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Yield Components and Yield of Three Soybean (*Glycine max* L.) Varieties under Different Irrigation Management

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Abstract: An experiment was conducted at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from December, 2005 to April, 2006 to study the responses of soybean varieties to the time of irrigation. The experiment was carried out with three soybean varieties viz. Shohag, Bangladesh soybean 4 and BARI soybean 5 and 5 levels of irrigation viz. no irrigation, irrigation at elongation of main stem (EMS), irrigation at flowering (F), irrigation at pod development (PD) and EMS+F+PD stages of crop growth. Among the three varieties, BARI soybean- 5 influenced plant to have maximum number of branches plant^{-1}, pod length, number of seeds pod^{-1}, seed yield, stover yield and also harvest index. But, the maximum plant height and number of pod plant^{-1} was found highest in Bangladesh soybean-4. The grain yield status among the three varieties in this experiment was that the BARI soybean-5 out yielded than shohag and Bangladesh soybean-4, by 6.93% and 0.28% respectively. Irrigation at EMS+F+PD stages increased yield with higher values of harvest index as the yield attributes like branches plant^{-1}, pod plant^{-1}, seed pod^{-1}, pod length, 100 seed weight higher. Application of irrigation at different times significantly increased seed yield ranged between 23.94% and 96.92% than the control (no irrigation). In most of the cases BARI soybean-5 coupled with irrigation at EMS+F+PD were found to be influenced for better yield of plant. The highest seed yield was found with the interaction of BARI soybean-5 with irrigation at EMS+F+PD stage. This was achieved due to maximum number of branches plant^{-1}, number of seed pod^{-1} and pod length.

Key words: Soybean, Irrigation, Pod, Yield

INTRODUCTION

As a high energy food, edible oil is important for meeting the caloric requirement. Fat and oils act as a carrier for fat soluble vitamins (A, D, E and K) in the body and therefore, the presence of some fat or oil in the diet is essential for their absorption [1]. The oil crop area of Bangladesh is gradually decreasing due to the replacement of oil crop area by HYV Boro rice. So, every year the government has to import oil and oilseeds mainly soybean, rapeseed and plam oil at the cost of huge amount of foreign exchange.

Soybean (*Glycine max*) is one of the good sources of high quality oil and protein can play an important role in solving the malnutrition problem of Bangladesh. Soybean is a crop which can produce high quality and highest quantity of protein (seed contains about 40% protein) per unit area. The oil content of soybean is about 20%, while all other pulses contain about 1-2% oil [2]. Such an excellent crop, if grown extensively may reduce the fat and protein deficiency in the country. The crop is grown throughout the world with the largest production in the United States, Brazil, Peoples' Republic of China, Mexico, Indonesia and Argentina. The world production of soybean as estimated in 1999 was 161.99 million metric ton from an area of 73.44 million hectares [3]. In Bangladesh, in terms of area and production, soybean is such a minor crop concentrated only in few distinct locations. The total cropped area of soybean is 5000 ha and the total production of the country stands at 4000 tons [4]. Soybean yield varies from 1500-2000 kg ha^{-1} depending on variety and agronomic management practices. Improved variety and irrigation in particular can improve the yield of soybean [5].

Soybean cultivation is hindered due to lack of high quality seed. So, it is essential for us to produce quality seed. Irrigation applied at 20 + 40 + 60 days after sowing (DAS) increased plant height leaf area index, crop growth

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rate, shoot dry weight, number of filled pods per plant, number of seeds per plant, seed yield and harvest index of soybean [6]. Kazi *et al.* [7] reported that the growth, yield components and oil content of soybean were significantly affected by irrigation frequencies. Considering the above points, an experiment was undertaken to study the responses of three varieties of soybean under different dates of irrigation to evaluate the yield performance under these treatments.

