Research Article

Effect of Seed Rate on Yield Components and Grain Yield of Ridge Sown Wheat Varieties

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Abstract | Wheat productivity could be improved by ridge sowing with optimized seed rate for different varieties. This 3-years study was conducted to determine the optimum seed rate for different varieties of ridge sown wheat for better yield and related components. Wheat varieties (Faisalabad-08, Punjab-11 and Galaxy-13) were sown on ridges using two different seed rates (125 and 150 kg ha^{-1}). Increase in seed rate improved the emergence (plants per m^2), number of productive tillers per m^2 and grain yield (3-7%) of all wheat varieties although productive tillers per plant, number of grains per spike and 1000-grain weight was decreased. Faislabad-08 performed better regarding grain yield and related components among all varieties. Seed rate and varieties did not interact significantly for studied traits. Correlation analysis revealed that grain yield was positively correlated with number of productive tillers per m^2 during all years and grain weight during first year; while, negatively correlated with number of grains per spike during second year indicating that increase in grain yield was associated mainly with increase in number of productive tillers per unit area in response to seed rate. In conclusion, increase in seed rate improved the grain yield of ridge sown wheat by enhancing the number of productive tillers per unit area and could be exploited to improve the wheat productivity.

Introduction

Wheat (*Triticum aestivum* L.) is the major staple food cereal crop in most of the countries and cultivated in wide range of environments. Its yield is greatly influenced by crop management factors. Among several crop management factors sowing method, seeding rate and selection of appropriate genotype have prime role in affecting wheat productivity (Chauhdary et al., 2016; Isidro-Sánchez et al., 2017). Appropriate sowing method not only aids in establishment of proper crop stand but also

improves the conversion of light energy by balancing inter-plant competition thereby improving the crop yield (Ali et al., 2012; Ehsanullah et al., 2017; Rasool et al., 2017). Hence such cultivation system and/or sowing method should be adopted which could improve the soil properties such as moisture, temperature and root penetration in order to improve the plant growth and productivity (Krause et al., 2009). Ridge sowing of wheat improves the crop yield and water saving by improving the plant tillering capacity, soil moisture content and nutrient availability (Hussain et al., 2018). However, ridge sowing often

ensues in poor stand establishment (Hussain et al., 2015) which could become the limiting factor. Hence, optimization of seed rate with appropriate variety is crucial for maintaining proper plant population to acquire better crop yield from ridge sown wheat (Chauhdary et al., 2016).

Optimum seed rate is an important factor which regulates the capability of crop plants to capture the available resources (Lloveras et al., 2004). Seed rate determines the planting density which in turn influences the crop growth, nutrient uptake, tillering capacity, number and weight of grains, and ultimately grain yield due to inter-plant competition (Stephen et al., 2005; Nakano and Morita, 2009; Zohaib et al., 2018). Generally, the availability of environmental resources to plants is enhanced at optimum seed rate (Arduini et al., 2006). However, less seed rate results in low plant population which causes greater tiller production but decreased number of spikes per unit area due to inter-tiller competition for plant available resources (Ozturk et al., 2006; Tapley et al., 2013). On the other hand, use of high seed rate with narrow row spacing has been observed to enhance grain yield of winter wheat (Joseph et al., 1985). However, high plant density due to high seed rate don't always increase grain yield because of high inter-plant competition, and availability of nitrogen and soil moisture (Fischer et al., 1976; Read and Warder, 1982; Park et al., 2003). Previous studies have reported inconsistent yield increase in response to increase in seed rate of wheat (Staggenborg et al., 2003; Otteson et al., 2007; Kabir et al., 2009).

