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FUNCTIONAL RELATIONSHIP BETWEEN GRAIN YIELD AND SPIKES PER SQUARE METER OF WHEAT AS INFLUENCED BY SEED RATE UNDER LATE SOWN CONDITION

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Abstract

An experiment was conducted at Agronomy Research Field of Bangladesh Agricultural Research Institute, Gazipur for five consecutive years (2014-2015 to 2018-2019) to establish a functional relationship between grain yield and spikes/m^2 of wheat at late sown condition. Variation of spikes/m^2 was created by five seed rates (90, 120, 150, 180 and 210 kg/ha). Pooled average value of spikes / m^2 was observed the highest (479-506) in 180-210 kg seed /ha. From the structural treatment, the highest grain yield (pooled average of 3876-4153 kg/ha ranged 3295-5028 kg/ha) of wheat was produced in the seed rate of 150-180 kg/ha. The estimated optimum seed rate was found 162.29 kg/ha with the estimated grain yield 3989 kg/ha of wheat at late sown condition through the developed function model of $Y=485.91+43.17X-0.133X^2$ ($R^2=0.87$). Again, the estimate optimum spikes/m^2 was noticed 423 when the estimated grain yield of wheat was 4135 kg/ha at late sown condition through the developed functional model of $Y=-2837+32.98X-0.039X^2$ ($R^2=0.83$). The grain yield would be increased about 13% as compared to recommended seed rate (120 kg/ha) of wheat. Spikes / m^2 had significant positive correlation with seed rate ($r=0.79$ at $p=0.05$) of wheat. Relationship between observed grain yield and predicted grain yield (when relationship between spikes/m^2 and grain yield) showed a good consistency ($Y=1.0006X$, $R^2=0.94$ and $r = 0.97$ at $p<0.01$). From the results of the study it is concluded that 162 kg/ha of seed rate and 423 spikes / m^2 would be optimum for maximum yield) 4135 kg/ha) of wheat at late sown condition.

Introduction

Wheat is an important cereal food grain after rice in Bangladesh. Wheat cultivation increased (4.29 times) after independence of Bangladesh (1971) due to development of high yielding varieties along with improved production technology (BARI, 2011; BARI, 2017; AIS, 2018). In Bangladesh, area coverage of wheat is 428800 hectares with an annual production of 1423600 tons (AIS, 2018). Optimum sowing time of wheat is 15 November to 30 November in Bangladesh (BARI, 2017). The majority farmers usually grow wheat in the same land after harvesting of T. *aman* rice and thus, sowing of wheat is often delayed (BARC, 2013). Sowing of wheat in Bangladesh may extend upto 20 December depending on the weather, topography and harvesting of the preceding rice crop (BARC, 2013). Grain yield of wheat is reduced @ 82-87 kg/ha/day (32-36%) after 30 November sowing (Begum and Mian, 2019). Spikes/m^2 is a major yield component which has a significant effect on the grain yield of wheat (Kadum*et al.*, 2019). The increase of spikes/m^2 increased the grain yield of

wheat (Mian, 2008; Shankarrao*et al.*, 2010). Spikes/m^2 is mainly influenced by seed rate and yield is the function of spikes/m^2 of wheat (Bolton, 2018; Sokoto *et al.*, 2012). More number of tillers as well as more number of spikes/m^2 is generally noticed in higher seed rate (BARI, 2018; Nimat *et al.*, 2013). Proper growth environment also enhances tillering as well as spikes/m^2 of wheat (Mian, 2008; Njuguna *et al.*, 2010). Again, the excess seed rate would create more competition among the tillers producing lower effective spikes/m^2 and grain yield of wheat (Seleiman *et al.*, 2016). On the other hand, lower seed rate produces higher number of tillers per plant up to a level if proper growth environment is provided. Delayed sowing due to late harvesting of T. *aman*rice and excess soil moisture in southern part of the country reduce grain yield of wheat (BARC, 2013). At late sown condition, crop growth is retarded with reduced tillering of wheat producing lower grain yield. Moreover, only main tiller (stem) produces effective spikes but lateral or tender tiller fail to produce effective tiller or spike at late sown condition. In modeling concept scientists are trying to establish relationship between yield and spikes/m^2 of wheat for estimating the optimum spikes/m^2 for maximum yield (Mian *et al.*, 2012; Moucheshi *et al.*, 2013; Bolton, 2018). Therefore, the experiment was undertaken to establish a functional relationship between grain yield and spikes/m^2 of wheat and to estimate the optimum spikes / m^2 for maximum grain yield at late sown condition.

