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Performance of wheat with System of Wheat Intensification (SWI) using different nutrient management and plant spacing

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ABSTRACT

The study was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during the period from November 2011 to March 2012 to evaluate the performance of wheat under various nutrient management and plant spacing as a System of Wheat Intensification (SWI). A widely used wheat variety BARI GOM-24 (*Prodip*) was tested under the system. The treatments include (i) three nutrient doses viz. full recommended fertilizer (RF), full compost (12 t ha^{-1}) and 50% RF+50% compost (ii) two line spacing viz. 25 and 30 cm and (iii) three plant spacing viz. 10, 15 and 20 cm. The experiment was laid out in randomized complete block design with three replications. The main effects of fertilizer dose and interaction effect between fertilizer dose and line spacing, fertilizer dose and plant spacing and three-factor interaction i.e. fertilizer dose, line spacing and plant spacing were significant at $P<0.01$ for almost all yield attributes and grain yield of wheat. Full RF dose performed extraordinary for all the plant characters giving the highest number of tillers $plant^{-1}$ (5.58), the length of spike (11.32cm), the number of grains $spike^{-1}$ (46.92), grains (2.99 t ha^{-1}) and straw yield (5.26 t ha^{-1}). The grain yield reduced by 47.2 and 40.5% for using full compost and half RF and half compost dose, respectively. The most remarkable interaction effect of line and plant spacing is the production of the greater amount of biomass that eventually gave the highest grain yield (3.05 t ha^{-1}) for closer spacing (25×10 cm). The overall performance of wheat in respect of yield contributing characters and grain yield was much better for full RF dose irrespective of spacing indicating fertilizer nutrient plays the dominant role in improving plant performance. Comparing the conventional system of fertilization with other treatment combinations, full RF dose and closer spacing increased grain yield by 50.5% followed by 18.2% for full RF dose and closer plant spacing with wider line distance. The result suggests that adoption of SWI methods by maintaining appropriate plant spacing and nutrient management could greatly enhance wheat production in the subtropical regions.

INTRODUCTION

Wheat *(Triticum aestivum* L.) is one of the most important cereal crops in the world ranking first both in area and production of the grain crops (FAO, 2002). It is one of the world's most widely adopted food grain crops, which supplies more than 50% of the calorie needed for one-third of world population. In Bangladesh, the area under wheat cultivation was about 0.36 million hectares during 2011-2012 producing 0.99 million tons of wheat with an average yield of 2.78 tons per hectare (BBS, 2012). This average yield of wheat is much lower compared to advanced countries of the world (FAO, 2005). Low soil fertility and lack of fertilizer management are considered the major constraints of the low yield of the crop. The System of Wheat Intensification (SWI) method has a great potential to increase wheat productivity and creates a very good growing condition through modified soil, water, plant and nutrient management. SWI and some modified SWI intervention may give 54% more yield than the available best practices (Uphoff et. al., 2011; Adhikari 2012) and showed a better economic return (Raol, 2012). This is a system of modified agronomic practices such as lower seed rate, seed treatment, sowing of seeds at proper spacing, control of water in the crop field, weeding or hoeing outputs which result in higher ratio of tillers to mother seedlings, increased number of effective tillers $hill^{-1}$, enhance panicle length and bolder grains and finally enhanced yield of wheat. In the conventional system, farmers use about 100-140 kg ha^{-1} of seed, but in the SWI method,

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seed requirement is only 5%- 7.5% of this amount (Styger and Ibrahim, 2009).

In the System of Wheat Intensification, the nutrient management and spacing play a vital role in producing higher grain yield of wheat. Cow dung and compost with half of the recommended dose of chemical fertilizers showed a positive impact on soil physical properties and the yield of wheat, though the application of chemical fertilizers at recommended doses performed better. A suitable combination of organic and inorganic sources of nutrients is necessary for a sustainable agriculture (Reganold et al., 1990). Besides, optimum row spacing ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation and nutrient uptake as well as air space and water (Nazir et al., 1987). Chatha and Nazir (1984) found that 40 cm row spacing gave the higher yield in wheat cultivation while Oliveira and Bego (1983) suggested 25 cm row spacing is optimum for achieving higher yield. However, 20 to 30 cm row spacing is found to be superior by many authors (Singh and Uttam, 1995; Raj-Sing et al., 1992; Barthakur et al., 1979). Maximum yield of a particular crop in a given environment can be obtained at spacing where competition among the plants is minimum. This can be achieved with the optimum spacing which not only utilizes soil moisture and nutrients more effectively but also avoids excessive competition among the plants. Hence, optimum row spacing in SWI induces the plant to achieve its potential yield. The promotion of SWI has shown very good results in combating hunger among marginalized farmers. These technologies are supposed to reduce the dependency of the farmers on multi-national companies for seeds, fertilizers or for their livelihoods (Raut et al., 2010). A suitable combination of nutrient dose and spacing is necessary for higher yield of wheat under the SWI. Therefore, the present study was undertaken to formulate a package with a combination of nutrient dose and spacing in SWI, so that it will be technically effective and feasible, economically viable, socially acceptable and environmentally sound for the wheat production. Keeping above facts in mind the study was undertaken to assess the effect of nutrient management and plant spacing on the performance of wheat under System of Wheat Intensification and superior yield performance of wheat between SWI and conventional system.

