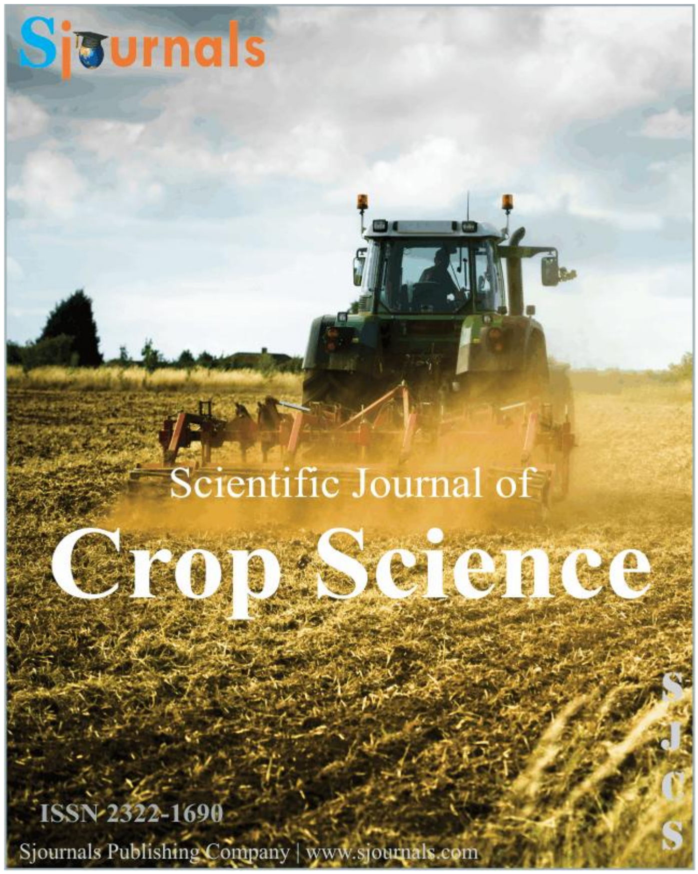
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Original article

Determination of seed rate of wheat (*Triticum aestivum* L.) varieties with varying seed size

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An experiment was conducted with three seed rates (100, 120 and 140 Kg ha^{-1}) and five varieties (BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28) in the rabi season of 2012-13 in the research field of Wheat Research Centre, Bangladesh Agricultural Research Institute, Dinajpur, Bangladesh to determine the optimum seed rate for newly released varieties. As factorial arrangement the experiment was laid out in a randomized complete block design with three replications. All agronomic practices were applied as per recommendation. The highest grain yield was found in BARI Gom 26, which is medium sized seeded variety. The bolded seeded variety BARI Gom 24 and BARI Gom 25 failed to produce higher grain yield due to lower number of spikes per m^2 and lower number of grains per spike. A seed rate of 140 kg ha^{-1} produced the highest yield traits and grain yield across all the varieties, but there was no statistical difference with the seed rate of 120 kg ha^{-1}. The performance of yield traits and yield of the wheat varieties varied with the seeding rates. Therefore, the seed rate of the variety BARI Gom 24, BARI Gom 26 and BARI Gom 28 can be considered as 140 kg seed ha^{-1} and the variety BARI Gom 25 and BARI Gom 27 can be considered as 120 kg seed ha^{-1}.

1. Introduction

Wheat (*Triticum aestivum* L.) is a widely adapted crop grown in warm, humid to dry and cold environments. It is foremost among cereals and stands first globally in terms of production and acreage (FAO, 2016). It is the second most important cereal crops next to rice in Bangladesh. However, the average yield of wheat (3.08 t ha^{-1}) in Bangladesh is lower than other wheat-growing countries like Egypt (5.10 t ha^{-1}), around the world (FAOSTAT, 2016). The potential yield of wheat varieties is 4.0 to 5.5 t ha^{-1} but in farmers' fields (national average) it is 3.08 t ha^{-1} (AIS, 2016). The reason for this gap in yield between farmers' and research fields is the lack of awareness among farmers about the use of proper agronomic management involving variety, sowing time, seed rate, balanced dose of fertilizers and other factors associated with crop production. Among them seed rate along with varying seed size is the most important agronomic practice which significantly influenced the grain yield of wheat (Sarker et al., 2007). Numerous studies have documented how seeding rate, row spacing, and seeding depth affect yield and yield components of wheat (Wajid et al., 2004; Guberac et al., 2005; Schillinger, 2005; Kristó et al., 2007; Maric et al., 2008; Otteson et al., 2008; Valério et al., 2009). Seeding rates for winter wheat can vary widely due to differences in seed quality (seed size), planting conditions, planting dates planting methods (Lloveras et al., 2004). Plant population is one of the major factors determining the ability of the crop to capture resources. There has been interest in defining the relationships between seed rate and crop yield quantitatively in order to establish optimum populations and maximum attainable yields under various situations. Therefore, the effect of density on wheat plant size and crop productivity has received attention.