MATERIALS AND METHODS

The research work was carried out at the field Laboratory of Agronomy Department of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the rabi season from December 2005 to April 2006. The land was medium high and the soil of the experimental site was silty loam in texture with 29.97% sand, 54.86% loam and 15.28% clay particles. The variety of soybean used in this experiment were Shohag (V_1), Bangladesh soybean-4 (V_2) and BARI soybean-5 (V_3). These released varieties have excellent seed quality and superior to existing Bragg and Davis varieties. Different irrigation treatments were I_0 = control (No irrigation), I_1 = Irrigation at main stem elongation stage (EMS), I_2 = Irrigation at flowering stage (F), I_3 = Irrigation at pod development stage (PD) and I_4 = Irrigation at EMS+F+PD stages. The experiment was laid out following two factors split plot design with 3 replications. irrigation was given in main plot and variety in the sub-plots.

The plots were fertilized with urea, triple super phosphate, muriate of potash and gypsum at the rate of 60, 175, 120 and 115 kg ha^{-1}, respectively [8]. All the fertilizers were applied at the time of final land preparation. Sowing was done on 22 December 2005. Seeds were sown in 30 cm apart rows and seed to seed distance was 6 cm. Intercultural operation like thinning, weeding and pest control were done as per requirements. Ten plants were selected at random from each plot on maturity. Seeds and stover were cleaned and dried in the sun for three to four consecutive days. After proper drying of seeds to a moisture content of 16-18%.

Data were analyzed using analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test [9] with the help of computer based statistical package programme, MSTAT-C. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

RESULTS AND DISCUSSION

Effect of Variety: Plant height varied significantly due to variety (Table 1). The tallest plant (54.20 cm) was found in Bangladesh soybean-4 while the shortest plant (46.26) was found in BARI soybean-5. Similar observation was noted by Ponnushwamy *et al.* [10] who observed that plant height differed between varieties.

The number of branches $plant^{-1}$ was affected not significantly by varieties (Table 1). But the highest number of branches $plant^{-1}$ (6.71) was found in the variety BARI soybean-5 and the lowest number (5.97) was recorded with the variety Bangladesh soybean-4.

Pod length exerted non significant influence on variety (Table 1). Numerically highest pod length (3.42 cm) was found in BARI soybean-5 than shohag (3.35 cm) and Bangladesh soybean-4 (3.25 cm).

Number of pod $plant^{-1}$ was significantly influenced by the varieties (Table 1). The highest number of pods $plant^{-1}$ (36.72) was found in Bangladesh soybean-4 than varieties shohag (21.34) and BARI soybean-5 (21.19). That means Bangladesh soybean produced 72.09% and 73.29% higher pod $plant^{-1}$ than shohag and BARI soybean-5, respectively. The result corroborates with the findings of Saad [11].

Number of seeds pod^{-1} differed significantly due to varieties (Table 1). From the table it is evident that the highest number of seeds pod^{-1} (1.62) was obtained with the variety BARI soybean-5. The lowest number of seeds pod^{-1} (1.43) was observed by the variety shohag which was similar with Bangladesh soybean-4 (1.49). This result is supported by Molhotra [12].

Variety exerted significant variation on 100 seed weight (Table 1). The highest 100 seed weight (8.58 g) was obtained in shohag which was statistically similar with BARI soybean-5 (8.41 g). The lowest 100 seed weight (5.18g) was obtained in the variety Bangladesh soybean-4 which was 39.63% and 38.41% lower than shohag and BARI soybean-5, respectively. The result corroborates with the findings of Das *et al.* [13].

The seed yield varied significantly among the varieties (Table 2). The seed yield status among the three varieties in this experiment was that the BARI soybean-5 out yielded by 100.76 and 4.38 kg ha^{-1} (6.93% and 0.28% higher) than shohag and Bangladesh soybean-4, respectively. But the seed yield between BARI soybean-5 and Bangladesh soybean-4 was significant. The variation in seed yield among the varieties may be attributed to the genetic make up of the varieties. The result agreed with