Materials and Methods

An experiment was conducted at Agronomy Research Field of Bangladesh Agricultural Research Institute, Gazipur to establish a functional relationship between grain yield and spikes / m^2 of wheat at late sown condition. The experiment was conducted for five consecutive years of 2014-2015 to 2018-2019. Variation of spikes /m^2 was created by five seed rates (90, 120, 150, 180 and 210 kg/ha). The wheat var. BARI Gom-30 was sown on 15-20 December (late sown condition) in 2014 - 2019. But the optimum sowing time of wheat is 15-30 November in Bangladesh (BARI, 2017). The experiment was laid out in a RCB design with four replications. Unit plot size was 8 m৭ 5 m. The crop was fertilized with 100-36-25-20-1.8-1.0 kg/ha of N-P-K-S-Zn-B (BARI, 2011). All the nutrients including two third of N were applied as basal. Rest one third of N was top dressed at CRI stage. Three irrigations were applied at 20 days after emergence (DAE), 60 DAE and 80 DAE. Crop field was weeded at 25 DAE by spading. The crop was harvested on 27-31 March in 2014--2019. Data on crop yield and yield components of wheat were recorded. There was no blast infection in the experimental field. Attempt was made to establish functional relationship between grain yield and spikes /m^2 of wheat using the quadratic equation like $Y= a + bx - cx^2$. Optimum seed rate and spikes / m^2could be estimated with the following formula from the developed functional model (Mian *et al.*, 2012).

Optimum seed rate and spikes / m^2=-b/2c (where b and c are the coefficients).

The experiment was repeated for the consecutive five years to get sufficient data for establishing the functional relationship. Five years' data on spikes/m^2 and grain yield of wheat from 2014-2015 to 2018-2019 were used to develop functional relationship. Some important yield components of wheat were recorded and presented on the basis of year wise and combined analysis (only combined effect). The data was subjected to statistical analysis (year wise and combined) and mean values were compared by $LSD_{(0.05)}$.

Results and Discussion

Yield component and yield

Spikes/m^2 was significantly influenced by seed rate (Table 1). The maximum number of spikes/m^2 was produced of 210 kg seed /ha (533) followed 180 kg seed / ha (505) while the lowest in 90 kg seed /ha (395) in 2014-2015. Similar trend of spikes / m^2 (the highest value ranged 444-573and the lowest value ranged 348-457) was noticed in the subsequent growing season of 2015-2016 to 2018-2019. The highest pooled value of spikes/m^2 was observed in 210 kg seed /ha (506) followed by 180 kg seed /ha (479) while the lowest in 90 kg seed /ha (398) (Table 1). The results expressed that increasing seed rate increased spikes/m^2gradually. Similarly, higher spikes/m^2 in higher seed rate (160 kg/ha as compared to 120 kg/ha) was also reported by BARI (2018). Seed rate had significant effect on grains / spike (Table 2). The highest grains/ spike was obtained in 90 kg seed /ha (42) followed by 120 kg seed /ha (41) but the lowest in 210 kg seed /ha (34) in 2014-2015 (Table 2). Similar trend of grains / spike (the highest value ranged 38-52 and the lowest value ranged 26-39) was noticed in the following growing seasons of 2015-2016 to 2018-2019. The highest pooled value of grains/ spike was noticed in 90 kg seed /ha (43) followed by 120 kg seed /ha (40). On the other hand, the lowest value was found in 210 kg seed /ha (32) (Table 2). The results reveal that grains/spike was reduced gradually with the increase of seed rate. Higher seed rate possibly exerted inter tiller competition resulting less number of grains/pike. Less number of grains/spike in higher seed rate was also reported by Seleiman *et al.* (2016) and BARI (2018). The weight of 1000-grain was found the highest in 90 kg seed /ha (45 g) followed by 120 kg seed /ha (44 g) while the lowest in 210 kg seed /ha (39 g) in 2014-2015 (Table 3). Similar trend of 1000-grain weight (the highest value ranged 42-58 g and the lowest value ranged 32-45 g) was observed in the growing season of 2015-2016 to 2018-2019. Pooled value of 1000-grain weight was recorded the highest in 90 kg seed /ha (48 g) followed by 120 kg seed /ha (46 g) giving the lowest in 210 kg seed /ha (38 g) (Table 3). Higher seed rate possibly exerted inter tiller competition reducing individual grain size and weight as well as lower 1000-grain weight. Reduced 1000-grain weight of wheat at higher seed rate (160 kg/ha) was also reported by Seleiman *et al.* (2016) and BARI (2018). The grain yield of wheat was significantly influenced by seed rate (Table 4). The highest grain yield (3803-3858 kg/ha) was produced in 150-180 kg seed /ha but the lowest (3652 kg/ha) in 90 kg seed /ha in 2014-2015. On the other hand, the highest grain yield (5028 kg/ha) was observed in 180 kg seed /ha followed by the 210 kg seed /ha (4839 kg/ha) while the lowest (3652 kg/ha) in 90 kg seed /ha in 2015-2016 (Table 4). Similar trend of grain yield (the highest grain yield ranged 3738-4376 kg/ha and the lowest value ranged 2436-3225 kg/ha) was noticed in the subsequent growing season of 2016-2017 to 2018-2019. Pooled grain yield was obtained the highest in 180 kg seed /ha (4153 kg/ha) followed by 150 kg seed /ha (3876 kg/ha) producing the lowest in 90 kg seed /ha (3418 kg/ha) (Table 4). Grain yield was mainly contributed by spikes/m^2. Similar results have also been described by other investigators (Nemat *et al.,* 2013; Sherwan *et al.*, 2015). Grain yield increased about 6-14% in 150-180 kg seed /ha as compared to recommended seed rate (120 kg/ha). The results expressed that higher seed rate up to 180 kg/ha increased grain yield, afterwards the grain yield declined as the increase of seed rate (210 kg/ha). Higher seed rate (210 kg/ha) might have exerted more inter tiller competition resulting poorer yield component and grain yield of wheat. Moreover, higher seed rate leads the crop to lodging producing lower grain yield. Higher seed rates (200 kg/ha) resulted in higher lodging of wheat was also reported by (Laghari *et al.*, 2011). The results are in agreement with the observation of Seleiman *et al.* (2016).

