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Yield potentials of recently released wheat varieties and advanced lines under different soil fertility

Md. Ilias Hossain[1], Md. Israil Hossain[1], M.A. Rahman[1], Md. Ashraful Haque[2], Sohel Hasan[3], Md. Shahidul Haque[3*]

[1]*Regional Wheat Research Center, Shyampur, Rajshahi, Bangladesh*

[2]*Department of Biotechnology, BSMRAU, Salna, Gazipur, Bangladesh*

[3]*Department of Biochemistry and Molecular Biology, Laboratory of Protein and Enzyme, Bangladesh*

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Abstract

An experiment was conducted to study the varietals/genotypic potentiality in producing maximum yield under different soil and environmental conditions and N-use efficiency of different genotypes and to support wheat breeding program in selecting the genotype with relatively higher yield potential. The experiment was conducted in split plot design with three replications to evaluate the two soil management practices: (i) Recommended fertilizer ($N_{100}P_{30}K_{50}S_{20}$) with all the production package of Wheat Research Center (WRC) (timely sowing, one weeding, 3 irrigations) (ii) Treatment (i) plus soil treatment (application of granular fungicide in moist soil before seeding) with plant protection (foliar application of tilt at anthesis and grain filling). One additional irrigation (schedules: 17-21, 35-40, 55-60, 75-80 DAS) in the main plot and eight varieties/lines, varities: i) Shatabdi ii) Prodip iii) Bijoy iv) BARI Gom-25 v) BARI Gom-26, lines: vi) BAW 1051 vii) BAW 1135 and viii) BAW 1141 in subplot were adopted. The results conclude that best management practice with Prodip, Bijoy and BAW 1141 are best performance among the genotypes/varieties and will give a new concept on identification of the strategy for the improvement of wheat cultivation and yield.

* **Corresponding Author:** Md. Shahidul Haque ✉ haque_drshahidul@yahoo.co.in

Introduction

Wheat is very nutritious food grain of all grains in the world and grows worldwide according to its genotypic adaptability. Accounting for a fifth of humanity's food, wheat is second after rice as a source of calories in the diets of consumers in developing countries and is first as a source of protein (Braun *et al.*, 2010). Wheat (*Triticum aestivum* L.) is the staple food for more than 35% of world population (Jing and Chang, 2003) and is the second main food of the people of Bangladesh also. Despite to higher yield potential, average yield of different varieties in Bangladesh is much less than the most countries of the world. To meet the increasing demand of food grains for rapidly growing population of the country, it is desired to have a higher yield per unit area. A number of factors, including, time of sowing, land preparation, seed bed preparation, fertilizer application, weed management, and irrigation scheduling are responsible for the variation in yield of wheat, but all these factors are agronomic and greatly influenced by temperature, rainfall and humidity. The vital factor for the harvesting suitable environment in grain yield is the genetic potential of the crops (Nadeem, 2001). It has been observed that reproductive processes are remarkably affected by high temperature in most plants, which ultimately affect fertilization and post-fertilization processes leading to reduce crop yield (Wahid *et al.*, 2007). Moreover, salinity is one of the major abiotic stresses that adversely affect crop productivity and quality (Chinnusamy *et al.*, 2005), especially in arid and semi arid regions (Bai *et al.*, 2011). Salinity affects many morphological, physiological and biochemical processes, including plant growth and nutrient uptake (Willenborg *et al.*, 2004). Although diverse factors cause impairment of wheat yield, it is necessary to find the strategy for selection of varieties of wheat to solve the problems

The introduction of new varieties with their high yield potential and wide range of adaptability is an important factor responsible for enhancing wheat production (Alam *et al.*, 2006). These varieties were shown to have higher biomass. Different varieties respond differently to varying environment and hence differ in their yield. Cultivars differed significantly due to difference in number of tillers m^{-2} (Jan *et al.*, 2003; Irfan *et al.*, 2005), number of grain spike^{-1} (Akmal *et al.*, 2000), 1000-grain weight (Silva and Gomes, 1990; Alam *et al.*, 2006) and grain yield (Nadeem, 2001). During the process of variety selection, trails in different agro-ecological zone are conducted under the general rate of fertilizer, other inputs and common production package. Thus the varietals potentiality to produce maximum yield remain unknown. Under the changed of global conditions, we already experienced that food may not be affordable through import from other countries. As plant responses to high temperature or other environmental conditions varies with plant species, varieties, locations and phenological stages, it is essential to observe the performance of advanced genotypes of wheat in respect of phonological traits. Depending on global food policy and production, it may need to maximize wheat production rather than economic yield. Therefore, the yield potentiality of newly developed wheat varieties and promising lines is needed to investigate in order to explore the varietals potentiality in maximizing wheat yield and to assist breeding program in selecting lines with higher yield potentials. The objectives of the current study are:

1. To investigate the varietals/genotypic potentiality in producing maximum yield under different soil and environmental conditions.