Table 1: Effect of variety on plant and yield contributing parameter of soybean

Variety	Plant height (cm)	Branch plant^{-1} (no.)	Pod Length (cm)	Pod plant^{-1} (no.)	Seed pod^{-1} (no.)	100 seed weight (g)
Shohag	48.94	6.07	3.35	21.34	1.42	8.58
Bangladesh soybean-4	54.20	5.97	3.25	36.72	1.49	5.17
BARI soybean-5	46.26	6.70	3.41	21.18	1.61	8.41
LSD (at 0.05)	4.26	NS	NS	0.62	0.90	0.82

NS = Not significant

Table 2: Effect of variety on yield and harvest index of soybean

Variety	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Shohag	1454.05	1723.66	45.37
Bangladesh soybean-4	1550.42	1770.83	46.25
BARI soybean-5	1554.80	1777.05	46.422
LSD (at 0.05)	53.30	NS	NS

NS = Not significant

Table 3: Effect of irrigation on plant and yield contributing parameter of soybean

Irrigation	Plant height (cm)	Branch plant^{-1} (no.)	Pod length (cm)	Pod plant^{-1} (no.)	Seed pod^{-1} (no.)	100 seed weight (g)
Without irrigation (control)	41.01	4.86	2.82	20.76	1.39	7.11
Elongation of main stem (EMS)	50.08	5.67	3.15	24.07	1.44	7.28
Flowering (F)	52.81	5.96	3.57	28.81	1.53	7.42
Pod development (PD)	46.28	6.94	3.41	27.26	1.49	7.52
EMS+F+PD	58.83	7.80	3.74	31.16	1.68	7.59
LSD (at 0.05)	4.13	0.73	0.21	1.48	0.09	NS

NS = Not significant

the findings of BARI [14] who reported that the variety BARI soybean-5 gave the higher yield than Bangladesh soybean-4 and shohag.

The effect of variety was found to be not significant in respect of stover yield (Table 2). The stover yield ranged from 1723.66-1777.05 kg ha^{-1} among the varieties. Apparently the maximum stover weight (177.05 kg ha^{-1}) was recorded in BARI soybean-5 and the lowest (1723.66 kg ha^{-1}) was recorded in shohag.

Harvest index was not significantly influenced by varieties at 5% level of significance (Table 2). The highest harvest index (46.42%) was observed in BARI soybean-5. The second highest (46.26%) harvest index was found in Bangladesh soybean-4 and the lowest (45.38%) was obtained in shohag.

Effect of Irrigation Management: Plant height at harvest was significantly influenced by time of irrigation at 5% level of significance (Table 3). In general, application of irrigation significantly enhanced plant height than control (without irrigation). However, the tallest plant (58.33 cm) was observed with irrigation applied at EMS+F+PD period. The shortest plant (41.01 cm) was obtained with no irrigation. The second highest (52.8 cm) plant was found to produce at irrigation applied at flowering stage which was similar with the irrigation applied at elongation of main stem stage (50.09 cm). This is result is supported by Boydak *et al.* [6].

Number of branches plant^{-1} was significant due to irrigation application. The highest branches plant^{-1} (7.80) was found with three irrigation application at EMS+F+PD period and the lowest number of branches plant^{-1} (4.8) was obtained in control treatment (without irrigation). The second highest branches plant^{-1} (6.94) was obtained with irrigation applied at pod development stage (Table 3). The findings in respect of number of branches plant^{-1}supported by Boydack *et al.* [6].

There was a significant difference on pod length in case of time of irrigation (Table 3). Irrigation applied at different times produced 6.03-32.62% higher pod length over control. The highest pod length (3.74 cm) was observed with three irrigations at EMS+F+PD applied plot. The shortest pod (2.83 cm) was obtained with control treatment (no irrigation).

