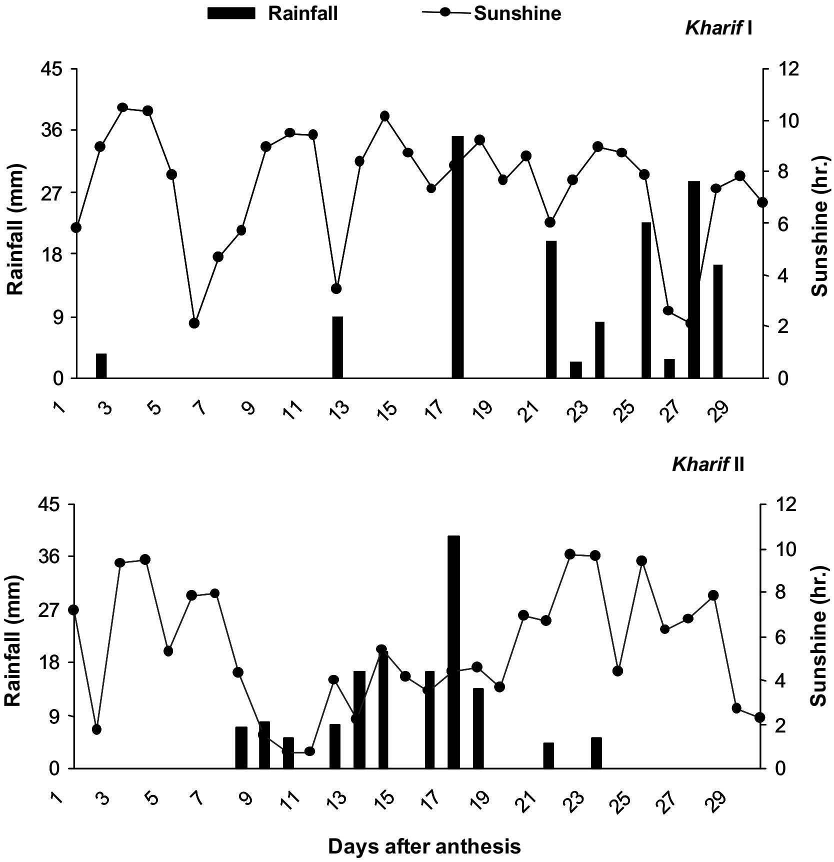

Figure 1. Rainfall and sunshine hours during seed development of mungbean in two seasons

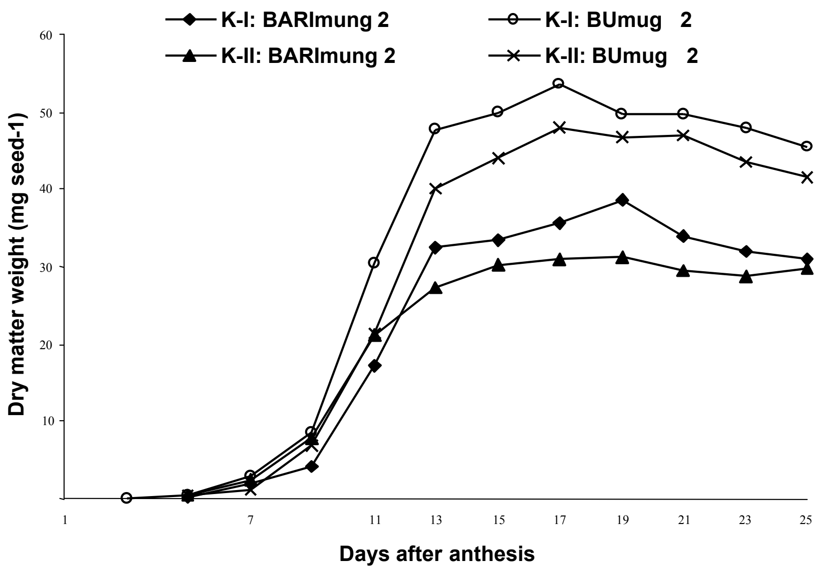

Figure 2. Pattern of seed growth of two mungbean cultivars in two growing seasons

Vigor index of BUmug 2 ranged from 1775 to 2689 in *Kharif* I season and 1397 to 2266 in *Kharif* II season. Contrarily, it was 825 to 1671 in *Kharif* I season and 723 to 1309 in *Kharif* II season in case of BARImung 2. BUmug 2 had significantly higher vigor index in both growing seasons (Table 2). However, irrespective of varieties, seeds harvested from first flush of pods gave significantly higher vigor index that declined in successive harvests. Interaction between variety and harvest time on vigor index was statistically significant indicating that the extent of reduction in vigor index over the harvest time was much less in BUmug 2 compared with BARImung 2. Also, BUmug 2's vigor index compared favorably with germination percentage; but due to harvest time, the variation in these two parameters was not consistent in BARImung 2. Afzal *et al.* (2003) also reported similar increase in hard seeds in later harvests of mungbean. Hardseededness was observed more in small seeded BARImung 2 than in the bold seeded BUmug 2. It reached its maximum (33%) in *Kharif* II season. Hardseededness provides protection against weather damage in mungbean seeds (Imrie, 1992). Development of higher percentage of hard seeds in the third harvest in *Kharif* II seems to be the natural mechanism of survival under unfavorable climatic condition.