MATERIALS AND METHODS

Experimental site and soil

The study was carried out during the period from November 2011 to March 2012 at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. The experimental site is located at the 24.75°N latitude and 90.50°E longitude at an elevation of 18 m above the mean sea level. The soil belongs to the non-calcareous dark grey floodplain under the Agro-ecological Region of the Old Brahmaputra Floodplain AEZ 9 (UNDP and FAO, 1988). The soil of experimental plot is silt loam in texture (32% sand, 60% silt, and 8% clay) having pH 6.80. Organic matter content was low (1.29%). The mineral content was as follows: total nitrogen 0.10 %, available P (Olsen) 16.7 ppm, exchangeable K 0.12 meq per 100 g soil, available S 14.2 ppm.

Treatment and experimental design

The experiment comprised of three factors (1) Factor A: Fertilizer doses: (i) F=100% recommended fertilizer (Urea: 220 kg ha^{-1}, TSP: 116 kg ha^{-1}, MP: 40 kg ha^{-1}, Gypsum: 100 kg ha^{-1}), (ii) C_1 = 100% Compost (12 t ha^{-1}) and (iii) 50% recommended fertilizer (Urea: 110kg ha^{-1}, TSP: 58 kg ha^{-1}, MP: 20 kg ha^{-1}, Gypsum: 50 kg ha^{-1}) + 50% Compost (6 t ha^{-1}); (2) Factor B: Line spacing (i) L_1=25 cm and (ii) L_2=30 cm; (3) Factor C: Plant spacing (i) S_1=10 cm, (ii) S_2=15 cm and (iii) S_3=20 cm. The experiment was laid out in a randomized complete block design with three replications. The total number of plots was 57. Out of 57 plots, 54 plots were with the area of 2.5×2.0 m and the rest 3 plots having the area of 2.5×4.0 m.

Planting materials

Wheat variety BARI GOM 24 (*Prodip*), developed by Bangladesh Agricultural Research Institute and released in 2005, was used as planting material. It is a high yielding variety and suitable for early and late planting (up to the second week of December).

This variety attains a height of 95-100 cm and it takes 64-66 days to heading and 105-112 days to mature. Tillers hill^{-1} 3-4, leaves are wide and deep green in color. Grains are white, light and large in size.

Crop establishment and management

The experimental field was ploughed and cross-ploughed three times by country plough followed by laddering to obtain the good tilth condition. All the weeds and stubbles were removed from the field and thus, the land was made ready for sowing. Prior to sowing seeds, the whole experimental area was divided into unit plots maintaining the desired spacing. Loosening of soil was done one day before planting for incorporating the fertilizers of basal dose. As per treatment, the total amount of TSP, MP and gypsum with one third of the urea was applied in each plot at the time of final land preparation and the fertilizers were mixed with soil thoroughly by spading. The rest urea was top dressed in two equal splits, one at crown root initiation stage and the other at booting stage. Seeds were sown in the well-prepared plots on 3 December 2011. A hand weeding was done at 25 days after sowing (DAS) and then another at 55 DAS. The experiment plot was irrigated twice i.e. first at the crown root initiation stage (22 DAS) and second at the tailoring stage (42 DAS).

Crop harvesting

At maturity, the experimental crops were harvested plot-wise on 21 March 2012. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The bundles were dried to open the sunshine, threshed and then grains were cleaned. The grain and straw yields were taken plot-wise and converted into t ha^{-1}. The grain and straw yields were recorded after sun drying to the constant weight.