2. To estimate the input use efficiency of wheat genotypes.

3. To support wheat breeding program in selecting the genotype with relatively higher yield potential.

Materials and methods

Wheat (*Triticum aestivum* L.) is an important cereal crop used as staple food in Bangladesh. It is a principal source of carbohydrates for human beings while its straw is an integral part of livestock feed. Its grain contains carbohydrates 60-80%, protein 8-15 %, fat 1.5-2.0%, inorganic ions 1.5-2.0% and vitamins such as B complex and E. The plants are taller (approximately 104cm height) with longer and heavier panicle, higher 1000 grain weight and more grain and straw yield. The improvement of wheat cultivation in Bangladesh is an important aspect in wheat research however, is retarded by diverse environmental factors. Plants are constantly subjected to changes in their environment, causing them to alter their metabolism in order to maintain a steady-state balance between energy generation and consumption. This balance largely depends on a delicate signaling network of two important compartments of plants, the chloroplast and mitochondria.

A field experiment was conducted in the research field of the Regional Wheat Research Centre, Shyampur, Rajshahi, Bangladesh (24°3'N, 88°41E, 18 m above sea level). The site has a subtropical climate and is located in Agro Ecological Zone 11 (High Ganges River Flood Plan) on flood-free high land, with coarse-textured, highly permeable soil (BARC, 2005). The area receives 1,257 mm mean annual rainfall, about 97% of which occur from May to September. Total rainfall was highest during the mungbean season and lowest in the wheat season in all years. The experiment was laid out in split plot design with three replications. Two soil management practices were done: (i) Recommended fertilizer ($N_{100}P_{30}K_{50}S_{20}$) with all the production package of WRC (timely sowing, one weeding, 3 irrigations); (ii) Treatment (i) plus soil treatment (application of granular fungicide in moist soil before seeding) with plant protection (foliar application of tilt at anthesis and grain filling) and one additional irrigation (schedules:17-21, 35-40, 55-60, 75-80 DAS) in the main plot and eight variety/lines were i) Shatabdi ii) Prodip iii) Bijoy iv) BARI Gom-25 v) BARI Gom-26 vi) BAW 1051 vii) BAW 1135 and viii) BAW 1141 in sub plot. The size of the main plot was 15m × 5m (8 rows of each genotype will be grown 5m length considering as sub-plot). Seeds were sown in 25 November, 2010. Two-thirds of the N and all others fertilizers were applied in the final land preparation and remaining one-third of urea were applied at crown root initiation (CRI) (Zadoks growth stage 1.3). According to the treatments, all management practices were done in due time.

Statistical analysis of data

MSTAT-C (version 7.2) and Microsoft Excel and DMRT were used to measure the variation of mean data of treatments. Treatment means were compared at $P \leq 0.05$. The data were analyzed statistically following computer package MSTAT-C. All the data were statistically analyzed following the ANOVA technique and the significance of mean differences was adjusted by Duncan's Multiple Range Test.