From the study, it is clear that seed quality of mungbean is related to seed growth and it is governed by genetics and environmental conditions during seed development and seed maturation. Highest germination corresponding to maximum seed dry weight suggests that mungbean should be harvested at optimal seed maturity. Optimal seed maturity, however, depends greatly on variety and season. Seasonal variation revealed that the mungbean seeds harvested in *Kharif* I are qualitatively better than *Kharif* II seeds. Among the varieties, BUmug 2 produced better quality seeds with faster growth rate and lesser percentage of hard seeds.

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Adoption and seed production mechanisms of modern varieties of mungbean in Bangladesh

M.A. Afzal[1], M. A. Bakr[1], A. Hamid[2], M. M. Haque[2], and M. S. Aktar[1]

[1] Pulses Research Centre, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh, [2] Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh

Abstract

Through systematic research on mungbean since the mid-sixties, a total of 14 improved varieties of mungbean have been released in Bangladesh. The yield potential of these varieties is much higher than the local ones. A substantial endeavor was made to expand the cultivation of modern varieties, replacing the old and degenerated varieties and the attendant production technologies. In a short span of four years, an increase in the annual production of 45,000 tons of mungbean replaced old varieties in about 70% mungbean growing areas. It has been estimated that a cumulative increase of US$ 192 million has been achieved by intensive efforts of mungbean technology dissemination.

Introduction

Mungbean is one of the major pulse crops in Bangladesh. The country produces grains of pulses to the tune of about 550,000 tons annually, out of which the contribution of mungbean ranges between 10-12% (BBS, 2002). Because of its taste, mungbean commands consumers' preference. In the pursuit of expanding mungbean cultivation and increasing yield, the national agricultural research system in Bangladesh, in collaboration with AVRDC, developed several improved varieties of mungbean during the past decade. Despite the downtrend in pulse crop production in the country due to strong competition with high-yielding cereals, the area and production of mungbean are increasing. Mungbean cultivation is moving non-traditional areas across ecosystems and growing seasons. The development of disease-resistant, bold-seeded, high-yielding, and early-maturing varieties, plus improved production technology, made the expansion and sustenance of mungbean production possible.

Area and production of mungbean

The distribution of mungbean in different agro-ecological conditions in Bangladesh is shown in Figure 1. Most of the mungbean area are in the southern districts. Farmers in the southern districts (Barisal, Jhalakati, Patuakhali, Barguna, Bhola and Pirojpur) grow mungbean in the post-monsoon dry season under non-irrigated conditions. In the past five years, nearly 50-70% of mungbean area in these districts is planted with modern varieties. However, yield is relatively low. In the southwestern districts of Jessore, Jhenaidah, Chuadanga, Meherpur, and Kushtia, mungbean is recently introduced through the DFID-Mungbean project in collaboration with the Lentil, Blackgram Mungbean Development Pilot Project (LBMDPP) of the Ministry of Agriculture. All farmers in the region grow improved varieties (BARImung 2, BARImung 5, BUmug 1 and BUmug 2) under irrigated conditions in the *Kharif*-I (March-May) season as the varieties were just recently introduced. Farmers in the central region grow mungbean mostly in the rainy season after harvesting Aus rice or jute (*Kharif*-II).

Area and production of *Kharif*-II mungbean has declined substantially during recent years. In the western districts of Natore and Rajshahi, mungbean is introduced during the pre-monsoon *Kharif*-I season. In collaboration with a private business enterprise, bold-seeded mungbean varieties are grown. Wheat is extensively grown in the northern districts of Bogra, Rangpur, Nilphamari, Dinajpur, Thakurgaon, and Panchagarh. In 2003, over 470,000 ha were under wheat in these districts, producing nearly 55% of the country's total wheat production. The land remains fallow after the harvest of wheat which begins late March or early April until transplanting rice in August. In these districts, growing mungbean as an additional crop after the wheat harvest bears promise. Mungbean area, production, and yield in Bangladesh is shown in Figure 2.

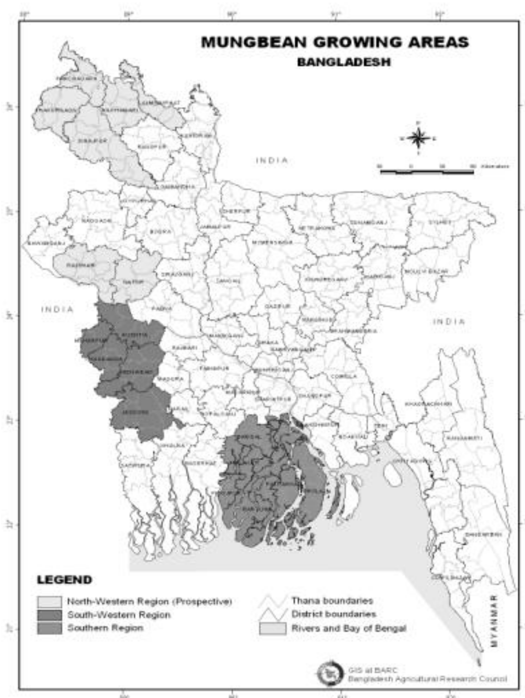

Figure 1. Distribution of mungbean in different agro-ecological conditions in Bangladesh

During the past 10 years, area and production of most pulse crops in Bangladesh either declined or stagnated but mungbean registered an increasing trend. Currently mungbean is grown in pre-and post-monsoon moist period. However, the major growing season is the pre-monsoon moist period. Nearly 65% of the total mungbean area is in the southern districts or Barisal region. The agro-climatic conditions of the region favor planting mungbean in late January to early February on the land where the preceding crop is usually wetland (aman) rice.