Sampling and data collection

Ten plants were selected randomly for collecting data on plant characters and yield attributes and uprooted from unit plot prior to harvesting. Data were recorded on plant height, total number of tillers plant^{-1}, the number of effective tillers plant^{-1}, the number of non-effective tillers plant^{-1}, the length of spike (cm), the number of spikelets spike^{-1}, the number of grains spike^{-1}, weight of 1000-grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), harvest index (%). Tillers having at least one visible leaf were counted and it included both productive and non-bearing tillers. The presence of any food materials in the spikelet was considered as grain and the total number of grains in each spikelet was counted. The grain was measured from 1m^2 area in each plot (14% moisture content) and was converted into t ha^{-1}. The sun-dried straw was weighed from the same sample area harvested for grain yield. Harvest index is the ratio of economic yield to biological yield i.e. grain and straw yield multiplied by 100.

Statistical Analysis

All data were statistically analyzed using analysis of variance (ANOVA) technique as applicable for three factorial RCB design with the help of computer package MSTATC and significance of mean difference were adjudged by Duncan's Multiple Range test (DMRT) as laid by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant characters

The data set for all plant characters was statistically analyzed considering fertilizer dose as a source of variation in addition to the line and plant spacing. It has been observed that the main effects of fertilizer dose and interaction effect between fertilizer dose and line spacing, fertilizer dose and plant spacing and three-factor interaction i.e. fertilizer dose, line spacing and plant spacing were significant ($P < 0.01$) for the number of grains per spike, grain and straw yield and harvest index. However, the main and interaction effects of the three factors were also significant for the tillers per plant and spike length but other cases i.e. main effect of line spacing, fertilizer and plant spacing for spike length, line spacing and plant spacing for both the characters and fertilizer dose, line and plant spacing for the number of tillers were insignificant. Computed-F values for some of the important parameters are shown in Table 1.

Table 1
Computed F values from analysis of variance (ANOVA) of crop characters, yield and yield components of wheat.

Source of variation	df	Tillers plant^{-1}	Spike length (cm)	Grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Fertilizer dose (A)	2	7.20**	14.37*	146.2**	10.54**	21.18**	74.96**
Line spacing (B)	1	0.04^{NS}	0.52**	1.23**	3.73**	8.47**	24.42**
A × B	2	0.25**	0.45**	4.25**	0.08**	0.55**	18.16**
Plant spacing (C)	2	0.30**	0.31**	6.13**	5.53**	15.31**	8.98**
A × C	4	0.10**	0.10^{NS}	2.29**	0.46**	0.57**	17.77**
B × C	2	0.07^{NS}	0.06^{NS}	6.84**	0.08**	0.21**	9.59**
A × B × C	4	0.05^{NS}	0.35**	1.18**	0.13**	0.61**	26.61**

** = Significant at 1% level of probability; ^{NS} = Not significant

Table 2
Effect of nutrient management on the performance of wheat under system of wheat intensification.

Treatments	Tillers plant^{-1}	Spike length (cm)	Grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
F	5.58a	11.32a	46.92a	2.99a	5.26a	36.03a
C_1	4.35c	9.63c	41.24c	1.58c	3.34c	31.95c
C_2	4.70b	9.95b	43.62b	1.78b	3.43b	34.12b
$LSD_{0.05}$	0.125	0.132	0.186	0.021	0.037	0.119
CV%	3.16	2.31	0.58	1.27	1.36	1.30

F= Recommended Fertilizer (Urea: 220 kg ha^{-1}, TSP: 116 kg ha^{-1}, MP: 40 kg ha^{-1}, Gypsum: 100 kg ha^{-1}), C_1= 100% Compost (12 t ha^{-1}), C_2= 50% Recommended Fertilizer (Urea: 110kg ha^{-1}, TSP: 58 kg ha^{-1}, MP: 20 kg ha^{-1}, Gypsum: 50 kg ha^{-1}) + 50% Compost (6 t ha^{-1})
LSD=Least Significant Difference; CV = Co-efficient of variation
In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letters differ significantly (as per DMRT)