Results and discussion

Analysis of soil composition

Before experimentation initial soil sample was collected and analyzed to know the nutrient status and the results were presented in Table 1. The soil was slightly alkaline (7.8 pH) having low organic matter content (0.94%) and the total N content is very low (0.05%). Different elements were also analyzed from the soil where medium K level (0.21 Meq/100 g) was observed. P, S and Zn contents in soil were 10, 23.3 and 0.14 μg/g respectively. In addition, the boron content was found to be very low (0.27 μg/g). The results regarding the soil composition and other parameters reveal that the overall soil fertility status was low. Therefore, fertilizer management may play the critical role in improving wheat cultivation and soil fertility. K, P and S are essential nutrients for the growth of wheat and other plants. A deficiency of these nutrients causes the severe impairment of plant production, also causes other pathogenic syndromes. Potassium is utilized by plants in the activation of enzymes and co-enzymes (specialized proteins serving as catalysts and co-factors), photosynthesis, protein formation, and sugar transport. K deficiency does not immediately result in visible symptoms (hidden hunger). Initially, there is only a reduction in growth rate, with chlorosis and necrosis occurring in later stages (Mengel and Kirkby, 2001). Plants require P for the development of ATP (energy), sugars, and nucleic acids. P deficiency symptoms are usually more noticeable in young plants, which have a greater relative demand for P than more mature plants. Cool soils during the early growing season may also be a factor causing P deficiency. P deficient plants generally turn dark green (both leaves and stems) and appear stunted. Phosphorus is also essential for cellular respiration, metabolism of starch and fats, which has been investigated by many researchers. Appropriate and balanced fertilization on wheat and rice not only causes yield enhancement, but also has good impact on phosphorus uptake of these crop plants (Rehman *et al*., 2006). Sulphur deficiency in crop plants has been recognized as a limiting factor not only for crop growth and seed yield, but also for the poor quality of products, because sulphur is a constituent of several essential compounds such as cysteine, methionine, coenzymes, thioredoxine and sulfolipids. Sulphur deficiency significantly affects the production and quality of winter wheat (Györi, 2005). Moreover, Zn and B are considered to the micronutrients and are substantial for the optimum growth of crops. Severe Zn deficiencies will cause leaves to turn gray white and fall prematurely or die. Because Zn plays a prominent role in internode elongation, Zn deficient plants generally exhibit severe stunting. Flowering and seed set is also poor in affected plants. Crop specific symptoms include smaller leaf size in alfalfa, gray or bronze banding on cereal leaves, reduced tiller production of wheat and other small grains, and abnormal grain formation (Wiese, 1993). Both zinc and boron are known to be required for all higher plants as essential crop nutrients and are well documented to be involved in photosynthesis, N-fixation, respiration and other biochemical pathways (Ali *et al*., 2009). Zinc, in addition, is reported to be having possible role in reducing the toxic effects of excessive boron (Singh *et al.,* 1990). Therefore, for wheat cultivation, these elements play the vital role in augmenting yield and growth.

Table 1. Fertility status of initial soil sample of the experimental site at RWRC, BARI, Rajshahi.

Sample	PH	OM (%)	Total N (%)	K	P	S	Zn	B
				Meq/100g		μg/g		
Value	7.8	0.94	0.05	0.21	10	23.3	0.14	0.27
Critical level	-	-	0.12	0.12	10	10.0	0.60	0.20
Interpretation	Slightly Alkaline	Very low	Very low	Medium	Low	Opt.	Very low	Very low

Management practices on yield and yield components

Spikes/m², grains/spike and grain yield were significantly influenced by the management practices (Table 2). Although yield components did not show any significant difference among the treatments, however appeared to be enhanced for best management practices. The highest grain yield (4.76 t/ha) was obtained from the best management practices and the lowest yield (3.97 t/ha) was found from the WRC recommended management. The maximum spikes/m² (334) was found from the best management practices and the minimum (305) was obtained from the WRC recommended management. The maximum grains/spike (51.7) was obtained from the best management practices and the minimum (49.3) was recorded from the WRC recommended practices. The information obtained from this research may be used to compare actual practices used by producers to recommended practices, to identify research and extension program needs, and to target extension programs to practices that deviate substantially from research-based recommendations. Variety selection is an important management decision. Some characteristics that may be used to select wheat varieties may induce wheat yield and yield attributes. The management practice recommended by the wheat research center in other countries similarly augment the cultivation of wheat and yield as demonstrated by Hossain *et al.* (2004).

Genotypic effect on plant/m² (with tillering)

Soil fertility and other environmental conditions have been found to be involved in affecting the growth and development of crops (Taheri *et al.*, 2012). These factors may induce growth related parameters like plant/m². In the current investigation, different varieties of wheat were examined regarding the development of plant/m² during 2010-2011. Plant/m² did not show any significant difference among the genotypes/varieties up to 40 DAS (Table 3). Plant/m² was increased with increase the days after sowing up to 40 DAS. The maximum plant/m² (585) including tiller was obtained from Bijoy variety followed by Shatabdi variety (574), 523 from BAW1135 genotype and 512 from BARI Gom 26 variety in 40 DAS. The lowest plant/m², 444 and 454 were obtained from Prodip and BARI Gom 25 varieties respectively. Similar trends were observed by Jan *et al.* (2003) and Irfan *et al.* (2005) who stated that different varieties respond differently due to differences in their genetic make-up, as far as the difference in different location was justified with change in agro-physiological and ecological conditions.

Table 2. Effect of different management practices on yield and yield attributes of wheat.

Managements	Spikes/ m²	Plant height (cm)	Spikelets/spike	Grains/spike	TGW (g)	Grain yield (t/ha)
M1 (WRC)	305 b	102	18.0	49.3 b	45.4	3.97 b
M2 (Best)	334 a	103	19.2	51.7 a	47.2	4.76 a
CV (%)	11.98	13.64	6.16	8.20	3.76	11.52
LSD (0.05)	11.573	NS	NS	0.124	NS	0.043

Table 3. Effect of genotypes/varieties on plant/m² (with tillering) stage of wheat in 2010-2011.