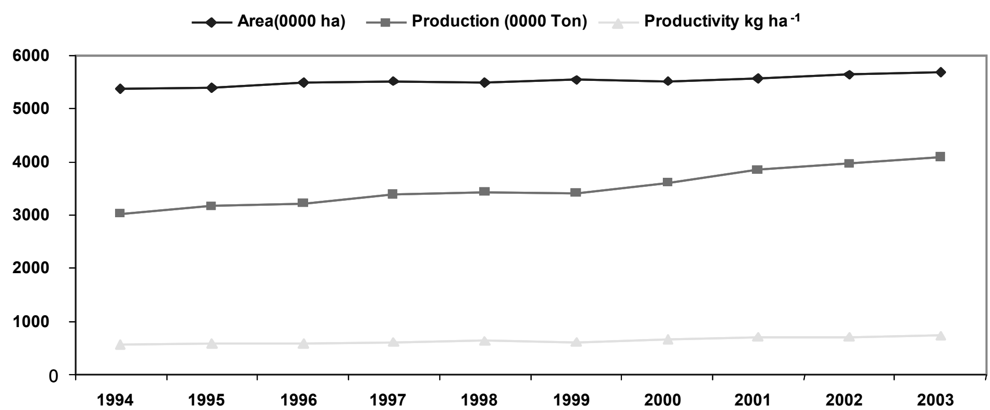

Figure 2. Area and production trend of mungbean in Bangladesh

Available technology

Farmers in Bangladesh have been growing mungbean over generations. In traditional growing areas, farmers still follow age-old practices for growing mungbean with no inputs. They were cultivating traditional, local varieties with low yield potential. To enhance the yield, the Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA), and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) developed 14 mungbean varieties with high yield potential in recent years (Table 1). These varieties are resistant to both yellow mosaic virus (YMV) and *Cercospora* leaf spot (CLS) diseases, and can produce 35-60% higher yield than local varieties (Afzal *et al.*, 1998).

Table 1. Mungbean varieties released in Bangladesh

Variety	Origin	Year released	Institute	Maturity (days)	Yield (kg ha^{-1})
BARImung 1	Local Selection	1982	BARI	70-75	950
BARImung 2	Philippines	1987	BARI	60-65	1100
BINAmung 1	Local Selection	1992	BARI	90-95	900
BINAmung 2	Local Cross	1994	BARI	70-80	1100
BARImung 3	Local Cross	1996	BINA	60-65	1250
BARImung 4	Local Cross	1996	BARI	60-65	1300
BARImung 5	NM-92 (VC 2768B x VC 1073A) from AVRDC	1997	BARI	55-60	1400
BINAmung 3	Local Cross	1997	BARI	80-85	1025
BINAmung 4	Local Cross	1997	BARI	75-80	1075
BINAmung 5	Local Cross	1998	BARI	60-65	1400
BINAmung 6	AVRDC	2002	BARI	55-60	1500
BUmug 1	AVRDC	2000	BSMRAU	55-60	1350
BUmug 2	AVRDC	2001	BSMRAU	55-60	1400
BUmug 3	BSMRAU collection of *Vigna* marina	2003	BSMRAU	55-60	1400

Mixed and intercropping

Mungbean is grown both as a mixed crop and as a pure crop. The practice of mixed cropping and intercropping of mungbean with crops such as sugarcane, banana, sesame, maize, and dibbled with Aus rice is followed in some parts of the country. This practice seems to have developed as a guarantee against complete crop failure, and characterizes subsistence farming. There is no experimental data, but CHESTA, an NGO, obtained excellent results in intercropping with banana and sugarcane in the farmers' fields in Jhenidah Districts (Table 2)

Table 2. Mungbean yield under relay and normal planting at Coat Chandpur, Jhenidah

Variety	Planting System	Seed Yield (kg ha^{-1})
BARImung 2	Single row of mungbean in between two rows of sugarcane	1370
	Several rows mungbean in between banana rows	1195
BARImung 5	Single row of mungbean in between two rows of sugarcane	1250
	Several rows mungbean in between banana rows	1175

Methods followed in technology dissemination

The project followed the farmer's participatory approach in the process of technology dissemination which involved all partners in each step in planning, execution, and evaluation. One of the activities involved in technology transfer mission include organizing broad-based planning workshop with the key personnel of all the partner organizations, NGO's, and farmers' representatives. As such, regional workshops were organized to discuss methods and strategies for effective implementation of the planned activities. Extension personnel of the Department of Agricultural Extension (DAE) took the major responsibility in implementing the plan. As an action plan was formulated, it was brought down to the grass root level extension workers, namely block supervisors and participating farmers, in the form of orientation training. This is where technology package and implementation methods were explained and new implementation strategies were developed.