Wheat Research Centre (WRC) recently under Bangladesh Agricultural Research Institute (BARI) developed new high yielding varieties of wheat. Some of these have bolder grain and some have smaller grain size than previously released varieties. It is reported that the varieties with bolder seed failed to produce the expected higher yield even with higher seed rate (WRC, 2004). New wheat varieties are more productive and some of them are of higher quality than the old ones. Therefore, their total technological requirements, planting density being one of them, are diverse, due to which they need to be continuously examined for determining their requirements in specific conditions (Bokan and Malesevic, 2004; Caglar et al., 2011). For getting maximum (or optimium) yield, seed rate for varieties having medium to large sized seed i.e., BARI Gom 20 (Gourab), BARI Gom 21 (Shatabdi), BARI Gom 23 (Bijoy) and BARI Gom 20 (Prodip) might be 120 kg ha^{-1} and that for the variety with small sized seed i.e., BARI Gom 22 (Sufi) might be 100 kg ha^{-1} (Sarker et al., 2007). A common seed rate of 120 kg ha^{-1} is used for all the varieties (Razzaque et al., 2000; Islam et al., 2004). But farmers are using very higher seed rate, sometimes even double of the recommendation for controlling weed, repeling birds and expecting higher yield. It is found that varieties having large seed size, seed rate should be used higher and varieties having smaller seed size, seed rate should be used lower. We should observe that generally, farmers yield is lower compare to research field due to shorter spike length and lower number of grains per spike resulted mostly from higher plant density. Therefore, the present piece of research work was conducted to determine the optimum seed rate for newly released varieties with verifying the existing seed rate for newly released varieties and minimizing the cost of seed for wheat cultivation.

2. Materials and methods

The experiment was conducted in the rabi season of 2012-13 in research field of Wheat Research Centre (WRC), Bangladesh Agricultural Research Institute (BARI) Nashipur, Dinajpur, Bangladesh. The area is situated in Agro Ecological Zone (AEZ) of Old Himalayan Piedmont Plain (AEZ-1) (FAO and UNDP, 1988). The geographical position of the area is between 25°38´ N, 88°41´ E and 38.20 m above sea level. The soil is sandy-loam and reaction is strongly acidic (pH ranges from 4.5 to 5.5). The organic matter content of the soil is 1.0% and fertility is poor (Bodruzzaman et al., 2005).

A two factorial experiment with three seed rates and five varieties was laid out in randomized complete block design with three replications. The seed rates were 100, 120 and 140 Kg ha^{-1}. The varieties were BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28. Thousand-grain weights of these varieties are 48-55, 54-58, 48-52, 38-42 and 42-44 g, respectively. Unit plot size was 3m × 3 m. Furadan 5G was broadcasted @ 10 kg ha^{-1} for controlling soil borne insect. A blanket dose of N-P-K-S-B-Zn @ 100-27-50-20-1-1.25 kg ha^{-1} was applied as basal to the experimental plot from urea, TSP, MoP, gypsum, boric acid and zinc sulphate, respectively. All of TSP, MoP, gypsum, boric acid, zinc sulphate and two-third of urea were used as basal during final land preparation. Rest urea was applied as top-dress at 18 days after sowing (DAS) followed by irrigation. Provax-200 treated seeds of five wheat varieties were sown in lines 20 cm apart on 21 November 2013, at the rate in accordance with the treatment. Natural mulching was done at 28 DAS. Four irrigations were made at 18, 50, 73 and 88 DAS. A hand weeding was done at 45 DAS.

Initial plant populations were recorded at 12 DAS. Tiller production was recorded at 30, 40 and 50 DAS. Numbers of spikes per m^2, plant height and spike length (cm) were recorded at physiological maturity stage. Yield and other yield attributes were recorded after harvesting the crop. Crop was harvested on 24 March 2013. Yield sample was taken from 2.5 m × 2.5 m area, avoiding border effect and the plants were cut at ground level. The grain yield and 1000-grain weight was adjusted to 12% moisture. Straw yield was taken sun-dry basis.

Recorded data were tabulated in proper form for statistical analysis and analyzed by analysis of variance with the help of computer package MSTAT (Gomez and Gomez, 1984). Mean differences among the treatments were compared with the Duncan's Multiple Range Test (Duncan, 1955).