Genotypes	10 DAS	20 DAS	30 DAS	40 DAS
Shatabdi	81	197	370	574
Prodip	65	135	292	444
Bijoy	77	184	371	585
BARI Gom 25	68	153	293	454
BARI Gom 26	87	185	348	512
BAW 1051	75	172	338	471
BAW 1135	87	189	376	523
BAW 1141	83	187	331	457
CV (%)	25.06	19.53	14.55	14.84

Genotypic effect on phenological stage

Alteration of soil fertility and environmental temperature has been recognized to be involved in the regulation of plant growth and development. These abiotic stresses cause diverse alteration of the physiological process of the plant. Since higher temperature enhanced plant growth and forced the maturity, the different growth and development stages of all the wheat genotypes occurred earlier in high temperature compared to optimum temperature condition. In both the thermal conditions, plant growth of the genotypes showed small differences in early vegetative stages, but at and after the onset of stem elongation, significant differences were found among the genotypes. Therefore, the number of days to booting, heading, anthesis and maturity of wheat varied significantly due to genotypic variations. As shown in Table 4, booting and heading days were greatly influenced significantly among the genotypes/varieties, but anthesis and maturity days did not show any significant difference among the treatments. The maximum booting days (72 days) was obtained from Shatabdi variety while the minimum (65 days) was recorded from BAW1051 and BAW1135 genotype. The maximum heading days (78 days) was obtained from Shatabdi variety and the minimum (72 days) were obtained from BAW1141 and BAW1051 genotype respectively. The maximum maturity (116 days) days were obtained from Shatabdi and the minimum (110 days) was obtained from BAW1135 genotype. As demonstrated by Araus *et al.* (2007) that the environmental factors affect on the number of days required for the occurrence of different growth stages of wheat varied with genotypes. Under high temperature conditions, earlier heading is advantageous in the retention of more green leaves at anthesis, leading to a smaller reduction in yield (Tewolde *et al.*, 2006). Growth chamber and greenhouse studies suggest that high temperature is most deleterious when flowers are first visible and sensitivity continues for 10-15 days. Among the reproductive phases, fertilization (13 days after anthesis) is one of the most sensitive stages to high temperature in various plants (Foolad, 2005).

Table 4. Effect of genotypes/ varieties on phenological stage of wheat in 2010-2011.

Genotypes	Booting days	Heading days	Anthesis days	Maturity days
Shatabdi	72 a	78 a	84	116
Prodip	67 ab	75abc	79	111
Bijoy	68 ab	76 ab	81	114
BARI Gom 25	67 ab	75 abc	80	112
BARI Gom 26	67 ab	74 abc	80	111
BAW 1051	65 b	73 c	77	112
BAW 1135	65 b	74 bc	77	110
BAW 1141	66 b	74 bc	76	112
CV (%)	2.13	1.77	15.69	0.84
LSD (0.05)	1.132	0.3152	NS	NS

(%) Ground coverage

Ground coverage of different varieties was increased with increase the days of sowing up to anthesis stage and the values were then decreased (Table 5). The maximum ground coverage (%98) was found from Shatabdi variety and it was similar with BAW1141 genotypes. It was also followed by Bijoy (%95), BAW1135 (%96) and BAW1051 (%95). The minimum ground coverage (%90) was noticed about the variety of BARI Gom 25.

Table 5. Effect of genotypes/ varieties on (%) ground coverage at different growth stage of wheat.

Varieties/ Genotypes	10 DAS	20 DAS	30 DAS	40 DAS	Booting stage	Heading stage	Anthesis stage	Maturity stage
Shatabdi	10	34	62	88	93	97	98	83
Prodip	11	33	54	79	94	93	94	81
Bijoy	12	34	56	81	97	94	95	88
BARI Gom 25	10	24	43	68	77	88	90	78
BARI Gom 26	9	29	47	73	78	91	93	81
BAW 1051	13	36	54	75	83	94	94	79
BAW 1135	11	33	54	80	87	96	96	88
BAW 1141	9	29	49	71	76	94	97	83
CV (%)	6.76	21.8	16.19	12.02	7.60	4.97	4.16	6.22
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Yield and yield components