Table 1. Spikes/m^2 (no.) of wheat as influenced by seed rate under late sown condition

Seed rate (kg/ha)	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Pooled
90	395	348	457	383	408	398
120	447	362	480	412	428	426
150	483	389	493	443	468	455
180	505	426	523	464	478	479
210	533	444	573	493	485	506
$LSD_{(0.05)}$	41	30	34	24	32	33
CV (%)	5.66	4.87	4.33	4.69	4.91	4.89

Table 2. Grains/spike (no.) of wheat as influenced by seed rate under late sown condition

Seed rate (kg/ha)	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Pooled
90	42	52	40	41	38	43
120	41	48	39	37	36	40
150	38	45	38	34	35	38
180	37	44	35	30	31	35
210	34	39	33	28	26	32
$LSD_{(0.05)}$	2.69	2.45	2.07	3.37	2.96	2.48
CV (%)	4.55	3.49	3.22	4.11	5.79	4.29

Table 3. Weight of 1000-grain (g) of wheat as influenced by seed rate under late sown condition

Seed rate (kg/ha)	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Pooled
90	45	58	43	42	50	48
120	44	57	41	41	49	46
150	43	48	36	38	47	42
180	40	46	34	35	46	40
210	39	43	32	32	45	38
L $SD_{(0.05)}$	2.89	4.03	3.65	2.05	2.11	2.89
CV (%)	4.46	5.92	4.86	2.54	2.87	4.37

Table 4. Seed yield (kg/ha) of wheat as influenced by seed rate under late sown condition

Seed rate (kg/ha)	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Pooled
90	3652	4520	3225	3187	2436	3418
120	3781	4592	3743	3405	2804	3651
150	3858	4633	4061	3532	3295	3876
180	3803	5028	4376	3738	3822	4153
210	3586	4839	4065	3584	2464	3708
$LSD_{(0.05)}$	287	378	373	318	313	328
CV (%)	4.98	5.21	6.22	5.93	5.59	5.66

Functional relationship

Functional relationship between seed rate and spikes/m^2 indicates that the effect of seed rate on spikes/m^2 of wheat can be explained 72% by functional model of $Y=2.8613X$ ($R^2=0.72$) (Table 5 and Fig.1). The coefficient value of 2.8613 indicates that the number of spikes/m^2 would be increased @ 2.8613 with the increase of 1 kg/ha of seed rate. Spikes/m^2 showed significant positive correlation with the seed rate ($r=0.79$ at $p=0.05$). Functional relationship between seed rate and grain yield of wheat shows that the effect of seed rate on grain yield can be explained 87% by functional model of $Y=485.91+43.17X-0.133X^2$ ($R^2=0.87$) (Table 5 and Fig.2). Number of spikes/m^2 had a great impact on the grain yield of wheat as described by Moucheshi *et al.* (2013). The optimum seed rate was estimated at 162.29 kg/ha by the functional model of $Y=485.91+43.17X-0.133X^2$ ($R^2=0.87$). Then the grain yield would be 3989 kg/ha at the estimated seed rate of 162.29 kg/ha. Again, functional relationship between spikes/m^2 and grain yield of wheat indicates that the effect of spikes/m^2 on grain yield can be explained 83% by functional model of $Y=-2837+32.98X-0.039X^2$ ($R^2=0.83$) (Table 5 and Fig. 3). The estimated optimum spikes/m^2 was found 423 by the functional model of $Y=-2837+32.98X-0.039X^2$($R^2=0.83$).