3. Results and discussion

Among the varieties the tallest plant was found from BARI Gom 25, followed by BARI Gom 24, BARI Gom 27, BARI Gom 26 and BARI Gom 28 but seed rate did not affect plant height significantly (Table 1). Sarker et al. (2009) reported that seed rate did not affect the plant height of wheat significantly. The highest number of plants per m^2 was found in BARI Gom-27 and the lowest in BARI Gom 25, which was statistically similar with BARI Gom 24, might be due to seed size was smallest in BARI Gom 27 and biggest in BARI Gom 25 and also BARI Gom 25. Plant population was depended on seed size i.e., number of plants per unit area was higher in a variety, which had smaller seed. The number of plants m^{-2} increased with the increasing seed rate and the highest number of plants m^{-2} (270.73) was from 140 kg ha^{-1} and the lowest (192.27) was from 100 kg ha^{-1} (Table 1). This result is in conformity with the findings of Sarker et al. (2009) who stated that plant population depended on the seed size i.e., number of plants per unit area was higher in a variety, which had smaller seed, and obviously it increased with the increase in seed rate.

Number of tillers per m^2 at 30 DAS was found higher in BARI Gom 27 lower in BARI Gom 24 and it also increased with the increase in seed rate and the highest number of tillers per m^2 was recorded at 140 kg seed ha^{-1}. However, the increasing rate of tillers per unit area was less compared to increasing rate of plant population. Number of tillers per m^2 at 30 DAS was highest in BARI Gom 27 suggest that it has more tiller producing potentiality and number of tillers per m^2 at 30 DAS was lowest in BARI Gom 24 reveal that it seed size was large, so plant population per unit area was less and also tiller producing capacity was less (Table 1). Number of tillers per m^2 at 40 DAS followed the similar trend. Number of tillers per m^2 was increased at 40 DAS than 30 DAS but the increasing rate was slow in all the varieties except BARI Gom 27, it also revealed again that tiller producing potentiality is maximum in BARI Gom 27 than all other varieties. Number of tillers per m^2 was decreasing at 50 DAS than 40 DAS in all the varieties except BARI Gom 28, it revealed that secondary tillers was produced in BARI Gom 28 and competition among tillers started after maximum tillering stage (40-45 DAS) so some tiller was disappear.

Although secondary tillers was produced in BARI Gom 28, at 50 DAS highest number of tillers per m^2 was found from BARI Gom 27 and lowest in BARI Gom 24 and highest number of tillers per m^2 was found from 140 kg seed ha^{-1} (Table 1). These results are in conformity with the finding of Jan et al. (2000), Malik et al. (2009) and Sarker et al. (2009) who obtained the highest number of tillers per m^2 by using the highest seed rate. Tunis et al. (1995) found increase in spike number at higher wheat densities established better crop and good competition with weeds. Consequently, more tillers m^{-2} was obtained. Ahmad et al. (1999) confirmed the present results, who reported that higher sowing rates increased the number of tillers m^{-2} due to more number of seeds sown and numbers of plants emerged, but tillers per seedling decreased with increased in seed rate. Arnon (1972) reported that when all the production factors are equal, the only means of increasing productivity is to use genotypes with a greater adaptation to high plant densities.

Significantly higher number of spikes per m^2 was observed in varieties BARI Gom26, BARI Gom 27 and BARI Gom 28 and the lowest was found in and BARI Gom 24 (Table 2). The number spikes per m^2 was the highest, due to the highest plant population. Lower plant population in BARI Gom 24 attributed to lower number of spikes per m^2. Number of spikes per m^2 increased with the increase in seed rate.

Table 1
Growth parameters of wheat as influenced by seed rate and variety.

Treatments	Plant height (cm)	Number of plants m^{-2}	Number of tillers m^{-2}		
			30 DAS	40 DAS	50 DAS
Seed rate (kg ha^{-1})					
100	98.79	192.27c	365.00b	404.60b	397.60b
120	99.03	234.40b	397.67ab	430.93	425.20ab
140	98.46	270.73a	416.27a	445.53a	430.47ab
Level of significance	NS	**	**	**	**
Variety					
BARI Gom 24 (48-55)	100.11b	199.44c	304.11c	310.67c	305.89c
BARI Gom 25 (54-58)	101.56a	193.11c	324.89c	328.44c	322.22c
BARI Gom 26 (48-52)	97.23c	248.33b	418.22b	456.67b	439.89b
BARI Gom 27 (38-42)	99.95b	286.00a	560.67a	607.33a	578.11a
BARI Gom 28 (42-44)	94.95d	235.56 b	357.00c	432.00b	442.67b
Level of significance	**	**	**	**	**
CV (%)	0.79	10.65	10.63	7.82	6.42

Figures in the parentheses indicate the thousand grain weigh (g) of the variety. Figures within a column, for a factor, followed by the same letter(s) are not significantly different at 5% level by DMRT. **, * and ns; significant at 1 and 5% level, and not significant, respectively.