A differential behavior exists among different genotypes of wheat pertaining to growth behavior and grain yield (Khan et al., 2002; Zecevic et al., 2014). Moreover, different varieties of same species respond differently to applied inputs regarding growth and yield formation indicating that selection of appropriate variety with specific set of management practices is required (Nizamani et al., 2014; Belete et al., 2018Zohaib et al., 2019). Wheat varieties differ in their growth habit and tillering capacity which necessitates the maintenance of specific plant density for specific variety. Hence, optimization of seed rate with variety of wheat is essential to obtain optimum plant density for maximum grain yield and potential benefits (Ciha, 1983; Stephen et al., 2005). Khan et al. (2002) reported that grain yield of cultivars Inqlab-91 and Bakhtawar-92 increased with increase in seed

rate up to 150 kg ha⁻¹; however, the performance of Bakhtawar-92 was better than Inqlab-91 in response to increase in seed rate. Similarly, Nizamani et al. (2014) reported that variety Sarsabz produced maximum grain yield at 150 kg seed ha⁻¹ while Kiran-95 and TD-1 at 125 kg seed ha⁻¹ indicating the differential response of varieties to different seed rate.

Ridge sowing affects the wheat productivity but poor crop stand establishment could become the limiting factor. Optimization of seed rate with different varieties is crucial for improving productivity of ridge sown wheat. It was hypothesized that increase in seed rate will improve the productivity of ridge sown wheat by improving the number of tillers per unit area through improved stand establishment. The present study was conducted to ascertain the effect of seed rate on yield components and grain yield of different ridge sown wheat varieties.

Materials and Methods

Experimental details
Study was performed to determine the effect of seed rate on yield components and grain yield of different wheat varieties at Adaptive Research Farm, Gujranwala, Pakistan (32°12′15″N 74°13′48″E 227 m above sea level) during 2014-15 to 2016-17. Soil samples were collected from the field before sowing the crop from a depth of 0-30 cm for analysis of physico-chemical properties. The collected samples were air dried, sieved (2 mm pore size) after grinding and submitted to Soil and Water Testing Laboratory, Gujranwala for analysis. The soil was heavy loam and medium in soil fertility status. The physico-chemical properties of soil are given in Table 1. The experiment was carried out using randomized complete block design with factorial arrangement and three replications. The net plot size was 19×9 m². The treatments included two different seed rates (125 and 150 kg ha⁻¹) and three varieties (Faisalabad-08, Punjab-11 and Galaxy-13) of wheat.

Crop husbandry
The crop was sown in last week of November during all the years. The varieties and seed rate was used according to the treatments. Sowing was accomplished by broadcasting the seed followed by formation of ridges using potato ridger. Recommended dose of NPK (115-85-62 kg ha⁻¹) was applied using urea (46% N), diammonium phosphate (DAP) (18%

N, 46% P_2O_5) and sulphate of potash (SOP) (50% K_2O). Full P, K and half N was applied as basal dose and remaining half dose of N was applied with first irrigation. Irrigations were applied according to soil and weather conditions and in total 2 irrigations were applied during each year. Local recommendations were followed for plant protection measures. The crop was harvested and threshed manually during last week of April during each year. Meteorological data during growing periods of wheat are presented in Table 2.

Table 1: *Physico-chemical characteristics of experimental soil.*

Characteristics	Value	Unit
Soil type	Heavy loam	-
pH	8.0	-
EC	1.4	dSm^{-1}
Organic matter	0.78	%
Total Nitrogen	0.047	%
Available phosphorus	10.4	ppm
Available potash	130	ppm

Observations

Data regarding emergence count (plants per m^2) was recorded after the completion of emergence by counting plants from randomly selected areas in all replications and averaged. Yield and yield attributes were recorded at harvest maturity. Number of productive tillers per m^2 was recorded by counting the productive tillers from randomly selected areas in each replication and averaged. Average number of tillers per plant was determined by dividing the number of tillers m^{-2} by number of plants per m^{-2}. Number of grains per spike was determined by randomly collecting and manually threshing the five spikes from each replication followed by counting the grains from each replication and averaging. The 1000-grain weight was determined by counting thousand grains from each replication, weighing with electric weight balance and averaging. Grain yield was recorded by manually harvesting and threshing the wheat from selected one m^2 area in each replication. The yield obtained was averaged and expressed as t ha^{-1}.