Grain yield and yield components were significantly influenced among the treatments for both the years (Table 6). The highest mean grain yield (5.32 t/ha), (5.32 t/ha), (5.17 t/ha) and (5.12 t/ha) were obtained from the interaction effect of best management with the genotypes of BAW 1135, 1141, Prodip and BAW 1051genotypes followed by (4.86 t/ha) and (4.83 t/ha) from best management with Bijoy and BARI Gom 26 genotypes respectively. The lowest mean grain yield (3.68 t/ha) from the WRC management with BARI Gom 25 variety was noted. Yield increases were 0.94, 0.85 and 0.81 t/ha from the genotypes of BAW 1135, 1141 and Prodip with best management practice respectively. Maximum 1000 grains weight (54.8 g) was found from Prodip variety and grains/spike (57.2, 57.2) was also found from best management with BAW 1135 and BARI Gom 26 variety respectively, and minimum 1000 grains weight (41.8 g) was obtained from WRC management with Shatabdi variety and grains/spike (41.8) was also found from BARI Gom 25 variety. Several lines of evidence have been demonstrated regarding the similar studies. Nadeem (2001) showed his results in conformity with this study and found significant differences among the different wheat varieties. Alam *et al.* (2006) and Irfan *et al.* (2005) also described significant differences for 1000-grain weight among wheat varieties at different locations because of the difference in the number of grains/spike and number of tillers/m^2 among different varieties. The differences in yield at different locations might be due to soil type and environmental conditions like temperature, humidity and rainfall. Stone and Nicolas (1995) and Gibson and Paulsen (1999) also reported the genotypic difference of grains/spike in response to high temperature. High temperature may affect the pollen viability and fertilization and thereby reduce the number of grains/spike. Individual grain weight, which considered as one of the major yield contributor was also significantly influenced by temperature. Higher temperature enhanced plant maturation causing reduction in grain growth duration (Rahman *et al.,* 2005) which ultimately resulted in small grains.

Table 6. Interaction effect of management and genotypes/varieties on the yield and yield contributing characters of wheat.

Management × Genotypes	Spikes/m^2	Grains/ spike	TGW (g)	Grain yield (t/ha)		Mean yield (t/ha)	Yield Increase (t/ha)
				2010-11	2011-12		
M1 × Shatabdi	273	46.2	41.8	3.68	4.60	4.14	-
M1 × Prodip	235	50.6	52.1	3.77	5.06	4.42	-
M1 × Bijoy	317	46.9	46.1	3.80	4.70	4.25	-
M1 × BARI Gom 25	267	41.8	47.5	2.92	4.43	3.68	-
M1× BARI Gom 26	299	51.2	46.6	3.27	4.96	4.12	-
M1 × BAW 1051	244	51.9	46.9	3.59	5.13	4.36	-
M1 × BAW 1135	307	51.4	46.4	3.40	5.04	4.22	-
M1 × BAW 1141	302	50.5	47.4	4.12	5.13	4.63	-
M2 × Shatabdi	331	49.7	39.6	4.08	5.36	4.72	0.58
M2 × Prodip	338	52.6	54.8	4.61	5.83	5.17	0.81
M2 × Bijoy	365	51.5	46.8	4.39	5.33	4.86	0.61
M2 × BARI Gom 25	303	46.0	48.8	3.43	4.97	4.20	0.53
M2 × BARI Gom 26	347	57.2	48.9	4.11	5.55	4.83	0.72
M2 × BAW 1051	370	55.4	49.8	4.58	5.66	5.12	0.51
M2 × BAW 1135	384	57.2	50.6	4.39	5.93	5.32	0.94
M2 × BAW 1141	339	56.6	51.8	4.58	5.76	5.32	0.85
CV (%)	11.98	8.20	3.76	11.52	9.67	10.23	
LSD (0.05)	27.53	4.753	0.235	0.653	1.367	1.154	

Conclusion

The results show that management practice is very important to produce higher yield of wheat and induces alterations of different yield attributes. Although different varieties of wheat were cultivated in Bangladesh, the potentiality of these varieties was remained unknown. Management practices including different agro-ecological zone with a rate of fertilizer, other inputs and common package were involved in identification of the good variety of wheat. Impairment of the management practice by diverse environmental or other stimuli cause the reduction of growth of the crops and other characteristics, thereby impairment of the regulation of crop yield. However, ongoing practice uses modified soil fertility caused by fertilizer management and other necessary elements thereby higher yielding of the wheat varieties. Among the varieties studied in the current research work, maximum yield was found from the best management practices with Prodip, BAW 1135 and BAW 1141 lines.

However, yield potential was higher in BAW 1135, 1141 and Prodip genotypes. Therefore, BAW 1135, 1141 and Prodip genotypes were recommended to be included to the best management practices.

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