In the technology transfer mission, the project employed demonstration as a tool in boosting production and educating farmers in the farmers' fields. The demonstrations were undertaken in cluster, with each cluster comprising 10 demonstrations of 1.25 ha each. Quality seeds of improved varieties particularly suited for the location and amount of fertilizers required for each demonstration were supplied to the farmers. Necessary inputs were given directly to the participating farmers. The setting up of the demonstrations was supervised by the front-line extension workers of DAE and the scientific assistant of the project based in the village.

The project personnel monitored the activities at least two times during the growing season – once at pre-flowering and the other at maturity stage. The monitoring tour provided opportunity to project personnel and farmers to interact and exchange ideas and experiences in growing crops in a given ecosystem. A formal mobile workshop was organized during the growing season where senior members from all partner organizations participated in. The team visited the farmers' plots and evaluated the crop performance in the demonstration plots, as well as farmers' crops beyond the demonstration area. The mobile workshop gave an opportunity to identify the constraints in the transfer of technology. At the time of workshop the best performing farmers and the extension workers were identified by judging the crop and the methods they followed. The project gave recognition to the works of the outstanding farmers and extension workers.

Organizing farmers' rally or field day was another important approach in technology dissemination. The activities were generally organized toward the maturity of the crop on successful demonstration blocks. The farmers from surrounding and distant villages were invited to participate. The participants observed and learned from the successful demonstrations. Apart from exhibiting the variety performance, the improved production technologies and methods adopted in growing the crop were highlighted in the discussion. Organizing field days involving farmers, scientists, extension personnel, and village leaders proved to be a useful vehicle for technology transfer in pulse production.

Motivating farmers in adopting improved technology

To make the farmers aware of the improved pulse technologies, several steps were taken. Farmers in the demonstration block were invited to participate in a training session held in the office of the Upazila Agricultural Officer of the DAE. Upazila is the lowest level of administrative unit where agricultural extension personnel plan and implement development programs. Farmers were given attractive posters and leaflets describing the variety with explanation of the improved production technology written in simple language. The training session was followed by distribution of packages of seeds and other inputs. The participating farmers returned their seeds after the harvest of the crop and the seeds collected from the farmers were again distributed to the neighboring farmers. This not only created awareness but also enhanced dissemination of modern varieties among the farmers. Demonstrations were set in well-communicated fields to expose the technologies to other farmers. All of the above steps coupled with a farmer-to-farmer seed exchange program created a high degree of awareness among the pulses growers about new and improved varieties and technologies.

Technology transfer of mungbean

To popularize the new varieties, demonstration trials were set through the DAE with the help of the Lentil Blackgram and Mungbean Development Pilot Project (LBMDPP). A total of 11,280 demonstrations were planned and implemented in 47 upazillas of 15 districts. Demonstration results on mungbean from 1999-2000 to 2002-03 are shown in Table 3. Average yield of mungbean in demonstration plots increased by 54-56% over the national average. This indicated that the project was successful.

Table 3. Performance of mungbean varieties under demonstration in farmers' field

Year	Growing Season	Average Yield (kg ha^{-1})				National Average (kg ha^{-1})	% increase over national Average yield
		BARI-mung 2	BARI-mung 5	BUmug 1	BUmug 2		
2000-01	Late *Rabi*	1028	933	-	-	692	54.85
	Kharif-I	1210	1210	1070	-	692	
2001-02	Late *Rabi*	933	1025	1021	-	703	53.23
	Kharif-I	1326	1126	1105	1091	703	
2002-03	Late *Rabi*	946	1000	1050	1005	710	55.67
	Kharif-I	1246	1251	1170	1176	710	
Mean (over season over year)		1115	1091	1083	1090	705	55.27

Seed village and seed exchange program

Seed production methods

Diversified efforts were made to produce quality seed of mungbean. Initially, certified seeds produced by the Bangladesh Agricultural Development Corporation (BADC) were used for demonstrations. Simultaneously, NGOs and individual farmers were employed for seed production in order to meet the seed demand. They produced seeds in close technical supervision of the project scientists. To enable farmers to be self-sufficient with mungbean seeds, seed villages were established following the pattern developed by Punjab Agricultural University in India. In each seed village, there were at least about six hectares of land for seed production. Farmers were given technical support and, in specific cases, assistance in seed production. Farmers kept seeds for selling to other farmers of the village. Distance between two seed villages was at least 10 km.

Beginning the year 2000, the project distributed nearly 16,605 tons of mungbean seeds in the southern regions. The seeds have been multiplied in the farmers' fields, and farmer-farmer seed exchange resulted in near-saturation condition. This helped in meeting the seed requirement in the regions. Most seeds were produced in the farmers' plots and distributed through farmer-farmer exchange program, while the seeds available in the Bangladesh Agricultural Development Corporation (BADC) were used in running on-farm demonstrations. All of the above steps, coupled with the seed exchange program from the participating farmers to no-participating ones, created a good level of awareness about the new and improved varieties and technologies of mungbean. Altogether, projects produced 16,605 t of seed and distributed among the farmers (Table 4).