Sarker et al. (2009) reported that the number of spikes per unit area was increased with the increase in seed rate upto 140 kg ha^{-1} and the increasing rate of spikes per unit area was less compared to increasing rate of plant population. This trend indicates that in higher seed rates competition among the plants started before maximum tillering stage, which was manifested in low increase in tiller and spike production. Sarker et al. (2007) also reported the similar trend in wheat varieties. BARI Gom 24 produced the longest spike, followed by BARI Gom 25, BARI Gom 27, BARI Gom 26 and BARI Gom 28. Seed rate significantly influenced the spike length in this study, but there were no significant differences between the seed rates of 100- 120 kg ha-1 in producing spike length. Seed rate more than 120 kg ha^{-1} significantly reduced the spike length. This result is in line with the findings of Sarker et al. (2009) who observed that spike length gradually decreased with increasing seed rates from 80-160 kg ha^{-1} but there was no significant difference of spike lengths within the seed rates of 80-120 kg ha^{-1} i.e. seed rate more than 120 kg ha^{-1} remarkably reduced the spike length.

There were significant differences among the varieties for number of spikelets per spike and the highest number of spikelets per spike was obtained in BARI Gom 24 followed by BARI Gom 25, BARI Gom 26, and BARI Gom 27 and the lowest at BARI Gom 28. Seeding rate had a significant effect on the number of spikelets per spike and it decreased with the increase in seed rate. It is reported that number of spikelets per spike was found higher in BARI Gom 22 (Sufi) and BARI Gom 24 (Prodip) compared to BARI Gom 21 (Shatabdi), and it decreased gradually with the increasing seed rate from 80 to 160 kg ha^{-1} (Sarker et al., 2009). Significantly the highest number of grains per spike was recorded at BARI Gom 26 but there was no difference among the varieties of BARI Gom 24 BARI Gom 5BARI and Gom 27 BARI Gom 28 (Table 2). Grains per spike also increased gradually with increasing seed rate and the highest grains per spike were recorded at 140 kg ha^{-1} seed rate, although no statistical difference was observed similar with 120 kg seed ha^{-1}. Sarker et al. (2009) reported that BARI Gom 22 (Sufi) produced significantly the highest number of grains per spike than BARI Gom 24 (Prodip) and BARI Gom 21 (Shatabdi) varieties, but the number of grains per spike decreased gradually with the increase in seed rate. Malik et al. (2009) did not find any significant effect of using different seed rates on number of grains $sipke^{-1}$. There was significant effect among the varieties on 1000-grain weight. The highest 1000-grain weight was recorded in BARI Gom 24 and it was statistically similar with BARI Gom 25 followed by BARI Gom 26, BARI Gom 28 and BARI Gom 27. The lowest 1000-grain weight was produced in BARI Gom 27. Lloveras et al. (2004), Otteson et al. (2007), Abd El-Wahed et al. (2015) EL Sabagh et al. (2015) and Barutçular et al. *(*2016) found that 1000-grain weight was significantly affected by environment and variety. There was a significant effect of using different seed rates on 1000-grain weight of wheat crop and it decreased with increasing seed rate. The heaviest 1000-grain weight (50.257 g) was recorded, when 100 kg ha^{-1} of seed rate was used, whereas the lightest 1000-grain weight (49.336 g) was observed when 150 Kg ha^{-1} seed rate was used. These results are in conformity with the findings of Baloch et al. (2010); Laghari et al. (2011), who stated that by increasing showing that higher seeding rate decreased 1000-grain weight.