Statistical analyses

The normality of data were checked by using scatter plot technique. The data were found normal and analyzed separately for each year because the year effect was found significant for studied traits. Data were analyzed statistically by Fisher's analysis of variance (ANOVA) technique (Steel et al., 1997) and least significance difference (LSD) test at 5% probability was used for comparing the treatments' means. Pearson's coefficients were calculated to determine the correlation between yield attributes (number of productive tillers per m^2, number of grains per spike and 1000-grain weight) and grain yield as well as among yield attributes of wheat to determine the association between yield attributes and grain yield in response to seed rate and varieties.

Results and Discussion

Seed rate significantly affected the emergence, number of productive tillers and grains per spike, and 1000-grain weight of ridge sown wheat during all years, and average number of tillers per plant during 2014-15 and 2016-17. Varieties significantly differed in emergence and number of grains per spike during 2014-15, number of tillers per m^2, average number of tillers per plant (and 1000-grain weight during all years, and grain yield during 2014-15 and 2015-16. However, interaction between seed rate and varieties was non-significant for all studied traits during all years (Tables 3 and 4).

Across varieties, the higher seed rate (150 kg ha^{-1}) gave higher emergence count and produced more number of productive tillers per m^2 during all years (Table 3). Conversely, average number of tillers per plant, number of grains per spike and 1000-grain weight were greater in response to lower seed rate (125 kg ha^{-1}) as compared to higher seed rate (150 kg ha^{-1}) during all years except 1000-grain weight during 2014-15 when the results were vice versa (Table 4). The grain yield was however increased (3-7%) by increasing the seed rate, as compared to lower seed rate, during all years (Table 4). Across seed rate, Galaxy-13 exhibited higher emergence followed by Faisalabad-08; however, higher number of tillers per m^2 and average number of tillers per plant was recorded by Faisalabad-08, during all the years (Table 3). Maximum number of grains per spike was produced by Faisalabad-08 during 2014-15 while statistically similar results were produced by all varieties during 2015-16 and 2016-17. The 1000-grain weight and grain yield of Faisalabad-08 was the greatest among all varieties during all years. Grain yield of Faisalabad-08 was followed by Galaxy-13 during 2014-15 and 2015-16, and Punjab-11 during 2016-17 (Table 4).

Table 2: *Meteorological conditions during wheat growing seasons.*

Month	Total Rainfall (mm)			Temperature (°C)								
				Monthly maximum			Monthly minimum			Daily mean		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
November	2.4	0.0	3.0	26.0	25.5	25.3	14.0	12.8	11.8	20.0	19.2	18.6
December	0.0	1.2	0.0	17.0	21.2	23.2	5.0	6.3	6.3	11.0	13.8	14.8
January	8.4	18.7	19.0	15.1	14.3	14.0	4.2	3.5	3.9	9.7	8.9	9.0
February	36.0	14.0	8.0	20.0	21.3	23.0	8.1	9.0	9.2	14.1	15.2	16.1
March	66.2	51.4	64.0	24.0	26.1	28.5	14.4	14.3	13.8	19.2	20.2	21.2
April	13.3	40.3	6.0	34.2	34.3	37.2	18.2	18.9	20.2	26.2	26.6	28.7

Source: *Meteorological Department, Punjab.*

Table 3: *Effect of different seed rates on emergence, number of productive tillers per m² and number of tillers per plant of ridge sown wheat varieties.*

Treatments	Emergence count (plants m^{-2})			No. of productive tillers per m²			Number of tillers per plant		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Seed rate (S) (kg ha^{-1})									
125	169.0 b	175.1 b	167.1 b	324.0 b	312.4 b	317.8 b	1.92 a	1.78 a	1.90 a
150	184.8 a	189.7 a	182.9 a	344.3 a	336.3 a	344.3 a	1.87 b	1.78 a	1.85 b
Varieties (V)									
Faisalabad-08	173.3 b	181.8 a	173.5 a	350.2 a	333.3 a	341.5 a	2.02 a	1.83 a	1.95 a
Punjab-11	170.2 b	181.8 a	175.0 a	317.3 c	317.0 b	323.0 b	1.87 b	1.74 ab	1.83 b
Galaxy-13	187.2 a	183.5 a	176.5 a	335.0 b	322.8 b	328.7 b	1.79 c	1.76 b	1.85 b
Source of variation (Pr > F)									
S	0.003	0.002	0.001	0.001	<0.001	<0.001	0.043	0.752	0.044
V	0.014	0.903	0.516	<0.001	0.005	0.004	<0.001	0.045	0.004
S × V	0.730	0.937	0.947	0.481	0.674	0.932	0.985	0.539	0.940