Table 4. Seed production in the farmers and research field

Year	Production (t)						
	BARI-mung 2	BARI-mung 5	BU-mug 1	BU-mug 2	BINA-mung 2	BINA-mung 5	Total
2000-2001	645	370	4	0	20	35	1074
2001-2002	2645	870	8	0.3	310	160	3993
2002-2003	5915	4200	82	61	450	830	11538
Total	9205	5440	94	61.3	780	1025	16605

Adoption and impact

The DFID-Mungbean Project and LBMDPP have conducted 11,280 block demonstrations in collaboration with the DAE during the last few years. Data on agronomic practices, cost of inputs, and local market price of the produce were collected from the participating farmers. Data were analyzed to calculate the impact of each crop on the basis of five indicators (Afzal and Bakr, 2002). The average yield of improved varieties of mungbean in demonstration plots was 1,225 kg ha^{-1}, which was about 28% higher than the plots managed by the farmers. Gross return of mungbean cultivation was \$240 ha^{-1} for demonstration plots and \$ 191 ha^{-1} for farmers' plot (Table 5). However, gross return and gross margin were also higher, at 33 and 39% respectively, in the demonstration plots.

Table 5. Economic performance of the improved mungbean varieties in the farmers field

Indicator	Demonstration	Farmers' management	Change (%)
Yield (kg ha^{-1})	1225	956	28.13
Gross return ($ ha^{-1})	554.00	416.00	33.23
Gross cost ($ ha^{-1})	240.00	191.00	26.31
Gross margin ($ ha^{-1})	314.00	226.00	39.36
Benefit: cost ratio	2.31	2.18	5.36

Conclusion

The project made a substantial contribution towards attaining self-sufficiency in pulses in Bangladesh. It has created a momentum in mungbean production in the country. The activity pattern of the project can be taken as a model in attempting any new legume development program. The project resulted in the progress in coordinating research, development, and NGO activities. Further expansion of such activities could lead the country towards increasing mungbean production by many folds, thereby increasing the people's daily intake of pulses to improve human nutrition.

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Economics of mungbean cultivation in Bangladesh

Katinka Weinberger, Md. Rezaud Karim, Mohd. Nazrul Islam

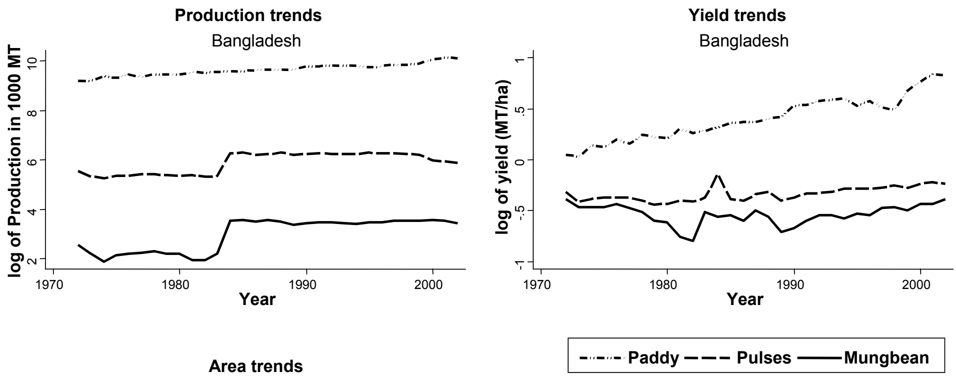
Abstract

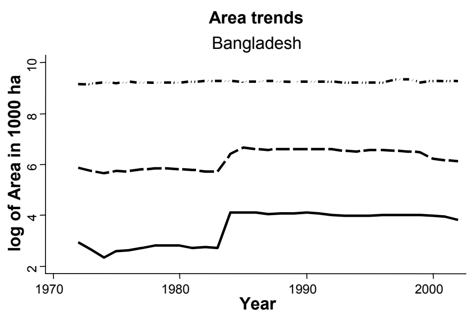
A socio-economic survey of 320 farmers in three districts of Bangladesh (Jessore, Barisal and Dinajpur) was undertaken during 2002 and 2003. Approximately half of these, 142 farmers, cultivate short duration mungbean cultivars during the summer season. The objectives of the study were: 1) to study the socio-economic profile of the selected farmers, 2) to estimate the benefits accrued to the adopters of improved short duration mungbean cultivars and 3) to suggest measures for the promotion of mungbean cultivation.

Introduction

In order to explore the potentials and possibilities of expansion in the acreage and production of mungbean, it is essential to know the performance of mungbean related cropping patterns. Mungbean is a short duration crop. A large area remains fallow in the Fallow-T Aus/T. Aman- *Rabi* cropping pattern in the South-Western region. This fallow period can be utilized by short duration improved mungbean varieties without disturbing the existing cropping pattern. Advantages would be increased incomes for farmers and enhanced soil fertility. But the rate of adoption and sustainability of mungbean depends largely on its economic profitability. Economic viability is one of the important criteria for assessing the suitability of a new crop technology. In this regard, all crops in a pattern have been studied to fulfill the objectives of study.