Table 5. Relationship between different parameters of wheat as influenced by seed rate

Fig. no.	Variable	Functional relationship	R^2
1.	Seed rate and spikes/m^2	$Y=2.8613X$	$R^2 = 0.72$
2.	Seed rate and grain yield	$Y=485.91+43.17X-0.133X^2$	$R^2 = 0.87$
3.	Spike/m^2 and grain yield	$Y= -2837+ 32.98 X-0.039X^2$	$R^2 = 0.83$
4.	Observed and predicted grain yield	$Y= 1.0006X$	$R^2 = 0.94$
-	Seed rate and spikes/m^2	correlation coefficient	$r=0.79$ at $p=0.05$
-	Observed grain yield and predicted grain yield	correlation coefficient	$r=0.97$ at $p<0.01$

Then the grain yield would be 4135 kg/ha at the estimated spikes/m^2 of 423 giving 13% higher grain yield as compared to recommended seed rate (120 kg/ha) of wheat. Kadum *et al.* (2019) reported that 481-492 spikes/m^2 gave the highest grain yield (6.46-6.62 t/ha) of wheat. Sokoto *et al.* (2012) also found that spikes/m^2 had significant positive correlation with grain yield of wheat. Relationship between observed grain yield and predicted grain yield (when relationship between spikes/m^2 and grain yield by the functional model of $Y=-2837+32.98X-0.039X^2$, $R^2=0.83$) showed a good consistency ($Y=1.0006X$, $R^2=0.94$ and $r=0.97$ at $p<0.01$) (Table 5 and Fig. 4).