Means in a column having same letters don't differ significantly at P < 0.05

Table 4: *Effect of different seed rates on yield related attributes and grain yield of ridge sown wheat varieties.*

Treatments	Number of grains per spike			1000-grain weight (g)			Grain yield (t ha^{-1})		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Seed rate (kg ha^{-1})									
125	40.1 a	40.0 a	40.9 a	35.67 b	38.58 a	37.68 a	3.07 b	4.01 b	3.96 b
150	38.6 b	38.7 b	38.9 b	36.17 a	37.03 b	36.66 b	3.28 a	4.13 a	4.10 a
Varieties									
Faisalabad-08	40.8 a	39.2 a	39.8 a	36.79 a	39.01 a	38.59 a	3.49 a	4.10 a	4.30 a
Punjab-11	38.5 b	39.5 a	40.6 a	35.37 b	37.33 b	36.57 b	2.94 c	4.04 a	3.92 b
Galaxy-13	38.7 b	39.4 a	39.3 a	35.60 b	37.07 b	36.35 b	3.09 b	4.07 a	3.88 b
Source of variation (Pr > F)									
S	0.011	0.029	0.005	<0.001	0.001	0.018	0.001	0.021	0.037
V	0.007	0.855	0.231	<0.001	0.002	0.001	<0.001	0.667	0.001
S × V	0.811	0.696	0.340	0.365	0.147	0.443	0.499	0.689	0.615

Means in a column having same letters don't differ significantly at P < 0.05

Table 5: *Pearson's coefficients of correlation between grain yield and related attributes of ridge sown wheat varieties under the influence of different seed rates.*

Variables	Grain yield (t ha^{-1})			No. of tillers per m²			No. of grains per spike			1000-grain weight (g)		
	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17	2014-15	2015-16	2016-17
Grain yield (t ha^{-1})	1	1	1									
No. of tillers per m²	0.925***	0.959***	0.736*	1	1	1						
No. of grains per spike	0.458^{ns}	-0.829***	-0.230^{ns}	0.182^{ns}	-0.885**	-0.788*	1	1	1			
1000-grain weight (g)	0.987***	-0.327^{ns}	0.663^{ns}	0.899**	-0.225^{ns}	0.041^{ns}	0.512^{ns}	0.557^{ns}	0.381^{ns}	1	1	1

*** P < 0·01; ** P < 0·05; * P < 0·1; ^{ns} non-significant.

In present study, the grain yield of ridge sown wheat was improved by enhancing the seed rate. The increase in grain yield due to increase in seed rate was associated with enhanced number of productive tillers per m^2 although average number of tillers per plant, number of grains per spike and grain weight was decreased, as compared to low seed rate (Tables 3 and 4). The increase in number of tillers per m^2 due to higher seed rate was mainly associated with higher number of plants per m^2 (emergence count) as it was also evident from the fact that the average number of tillers per plant was decreased, as compared to low seed rate (Table 3; Tahir et al., 2019). Moreover, it has been observed that increase in plant population due to increase in seed rate results in decrease in number of grains per spike and grain weight due to competition among plants for available resources (Faris and Pauw, 1980; Iqbal et al., 2010; Isidro-Sánchez et al., 2017). Similar increase in emergence, number of tillers per m^2 and grain yield while decrease in spike length, spikelets per spike, grains per spike and grain weight in response to higher seed rate has been reported by Sarker et al. (2009). Similarly, Chauhdary et al. (2016) reported that higher seed rate (160 kg ha^{-1}) increased the number of tillers per m^2 and grain yield of bed planted wheat while decreased number of grains and grain weight, as compared to low seed rates (100 and 130 kg ha^{-1}).