The highest grain yield obtained from BARI Gom 26 and the lowest from BARI Gom 25. The second highest grain yields were statistically similar at BARI Gom 27, BARI Gom 28 and BARI Gom 24 but numerically higher in BARI Gom 27. The highest yields in BARI Gom 26 were attributed by the higher number of spikes per m^2 and higher number of grains per spike. The highest grain yield was observed from 140 kg seed ha^{-1} and it was statistically similar with 120 kg seed ha^{-1}. Although the thousand grain weight of BARI Gom 24 and BARI Gom 25 was highest i.e. seed size was largest, but grain yield was lower because of lower number of spikes per m^2 and lower number of grains per spike. The difference in the grain yield of wheat varieties might be due to the difference in their photosynthetic efficiency. Grain yields were reduced significantly with the seed rates lower than 120 kg seed ha^{-1} might be due to lower seed rate produces lower tillers that came later failed to compensate the plant population. For this reason, seed rate less than 120 kg ha^{-1} failed to produce comparable yields. Although the interaction effect of variety and seed rate was not significant, highest grain yield was obtained from BARI Gom 26 at 100, 120 and 140 kg seed ha^{-1}. Hussain et al. (2010) reported that grain yield increased as seed rate was increased from 50 kg to 150 kg ha^{-1} and thereafter decreased slightly at the highest seed rate (200 kg ha^{-1}). A seed rate of 100 kg/ha produced the highest grain yield of wheat in Pakistan, where duration of winter is longer than Bangladesh (Khan, 2003). Caglar et al. (2011) seeding rates had significant impacts on the yield of wheat. Various sowing rates had a highly significant influence on the number of fertile tillers (Wajid et al., 2004), and that sowing rate influences mainly of number of spikes per square meter, which has the closest relationship to yield from all yield components (Lloveras et al., 2004; Lithourgidis et al., 2006; Ozturk et al., 2006). The yield advantages of BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27 and BARI Gom 28 at seed rate 140 kg ha^{-1} over 120 kg seed ha^{-1} was 467, 63, 158, 23 and 352 kg ha^{-1}, respectively. Therefore, the seed rate of the variety BARI Gom 24, BARI Gom 26 and BARI Gom 28 can be considered as 140 kg seed ha^{-1} and the variety BARI Gom 25 and BARI Gom 27 can be considered as 120 kg seed ha^{-1}. Biological yield was highest in BARI Gom 28 followed by BARI Gom 27, BARI Gom 26, BARI Gom 24 and BARI Gom 25. Biological yield was highest in BARI Gom 28 might be due to produce more secondary tiller. Biological yield was influenced by different seed rate and the highest was at 140 kg seed ha^{-1} which was statistically similar with 120 kg seed ha^{-1}. Total biomass production was almost similar with the seed rates from 100 to 160 kg/ha as reported by Sarker et al. (2009). In higher seed rates, higher number of plants and tillers failed to produce higher biomass yield.

Table 2

Yield, yield contributing characters and biological yield of wheat as influenced by seed rate and variety.

Treatments	Number of spikes m^{-2}	Spike length (cm)	No. of spikelets spike^{-1}	Number of grains spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Seed rate (kg ha^{-1})							
100	289.93b	11.51a	17.49ab	50.72b	50.257a	5175b	12816b
120	297.93ab	11.65a	17.76a	51.39ab	49.526b	5232ab	13238a
140	306.73a	11.21b	17.13b	52.33a	49.336b	5389a	13406a
Level of significance	**	**	**	*	*	**	**
Variety							
BARI Gom 24 (48-55)	236.22c	13.45a	18.86a	51.28b	55.39a	5121b	12861bc
BARI Gom 25 (54-58)	264.56b	12.13b	17.42b	49.40b	55.20a	4802c	12729c
BARI Gom 26 (48-52)	336.89a	10.48c	17.28b	57.96a	51.31b	5724a	13086bc
BARI Gom 27 (38-42)	324.11a	10.81c	17.26b	49.53b	42.64d	5360b	13266b
BARI Gom 28 (42-44)	329.22a	10.39c	16.48c	49.24b	43.99c	5319b	13824a
Level of significance	**	**	**	**	**	**	**
CV (%)	3.30	3.66	2.87	3.43	1.84	3.45	2.81

Figures in the parentheses indicate the thousand grain weigh (g) of the variety. Figures within a column, for a factor, followed by the same letter(s) are not significantly different at 5% level by DMRT. **, * and ns; significant at 1 and 5% level, and not significant, respectively.

4. Conclusion

BARI Gom 26, medium sized grain, produced the highest grain yield among the varieties under all levels of seed rates. Almost all the yield contributing traits and yield were statistically similar with the seed rates of 120 and 140 kg ha^{-1} and produced maximum grain yield. From the results it can be concluded that the seed rate of the variety BARI Gom 24, BARI Gom 26 and BARI Gom 28 can be considered as 140 kg seed ha^{-1} and the variety BARI Gom 25 and BARI Gom 27 can be considered as 120 kg seed ha^{-1} for better performance of newly developed wheat varieties.

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