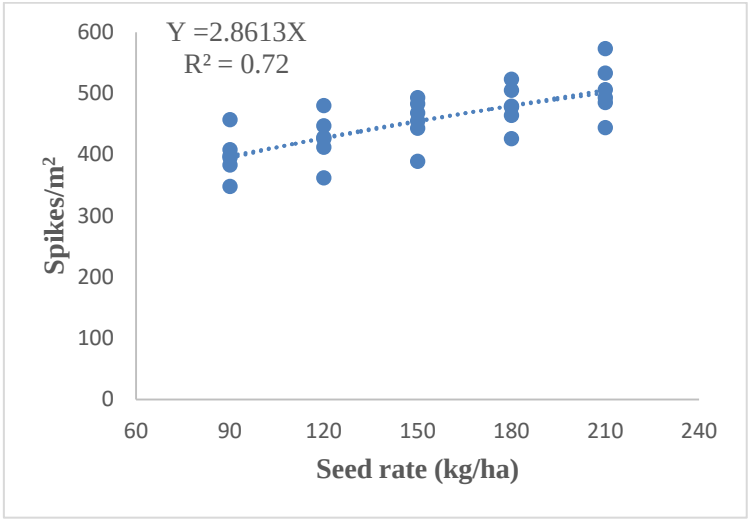

Fig. 1. Functional relationship between seed rate and spikes/m^2 of wheat

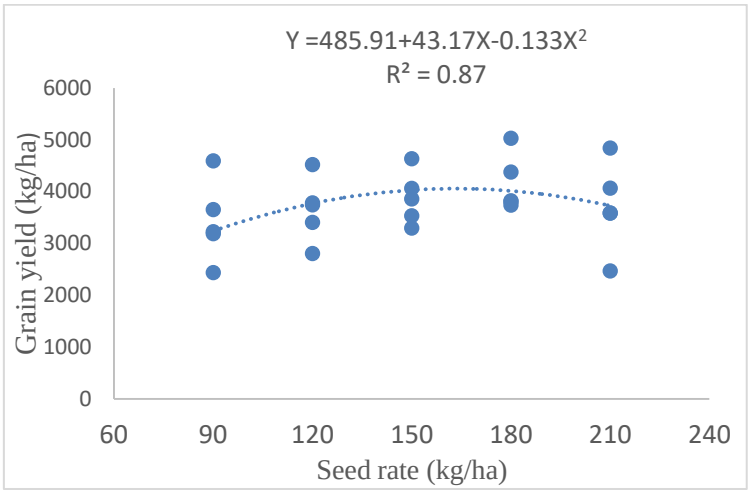

Fig. 2. Functional relationship between seed rate and grain yield of wheat

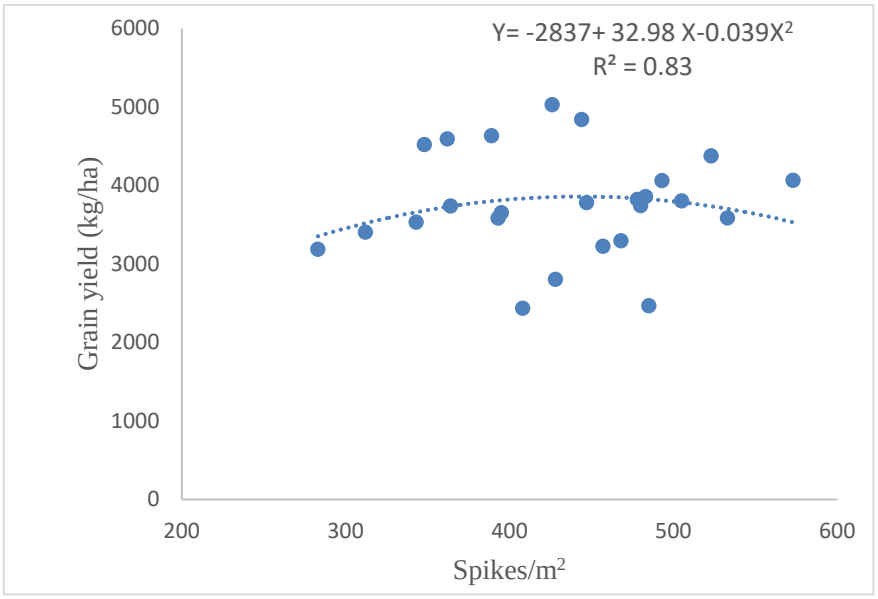

Fig. 3. Functional relationship between spike/m^2 and grain yield of wheat

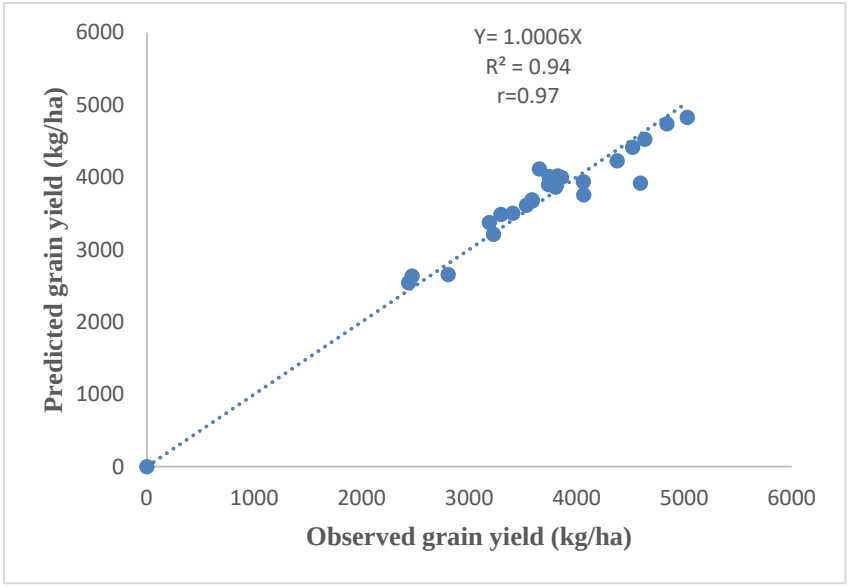

Fig. 4. Relationship between observed and predicted grain yield of wheat (Functional model of spike/m^2 and grain yield of wheat; Y= -2837+ 32.98X-0.039X^2, R^2 = 0.83)

Conclusion

From the structural treatment, the highest grain yield (pooled of 3876-4153 kg/ha ranged 3295-5028 kg/ha) of wheat was produced with 150-180 kg seed / ha. The estimated optimum seed rate was 162.29 kg/ha when the estimated grain yield was 3989 kg/ha of wheat at late sown condition through the developed function. Furthermore, the estimated optimum spikes / $m^2$was 423 with the estimated grain yield of 4135 kg/ha of wheat at late sown condition through the developed function. Then the grain yield would be increased about 13% as compared to recommended seed rate (120 kg/ha) of wheat. About 162 kg/ha of seed rate may be recommended for late sown wheat.

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