Nutrient management effect on wheat

The effect of nutrient management on the performance of wheat under System of Wheat Intensification (SWI) is illustrated in Table 2. Full recommended fertilizer (full RF) dose performed extraordinary for all the plant characters giving the highest number of tillers plant^{-1} (5.58), the length of spike (11.32cm), the number of grains spike^{-1} (46.92), grains yield (2.99 t ha^{-1}) and straw yield (5.26 t ha^{-1}). Half recommended fertilizer (half RF) dose performed very poorly in respect of all yield attributes and grain yield. However, the use of full compost (12 t ha^{-1}) improved plant characters and grain yield to some extent. It is most striking that grain yield reduced by 47.2 and 40.5% for using full compost, and half RF dose and half compost dose, respectively. The correlation coefficient were highly significant between yield attributes and grain yield that eventually contributed greatly to obtain the highest grain yield in the treatment received full fertilizer. The highest harvest index was found in plants applied with full fertilizer. This indicates better assimilates translocation from vegetative plant parts to reproductive part and grain. Saifuzzaman et al. (2011) observed that the grain yield of wheat increased by 4.0 t ha^{-1} with recommended fertilizer application under SWI method.

Table 3
Interaction effect of line and plant spacing on performance of wheat under system of wheat intensification.

Treatments	Tillers plant^{-1}	Spike length (cm)	Grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
L_1×S_1	4.84	10.44	43.60c	3.05a	5.35a	35.66a
L_1×S_2	4.89	10.29	44.21b	2.25c	4.45c	33.25d
L_1×S_3	4.98	10.47	43.52c	1.83d	3.43d	35.21b
L_2×S_1	4.72	10.16	42.93d	2.38b	4.59b	33.91c
L_2×S_2	4.76	10.06	44.09b	1.76e	3.42d	33.52cd
L_2×S_3	5.07	10.40	45.21a	1.42f	2.83e	32.65e
$LSD_{0.05}$	NS	NS	0.245	0.030	0.030	0.425
CV%	3.16	2.31	0.58	1.27	1.36	1.30

L_1= 25cm, L_2= 30cm, S_1= 10cm, S_2= 15cm and S_3= 20cm
NS = Not significant; LSD=Least Significant Difference; CV = Co-efficient of variation
In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letters differ significantly (as per DMRT).

Line and plant spacing effects on wheat

The interaction effect of line and plant spacing on the performance of wheat under SWI is given in Table 3. From Table, it is evident that the interaction between line and plant spacing were not statistically significant for the production of tillers and spike length. However, Adhikari (2013) showed that the numbers of tillers hill^{-1} and spike length were significantly higher in SWI method compared to line sowing and broadcast practices. The most remarkable interaction effect of line and plant spacing is the production of the greater amount of biomass that eventually gave the highest grain yield (3.05 t ha^{-1}) for closer spacing (25×10 cm). Barthakur et al. (1979) suggested maintaining 25 cm row spacing for getting higher grain yield in wheat. Closer spacing also showed the highest harvest index indicating better assimilate translocation to the grain. Interestingly, the number of grain per spike and tillers per plant was the highest for wider spacing (30×20 cm) but giving poor straw and grain yield. The plausible explanation of this is that the wider spacing may reduce the total plants per unit area resulting to a lesser amount of biomass production and eventually had poor grain yield. Styger and Ibrahim (2009) also claimed that wider spacing retained empty space between plants and reduced grain yield. The results reveal that the closer spacing would be better for higher grain yield, even reduced line spacing or plant spacing may increase grain yield to some extent. In this issue, Kumar et al. (2015) and Adhikari (2013) reported that SWI at closer spacing produced significantly higher grain yield compared to SWI at wider spacing.

Fertilizer management and plant spacing effects on wheat

The interaction effect of nutrient management and plant spacing and conventional system of fertilization on the performance of wheat under SWI is illustrated in Table 4. The maximum number of tillers per plant, the spike length and the grains per spike was obtained from wider spacing with full RF dose, whereas the highest straw and grain yield was found for closer spacing. The overall performance of wheat in respect of yield contributing characters and grain yield was much better for full RF dose irrespective of spacing indicating fertilizer nutrient plays the dominant role in improving the performance of the plant. A full dose compost performed a bit better compared to half RF dose with half compost. However, line and plant spacing had a significant influence on the performance of wheat. It is evident that wider spacing always showed better performance in increasing the number of tillers, the spike length and grains per spike, whereas closer spacing gave much higher straw and grain yield irrespective of fertilizer management. Reducing line distance or plant spacing increased plant performance indicating plant spacing need to be carefully maintained along with proper fertilizer management for better grain production in wheat.