Mungbean production in Asia has increased substantially in the past 20 years. However, only a small share of this production comes from Bangladesh. In Bangladesh, production increased with an average annual growth rate of 6.7% between 1972 and 2002 compared with the average 3.5% for all pulses. During the same period, area under mungbean has doubled, from 5.3% (in all pulses) to 11.5%. In 2002, a total of 45,600 ha was under production and average yield levels were 680 kg ha^{-1}, higher than the neighboring India, but lower than other countries such as Thailand and Myanmar (Weinberger, 2003). However, despite the impressive growth in overall production, productivity increases have actually been rather low. Between 1972 and 2002, average annual yield increases were only 0.1%, compared to yield increases in pulses as a whole at 0.5% and paddy at 2.4% (Figure 1).





Source: Bangladesh Bureau of Statistics (2002)

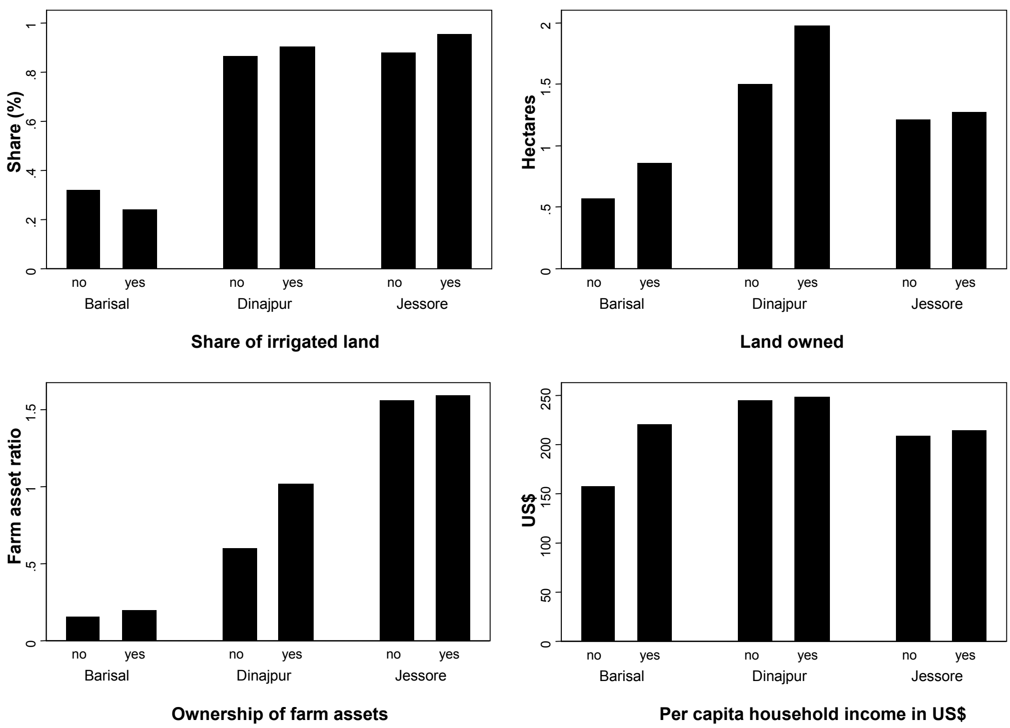
Figure 1. Production, yield and area trends for paddy, pulses, and mungbean, 1972-2002

Material and methods

Data used in this study were taken from the unpublished base-line survey, which were collected for the DFID-AVRDC Mungbean Project. The survey was undertaken in 2002 and 2003 and covered three regions, namely Dinajpur, Jessore and Barisal. The total sample size of randomly selected farmers was 320. The objective of the survey was (i) to study the socio-economic profile of farmers (growers/ non-growers), (ii) to assess economic benefits of improved short duration mungbean, (iii) to determine constraints (abiotic and biotic) in mungbean production, and (iv) to suggest measures for mungbean promotion. A large number of cropping pattern was found in the base-line survey from which only mungbean-related cropping patterns were chosen to be part of this study.

Farm characteristics

Of all farmers surveyed, 144 (44%) were found to grow mungbean, with a very unequal distribution across the three districts. In Barisal, 79 out of 100 farmers grew mungbean with 71% growing high yielding varieties. In Jessore, the share was 39 out of 100 farmers (all growing high-yielding varieties), while in Dinajpur the share was lowest with 23 out of 120 farmers growing mungbean (all high yielding varieties). A comparison of farmers showed that mungbean farmers were usually slightly better off in several socio-economic variables, but usually this relationship was not significant. Differences were much larger across regions than between farmers of one region (Figure 2 and Table 1). For the Barisal region, adopters of high yielding varieties were compared with growers of local varieties. Adopters earned a significantly larger share of their income from agricultural activities, and a larger share of their land was irrigated.



Source: BARI/ AVRDC farm survey. 2002-2003

Figure 2. Comparison of farmers growing/not growing mungbean

Table 1. Socioeconomic characteristics

	Barisal	Jessore	Dinajpur
School year	+	+	+
Per capita household income	+(*)[1]	+	+
Asset ownership	+	+(***)[2]	+/-
Land ownership (*)	+(*)[1]	+	+
Irrigated land	-	+	+(***)[2]

Note: [2]*** means significance at 0.01 level or better, [1]* means significance at 0.1 level or better.
Source: BARI/ AVRDC farm survey. 2002-2003

Economics of mungbean production

The following cropping patterns including mungbean were commonly found in the three regions (Table 2). In Barisal, farmers cultivated mungbean on 21% of all plots and on 27% of all cultivated area. The average area under cultivation per cultivating farmer was 0.32 ha. In Dinajpur, mungbean was cultivated on 11% of all plots and on 10% of all cultivated area. The average area under cultivation per farmer was 0.13 ha. Mean yields were highest in Jessore, followed by Barisal. The yield difference between high yielding varieties in Dinajpur and local varieties in Barisal was only 35 kg (Table 3).