Table 4: Effect of irrigation on yield and harvest index of soybean

Irrigation	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Without irrigation (control)	1068.60	1449.52	42.42
Elongation of main stem (EMS)	1324.37	1624.22	44.76
Flowering (F)	1678.29	1828.82	47.93
Pod development (PD)	1423.25	1652.20	46.27
EMS+F+PD	2104.28	2231.14	48.69
LSD (at 0.05)	102.00	149.90	2.37

Number of pods plant^{-1} was significantly influenced by time of irrigation at 5% level of significance (Table 3). In general application of irrigation at different times significantly increased the number of pod plant^{-1} than control treatment. The highest increase (50.10%) was found to produce in three irrigation at EMS+F+PD applied treatment and the lowest increase (16.04%) was recorded in the irrigation treatment applied at elongation of main stem period. Similar trend of number of pods plant^{-1} due to times of irrigation was reported by Korte *et al.* [15] who noted a positive effect of time of irrigation on the production of number of pods plant^{-1}.

Number of seeds pod^{-1} differed significantly due to times of irrigation (Table 3). Application of three irrigation at EMS+F+PD period showed the highest number (1.69) of seed pod^{-1}. The second highest number of seed pod^{-1} (1.54) recorded with irrigation treated plots (applied at flowering stage) which was statistically similar with irrigation applied at main stem elongation stage. However, control (without irrigation) plot showed the lowest (1.40) number of seed pod^{-1}. Variable effects of time of irrigation on number of seeds pod^{-1} was also supported by Svoboda [16].

The effect of time of irrigation was not significant in respect of 100-seed weight (Table 3). The 100 seed weight recorded from irrigation applied plots ranged from 7.11 to 7.59 g. Apparently, the maximum 100-seed weight 7.59g was recorded with irrigation applied at EMS+F+PD stage treatment and the lowest (7.11g) with no irrigation treatment. This result agreed with the findings of Svoboda [16].

Seed Yield: Different times of irrigation treatment had a significant influence on seed yield of soybean (Table 4). Application of irrigation at different times significantly increased seed yield ranged 23.94%-96.92% than the control (without irrigation). The highest increase (1035.28 kg ha^{-1}) was recorded with three irrigation at EMS+F+PD and the lowest increase (779.91 kg ha^{-1}) was found in single irrigation applied at EMS stage. However, single irrigation applied at flowering showed the second highest seed yield (1678.29 kg ha^{-1}). These results are in full compliance with those of Gaspari *et al.* [17], Moraru *et al.* [18], Ramseur *et al.* [19], who recorded increased seed yield with different times of irrigation. Seed yield increased with time of irrigation probably due to positive effect of time of irrigation for increasing number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight as observed in the present study.

Stover yield was significantly influenced due to time of irrigation at 5% level of probability (Table 4). The table showed that the highest stover yield (2231.14 kg ha^{-1}) was obtained by irrigation applied at EMS+F+PD stages followed by 1828.83 kg ha^{-1}recorded with irrigation applied at flowering period. The lowest stover yield (1449.52 kg ha^{-1}) was obtained in no irrigation treatment. In general, application of irrigation significantly enhanced stover yield than control (without irrigation).

Harvest index varied significantly due to different times of irrigation treatments (Table 4). The highest harvest index (48.70%) was observed by irrigation applied at EMS+F+PD period which was statistically similar with irrigation applied at flowering period (47.93%) and pod development period (46.28%). The lowest harvest index (42.42%) was observed with no irrigation treatment which was similar to irrigation applied at elongation of main stem (44.76%) stage. The results of present investigation showed higher harvest index value which was mainly due to higher seed yield in relation to biological yield [20]. Similar results were reported by Zebarth and Sheard [21].

Interaction Effect of Irrigation and Variety: Table 5 exerted significant variation on plant height due to interaction between time of irrigation and variety. The result showed that the tallest plant (61.90 cm) was found in irrigation at EMS+F+PD × Bangladesh soybean-4 treatment which was statistically similar with the interaction treatments of irrigation at flowering × Bangladesh soybean-4, irrigation at EMS+F+PD × shohag, irrigation at EMS+F+PD × BARI

Table 5: Interaction Effect of irrigation and variety on plant and yield contributing parameter of soybean