The yield components and grain yield for the conventional system of fertilization were compared with other treatment combinations in the study. The full RF dose and closer spacing increased grain yield by 50.5% but full RF dose and closer plant spacing but wider line distance increased by 18.2%. Grain yield also increased to some extent for full RF dose and closer line distance and medium plant spacing. SWI techniques were found to increase 18 to 67% grain yield in wheat at farmers field as compared to the broadcast method (Abraham et al., 2014). In Nepal, comparing SWI results with those from local practices reported an average grain yield increase of 91% with the adoption of SWI technology (Khadka and Raut 2012). Recently, Dhar et al. (2016) reported that System of Wheat Intensification (SWI) is a potential technique for improving wheat yield similar to the System of Rice Intensification (SRI) practiced in rice.

Table 4
Interaction effect of nutrient management and plant spacing on the performance of wheat under system of wheat intensification.

Treatments	Tillers $plant^{-1}$	Spike length (cm)	Grains $spike^{-1}$	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index (%)
Con. syst.	4.60	10.50	48.10	2.91	5.16	36.05
$F \times L_1 \times S_1$	5.60	11.40ab	46.92bc	4.38a	6.62a	39.83a
$F \times L_1 \times S_2$	5.47	10.93c	46.63c	2.90c	5.32c	35.30de
$F \times L_1 \times S_3$	5.60	11.37ab	45.60d	2.66d	5.19d	33.86gh
$F \times L_2 \times S_1$	5.40	11.17bc	47.20b	3.44b	6.40b	34.84ef
$F \times L_2 \times S_2$	5.67	11.37ab	47.07bc	2.42e	4.26fg	36.26c
$F \times L_2 \times S_3$	5.73	11.67a	48.10a	2.13g	3.77i	36.09c
$C_1 \times L_1 \times S_1$	4.33	9.60fg	40.20k	2.14g	4.34f	33.03i
$C_1 \times L_1 \times S_2$	4.47	9.70fg	42.00i	1.62j	3.76i	30.12j
$C_1 \times L_1 \times S_3$	4.73	10.17de	40.60k	1.54k	2.52m	38.14b
$C_1 \times L_2 \times S_1$	4.03	9.70fg	40.30k	1.94h	3.90h	33.16hi
$C_1 \times L_2 \times S_2$	3.93	9.10h	41.30j	1.25m	3.13k	28.52k
$C_1 \times L_2 \times S_3$	4.60	9.53g	43.07h	0.97o	2.39n	28.75k
$C_2 \times L_1 \times S_1$	4.60	10.33d	43.67g	2.63d	5.07e	34.13fg
$C_2 \times L_1 \times S_2$	4.73	10.23de	44.00fg	2.22f	4.24g	34.33fg
$C_2 \times L_1 \times S_3$	4.60	9.87efg	44.37ef	1.30l	2.57m	33.62ghi
$C_2 \times L_2 \times S_1$	4.73	9.60fg	41.30j	1.77i	3.47j	33.73ghi
$C_2 \times L_2 \times S_2$	4.67	9.70fg	43.90g	1.60j	2.87l	35.79cd
$C_2 \times L_2 \times S_3$	4.87	10.00def	44.47e	1.15n	2.317n	33.11hi
$LSD_{0.05}$	NS	0.394	0.425	0.052	0.091	0.736
CV%	3.16	2.31	0.58	1.27	1.36	1.30

F= Recommended Fertilizer (Urea: 220 kg ha^{-1}, TSP: 116 kg ha^{-1}, MP: 40 kg ha^{-1}, Gypsum: 100 kg ha^{-1}), C_1= 100% Compost (12 t ha^{-1}), C_2= 50% Recommended Fertilizer (Urea: 110kg ha^{-1}, TSP: 58 kg ha^{-1}, MP: 20 kg ha^{-1}, Gypsum: 50 kg ha^{-1}) + 50% Compost (6 t ha^{-1}), L_1= 25cm, L_2= 30cm, S_1= 10cm, S_2= 15cm and S_3= 20cm
Con. syst. = Conventional system

NS = Not significant; LSD=Least Significant Difference; CV = Co-efficient of variation

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letters differ significantly (as per DMRT).

From the results, it is evident that better yield attributes and grain yield of wheat could be attained only when full recommended fertilizer dose is applied. In addition, closer line and plant spacing ensure better utilization of soil, water and above ground resources and increased grain yield. Therefore, the maintenance of full recommended fertilizer is essential for getting full potential benefit from SWI method. Further studies directing to evaluate the whole system productivity including residual effects of using full RF dose on succeeding crops is recommended as an additional benefit of SWI technique in particular.

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