Table 4 shows big differences in the profitability of the mungbean crop across localities. Farmers in Barisal and Jessore growing high yielding varieties of mungbean earned approximately 40% more than farmers in Dinajpur. Even local varieties in Barisal had a higher return on per ha basis than high-yielding varieties in Dinajpur. The profitability of mungbean production ranged from 7,700 TAKA ha^{-1} in Dinajpur to 12,856 TAKA ha^{-1} in Jessore. In comparison, the profitability of Boro Rice was only 6,424 TAKA (1991 data). Mean return to labor days (family and hired) ranges from 162 TAKA in Dinajpur to 202 TAKA in Jessore and was highest in Barisal with 336 TAKA.

Figure 3 shows the various cost factors involved in the production of mungbean. Hired labor was by far the greatest cost factor in all three districts, followed by cost for fertilizer and power tiller. The cost structure was relatively similar across the three districts, however the absolute costs varied with locations (Table 4).

The analysis of the profitability of different cropping patterns (Table 5) showed that farmers would prefer a rotation of two or three crops based on their resources. The rotation including three crops (mungbean-rice-wheat and rice-rice-mungbean) yielded the highest gross return. In contrast, the benefit-cost ratio and the returns to labor were highest for the rotations based on two crops (mungbean-rice), including a fallow period. These rotations usually showed higher benefit-cost ratios, because the yield was higher. The average yields per ha were usually higher because longer duration varieties could be grown, and because, as farmers put it, *"the land could rest"*. Farmers also provided less labor input on per ha basis. Thus, where labor availability was a constraint, for instance because the farmer or some of his household members had other income earning opportunities outside agriculture, and when farmers wanted to minimize risk, then the less intensive cropping rotation such as mungbean-rice or wheat-mungbean would be preferred. In contrast, farmers would prefer the more intensive cropping patterns that yield higher gross and net returns because of higher total marketable yields, when labor availability was not a constraint and the objective of the farmers was maximization of cash income.

Table 2. Common cropping patterns

Barisal	Dinajpur	Jessore
Fallow – T.Aman – Mungbean (71%) T. Aus – T.Aman – Mungbean (27%)	Mungbean – T.Aman – Fallow (48%) Mungbean – T.Aman – Wheat (43%)	Mungbean – T.Aman – Wheat Mungbean – T.Aman - Fallow Mungbean – Fallow – Wheat

Source: BARI/ AVRDC farm survey. 2002-2003

Table 3. Yield per hectare (in kg)

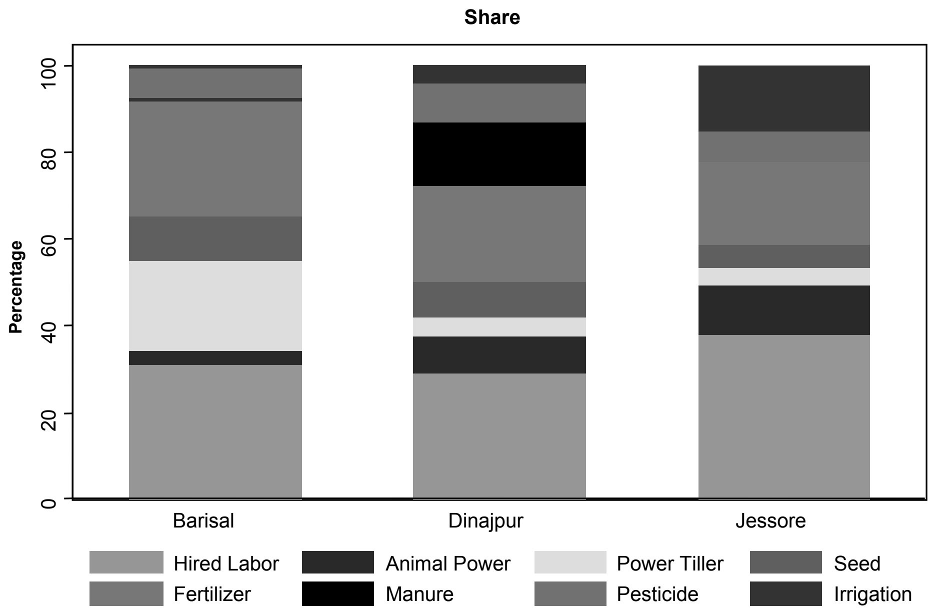
	Local		HYV		Total	
Region	Mean	N	Mean	N	Mean	N
Barisal	658	23	777	56	742	79
Dinajpur			693	23	693	23
Jessore			1099	39	1099	39

Source: BARI/ AVRDC farm survey. 2002-2003

Table 4. Economics of mungbean production (TAKA/ha)