Irrigation × variety	Plant height (cm)	Branch plant^{-1} (no.)	Pod length (cm)	Pod plant^{-1} (no.)	Seed pod^{-1} (no.)	100 seed weight (g)
Without irrigation (control) × shohag	39.30	4.86	2.91	17.03	1.30	8.26
Without irrigation (control) × Bangladesh soybean-4	44.06	4.16s	2.72	29.23	1.35	5.02
Without irrigation (control) × BARI soybean-5	39.66	5.56	2.84	16.02	1.53	8.06
Elongation of main stem (EMS) × shohag	49.30	5.23	3.11	20.23	1.33	8.52
Elongation of main stem (EMS) × Bangladesh soybean-4	55.33	5.76	3.23	33.00	1.45	5.09
Elongation of main stem (EMS) × BARI soybean-5	45.63	6.03	3.10	19.00	1.55	8.22
Flowering (F) × shohag	51.63	5.40	3.58	23.11	1.45	8.70
Flowering (F) × Bangladesh soybean4	58.90	6.00	3.40	40.02	1.51	5.12
Flowering (F) × BARI soyben-5	47.90	6.50	3.74	23.30	1.64	8.46
Pod development (PD) × shohag	45.60	7.03	3.35	21.20	1.40	8.73
Pod development (PD) × Bangladesh soybean-4	50.83	6.67	3.33	38.36	1.48	5.21
Pod development (PD) × BARI soybean-5	42.43	7.13	3.56	22.23	1.60	8.62
EMS+F+PD × shohag	58.90	7.83	3.78	25.13	1.65	8.68
EMS+F+PD × Bangladesh soybean-4	61.90	7.26	3.60	43.00	1.65	5.42
EMS+F+PD × BARI soybean-5	55.70	8.30	3.84	25.36	1.75	8.68
LSD (at 0.05)	7.15	1.28	0.36	2.56	0.15	1.39

Table 6: Interaction effect of irrigation and variety on yield and harvest index of soybean

Irrigation × variety	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
With out irrigation (control) × Shohag	1015.93	1467.21	40.91
Without irrigation (control) × Bangladesh soybean-4	1100.51	1450.50	43.14
Without irrigation (control) × BARI soybean-5	1089.36	1430.86	43.22
Elongation of main stem (EMS) × Shohag	1273.54	1642.70	43.67
Elongation of main stem (EMS) × Bangladesh soybean –4	1353.06	1641.33	44.74
Elongation of main stem (EMS) × BARI soybean -5	1346.52	1588.63	45.88
Flowering (F) × Shohag	1563.78	1748.24	47.50
Flowering (F) × Bangladesh soybean-4	1718.91	1837.91	48.32
Flowering (F) × BARI soybean-5	1752.16	1900.33	47.97
Pod development (PD) × Shohag	1380.61	1610.03	46.16
Pod development (PD) × Bangladesh soybean-4	1443.62	1653.87	46.60
Pod development (PD) × BARI soybean-5	1445.89	1692.71	46.07
EMS+F+ PD × Shohag	2036.37	2150.13	48.64
EMS+F+PD × Bangladesh soybean-4	2136.38	2270.55	48.48
EMS+F+PD × BARI soybean-5	2140.10	2272.74	48.97
LSD (at 0.05)	176.7	259.7	4.111

soybean-5 and irrigation at elongation of main stem × Bangladesh soybean-4. However, the control irrigation showed lower level of plant height with all the three varieties. The lowest height was recoded with the treatment of no irrigation × shohag.

Significant variation was observed in number of branches plant^{-1} due to interaction effect of irrigation and variety (Table 5). The highest number of branches plant^{-1} (8.30) was found in irrigation applied at EMS+F+PD with BARI soybean-5. The lowest number of branches plant^{-1} (4.87) was found in no irrigation with shohag variety. However, irrespective of varieties irrigation application increased the production of number of branches plant^{-1} than the control (without irrigation).

There was a significant variation in pod length due to interaction effect of variety and time of irrigation and variety. The largest pod (3.84 cm) was found in the interaction of irrigation at EMS+F+PD × BARI soybean-5 fallowed by irrigation at EMS+F+PD × shohag, irrigation at flowering × BARI soybean-5, irrigation at EMS+F+PD × Bangladesh soybean-4, irrigation at pod development × BARI soybean-5 and irrigation at flowering × shohag periods which produced statistically similar pod length with the highest one (Table 5).