In present study, there was no significant interaction between seed rate and varieties of ridge sown wheat; however, different varieties performed differently regarding yield and yield attributes (Tables 3 and 4). However, Laghari et al. (2011) reported that varieties had significant interaction with seed rate and different varieties responded differently to varying seed rates. In present study, highest grain yield and related attributes were recorded by Faisalabad-08 and it was followed by Galaxy-13, whereas Punjab-11 exhibited the lowest yield and related attributes during all the years (Tables 3 and 4). The maximum yield of Faisalabad-08 was associated with higher number of productive tillers per m^2, grains per spike and 1000-grain weight during all the years despite of different climatic conditions during different years (Tables 3 and 4). The difference in yield and yield attributes of different varieties might be associated with differential genetic potential as well as ability to adapt to different environmental conditions (Zecevic et al., 2014; Isidro-Sánchez et al., 2017). Moreover, sowing method has been observed to affect the yield performance of different varieties of wheat (Wang et al., 2004). Kiliç (2010) reported that different varieties performed differently pertaining to yield and related traits in response to sowing method i.e. Sarıçanak-98 performed better with bed planting while Aydın-93 with flat planting method.

The grain yield of ridge sown wheat varieties was influenced by variation in seed rate and it was related to variation in different yield attributes (Tables 3, 4 and 5). The correlation analysis revealed that grain yield of different varieties of ridge sown wheat had significant positive relationship with number of tillers per m^2 ($p < 0.001$, $p < 0.001$, $p < 0.1$) during all years, while significant positive relation with 1000-grain weight ($p < 0.001$) and negative relation with number of grains per spike ($p < 0.001$) during 2014-15 and 2015-16, respectively, under the influence of different seed rates. On the other hand, the number of tillers per m^2 had significant negative relationship with number of grains per spike ($p < 0.05$, $p < 0.1$) during 2015-16 and 2016-17, while positive relationship with 1000-grain weight ($p < 0.05$) during 2014-15. Nonetheless, there was non-significant relationship between number of grains per spike and 1000-grain weight of wheat varieties in response to variation in seed rate, during all years (Table 5).

In present study, the grain yield was positively correlated with number of tillers per m^2 during all the years; however, positively correlated with 1000-grain weight and negatively with number of grains per spike during 2014-16 and 2015-16, respectively (Table 5). The positive relationship of yield with tillers was associated with increase in plant population due to increase in seed rate (Table 3). However, negative relationship of yield with number of grains per spike was due to decrease in number of grains per spike with increase in plant population and increase in yield due to increased tillers per unit area (Tables 3 and 4). Yield and 1000-grain weight were positively correlated during first year of study which was attributed to increase in grain weight despite of increase in plant population; however, this was only during 2014-15 (Table 4). In addition, negative relationship of number of tillers with grains per spike indicated that increase in competition among tillers for available plant resources (Table 5). Furthermore, these relationships indicated that number of tillers per unit area is the main determinant of grain yield in response to seed rate. Previous studies have reported

similar relationships between yield and related attributes (Spink et al., 2000; Lloveras et al., 2004; Guberac et al., 2005; Lithourgidis et al., 2006; Ozturk et al., 2006).

Conclusions and Recommendations

The grain yield of ridge sown wheat varieties was improved by increase in seed rate from 125 kg ha^{-1} to 150 kg ha^{-1} and variety Faisalabad-08 performed better among all varieties. Increasing the seed rate resulted in increase in number of tillers per unit area and decrease in other yield attributes. In conclusion, increase in seed rate improved the grain yield of ridge sown wheat by increasing the number of productive tillers per unit area and could be exploited to improve the wheat productivity.

Author's Contributions

Javed Iqbal conducted experiment and collected data. Ali Zohaib performed statistical data analysis, prepared the write up and did overall management of article. Muzzammil Hussain supervised the study and gave technical input at every step. Adnan Bashir managed crop in field. Muhammad Hamza helped in conclusion. Wardah Muzaffer collected literature. Muhammad Tahir Latif helped in data analysis. Naeem Faisal helped in data collection.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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