	Barisal		Dinajpur	Jessore
	local	HYV		
Gross income	16118	18699	16418	24247
Cash cost	7247	5949	8647	11390
Net income	8871	12750	7771	12857

Source: BARI/ AVRDC farm survey. 2002-2003



Source: BARI/ AVRDC farm survey. 2002-2003

Figure 3. Cost factors in mungbean production

Table 5. Cropping patterns in comparison

Region	Pattern	GR	NR	BCR	RtL
		TK ha^{-1}	TK ha^{-1}		TK day^{-1}
Dinajpur	MB-T.AM-WH	54,917	33,550	0.62	225
	MB-T.AM	43,586	36,173	1.30	257
Barisal	T.AUS-T.AM-MB	51,375	34,924	0.86	189
	T.AM-MB	39,392	26,787	1.20	459
Jessore	MB-T.AM	52,382	28,166	0.77	491
	MB-T.AM-WH	60,277	29,972	0.44	182
	MB-FL-WH	43,623	27,155	0.62	316

Source: BARI/ AVRDC farm survey. 2002-2003.
Note: GR = Gross return, NR = Net return, BCR = benefit cost ratio, RtL = Returns to labor.
MB: mungbean; T.Am: T. Aman Rice;T. Aus: Rice; WH: Wheat; FL: Fallow.

Mungbean consumption

A further increase in mungbean production appears to be constrained by low consumption rates. However, consumers show relatively large income elasticities for pulses, of 0.779 in urban areas and 1.147 in rural areas. It can thus be assumed that as incomes rise, demand for pulses and mungbean will also increase. With the survey, mungbean ranked second in consumed quantity, after lentils. Average per capita per annum consumption ranged from 470 g in Dinajpur to 3.2 kg in Jessore. Average pulses consumption ranged from 5.7 kg to 8.6 kg. However, there are stark differences between this survey and other surveys. In the Bangladesh Household Expenditure Survey (2002), mungbean ranks only fourth in per capita quantity consumed. Considering the overall production of pulses in Bangladesh, mungbean occupies third place, after khesari and lentils. However, the survey does show that farmers producing this crop have a greater probability to consume, as the average consumption figures in Figure 4 show. Note that among farmers growing mungbean, no substitution for other pulses takes place, since average pulse consumption levels are also higher among farmers growing mungbean. In the market, mungbean competes with lentils, because as one buyer on a local market put it *"From one kg of lentils I can feed 20 people. From one kg of mungbean I can only feed 10 people".* The price of both crops is similar.

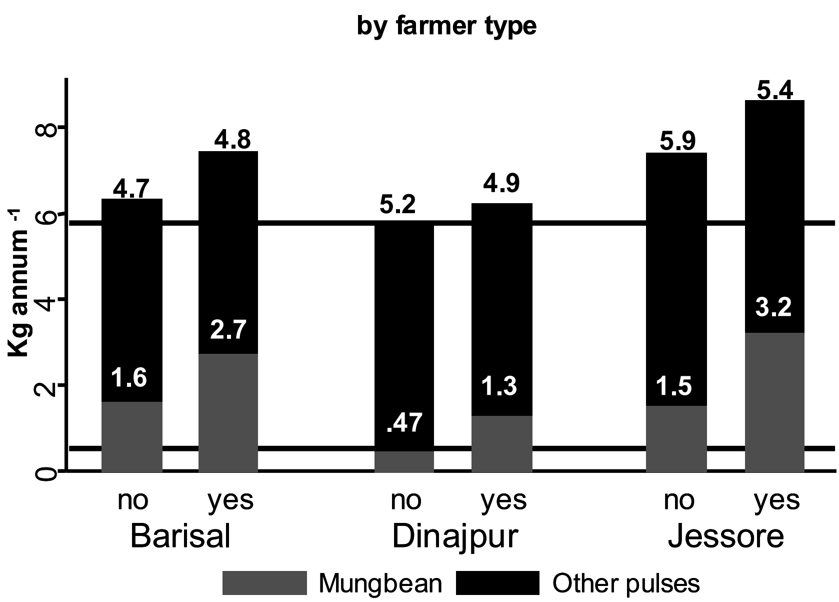


Figure 4. Mungbean and pulses consumption by farmers who grow mungbean (yes) and those who do not grow mungbean (no). The line indicates the respective values from the Bangladesh Household Expenditure Survey

Conclusion

Mungbean is an attractive crop and particularly the high-yielding varieties achieve high returns on per ha basis. However, it should be kept in mind that mungbean as a third crop is feasible only where sufficient labor is available. The crop has low returns to labor compared with rice, thus the introduction of labor-saving technologies may provide an incentive for progressive farmers under such circumstances. Since labor cost makes up a big share of total cost, labor-saving technologies could be expected to show a great impact. On the other hand, mungbean in fallow-based systems will become more attractive if the average yield can be improved and the yield gap to scientifically possible yields closed.

Consumption of mungbean and pulses was found to be significantly higher among farmers producing the crop, thus the project was successful in enhancing consumption rates of mungbean. For the effect to spill over to other rural and urban consumers, it will be essential that the price of mungbean becomes less and that consumers are provided with information about the nutritional properties of this crop compared with other pulses.

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