Interaction effect of irrigation and variety had significant influence on the number of pods plant^{-1} (Table 5). In general, irrigation application increased the number of pod plant^{-1} that was 18.60-158.41% increase

over control (without irrigation) irrespective of varieties. Irrespective of irrigation application, Bangladesh soybean-4 showed higher number of pod plant^{-1} (ranged 29.23-43.00) than other two varieties shohag (ranged 17.03-25.11) and BARI soybean-5 (ranged 16.02-25.36). Bangladesh soybean-4 produced the highest number of pods plant^{-1} (43.00) with irrigation at EMS+F+PD period and the lowest (16.02) number was recorded in BARI soybean-5 with control irrigation treatment. However, highest number of pod plant^{-1}(43.00) was counted in irrigation at EMS+F+PD × Bangladesh soybean-4 and that of lowest (16.02) was found in without irrigation × Bangladesh soybean-5.

Significant influence was found on number of seeds pod^{-1} due to interaction of irrigation and variety (Table 5). Three irrigations at EMS+F+PD with all the varieties increased the production of number of seed pod^{-1} than control (no irrigation) as well as other irrigation × variety treatment except irrigation at flowering × BARI soybean-5 and irrigation at pod development × BARI soybean-5. However, the lowest (1.31) number of seeds pod^{-1} was counted in shohag with without irrigation treatment.

The interaction effect of irrigation and variety on 100 seed weight was found significant (Table 5). Irrespective of irrigation treatment, significantly higher 100 seed weight was observed in shohag (ranged 8.27-4.73g) and BARI soybean-5 (ranged 8.07-8.68g) than Bangladesh soybean-4 (ranged 5.02-5.42g). On the other hand, irrigation treatment increased seed weight than the without irrigation treatment for all the three varieties. However, the variety shohag gave the highest 100 seed weight (8.7g) with irrigation applied at pod development period. The lowest 100 seed weight (5.10g) was found to produce in Bangladesh soybean-4 with irrigation applied at elongation of main stem.

The interaction effect of irrigation and variety on seed yield was significant (Table 6). The highest seed yield (2140.10 kg ha^{-1}) was obtained from variety BARI soybean-5 when irrigated at EMS+F+PD stages which was similar with the treatments irrigation at EMS+F+PD × Bangladesh soybean-4 (2136.38 kg ha^{-1}) and irrigation at EMS+F+PD × shohag (2036.38 kg ha^{-1}). The lowest seed yield (1015.94 kg ha^{-1}) was obtained from variety shohag with without irrigation applied treatment. The result indicated that the response of three varieties were different to different time of irrigation in the same location.

Significant influence was found on stover yield due to interaction of irrigation and variety (Table 6). Three irrigation at EMS+F+PD stages with all the varieties increased the production of stover yield than control (no irrigation) as well as other irrigation × variety treatment. However, the lowest (1430.86 kg ha^{-1}) stover yield was found to produce in BARI soybean-5 with no irrigation treatment.

There was a significant variation in harvest index due to interaction effect of time of irrigation and variety (Table 6). The highest harvest index (48.97%) was found in BARI soybean-5 with irrigation at EMS+F+PD periods followed by irrigation at EMS+F+PD × shohag, irrigation at flowering x shohag, irrigation at pod development × shohag, irrigation at elongation of main stem x Bangladesh soybean-4, irrigation at flowering × Bangladesh soybean-4, irrigation at pod development × Bangladesh soybean-4, irrigation at EMS+F+PD × Bangladesh soybean-4, irrigation at elongation of main stem × BARI soybean-5, irrigation at flowering x BARI soybean-5 and irrigation pod development × BARI soybean-5. These treatments also produced statistically similar harvest index with the highest one. The lowest harvest index (40.91%) was found in shohag variety with control (without irrigation) treatment.

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