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Comparison of yield and yield related traits of spring wheat varieties to various seed rates

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Abstract

A study was conducted to define the relationship between plant density and wheat grain yield to establish optimum seeding rates of different varieties for various regions.Five wheat varieties (Lasani-2008, Faisalabad-2008, BARS-2009, Millat-2011and Punjab-2011) were sown at five seed rates (60, 80, 100, 120 and 140 kg ha^{-1}) in split plot design replicated four times. Data of various attributes were recorded which revealed that maximum tillers m^{-2} (380.35), leaf area index (5.14), grains spike^{-1} (72.9), 1000-grain weight (46.19 g), biological yield (10299kg ha^{-1}), grain yield (4222.7 kg ha^{-1}), net income (Rs. 70017), benefit cost ratio-BCR (1.80) and minimum rate of return-MRR % (180.4) were observed for the treatment Punjab-2011. The seeding rate of 120 kg ha^{-1} gave maximum tillers m^{-2}(372.25), grains spike^{-1}(69.75), leaf area index (5.06), 1000-grain weight (46.25 g), biological yield (10604 kg ha^{-1}), grain yield (4423 kg ha^{-1}), , net income (Rs. 76542), BCR (1.88%) and MRR % (187.93). The interactive effect ofPunjab-2011 sown at seed rate of 120 kg ha^{-1} exhibited maximum tillers m^{-2}(423.30), leaf area index (5.82), grains spike^{-1} (77.05), 1000-grain weight (48.28 g), biological yield (11554 kg ha^{-1}), grain yield (4876.5 kg ha^{-1}), net income (Rs. 92217), BCR (2.06) and MRR % (205.93) suggesting that Punjab-2011 is the best variety and optimum seed rate of 120 kg ha^{-1} in arid agro climate of thal zone.

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Introduction

Wheat (*Triticum aestivum* L.) is the second most widely produced crop in the world (FAO, 2015) and the demand for food is projected to be doubled by 2050 in addition to the increasing demand for high-quality food for a healthy diet (Singh*et al.,* 2015). Wheat is the most important crop and staple food of the peoples of Pakistan (NARC, 2008).Its importance is evident as it contributes 60% of the daily diet of common man in Pakistan. The cultivation of wheat reaches far back into the history. Wheat is one of the first domesticated food crops. Wheat is a major diet component of living organisms. It is adapted to a wide range of environmental conditions is the best of cereals foods providing more nourishment to human being. Wheat is grown on large area on account of its wider agronomic adaptability, ease of grain storage and conversion grain into flour for making edible, palatable and nourishing food. Improved cultivars and cultural practices which confer heat tolerance and enable it to withstand adverse edaphic conditions along with, frequent wind storms and extreme temperatures in spring during reproductive phases the main concern of crop scientists. Genetic potential in wheat for high yield does exist but terminal heat stress jeopardizes the yield stability.

Therefore crop yield stability is key factor to ensure the food security. The yielding ability of a variety is dependent on interaction of socioeconomic, biological, technological and ecological features. The cultivar and environmental interactions are of major importance in developing high yielding varieties for a specific agro-ecological zone. The variations in environments have been used effectively to reduce the cultivar-environment interaction. A vast yield gap exists between yields that have been achieved in experimental plots and that of those attained in farmers' fields. The highest commercial attainable yield reported is 14 tones ha^{-1}under a given environment, location and year (Cook and Veseth, 1992).The region for which a breeder is developing a variety can often be so sub-divided in to macro-environmental differences as temperature gradients, rainfall distribution, and soil types. Greater efforts need to be made to breed new wheat varieties with higher yield potential and wide range of adoptability.

Plant density is an important factor that influences the growth and yield formation in wheat (Hiltbrunner *et al.,* 2007; Grassini *et al.,* 2011) and is one of the major factors determining the ability of the crop to capture resources. It is of particular importance in wheat production because it is in the farmer's controlling many cropping systems. Optimum plant densities vary greatly between areas as per climatic conditions, soil, sowing time, and varieties.

In wheat, the number of spikelet's per spike changes under different seeding rates (Dornbusch *et al.,* 2011). Hui Juan *et al.* (2009) reported that grain yield was improved with increasing plant density as a result of the increased spikelet's number. Iqbal *et al.* (2010) narrated that 150 kg seed ha-1 has given maximum grain yield 4.12 tons ha^{-1} of spring wheat in contrast Khan *et al.,* (2004) reported that higher seed rate than 100 kg/ha is the wastage and adds to production cast and create conducive conditions for spread of insect pest and diseases. However, some studies have reported that dense planting does not increase the grain yield (Takeda and HI Rota, 1971; Akita and Tanaka, 1992). Plant density affected the yield by controlling the seed-setting characteristics in the tiller spike. Consequently, there is value in defining relationships between density and wheat yield to establish optimum seeding rates for various regions. To boost wheat production, the appropriate plant density based on cultivars to maintain the seed-setting characteristics of the tiller spike, increase the seed-setting rate by supplying sufficient nutrients, mainly nitrogen nutrient (Li *et al.,* 2016). Therefore, this study was conducted at Land Reclamation Research Station, Chak No 37/TDA, Bhakkar, during 2014-15 to check the best performance of wheat varieties sown under different seeding densities.

Materials and methods

The main objective of this study was to evaluate the performance of different wheat varieties using various seed rates for higher yield in a suitable environmental condition in District Bhakkar Punjab, Pakistan(31° .37/ N latitude and 71°. 02/ East longitude) above the sea level. This study comprised the following treatments.

(A) Main Plot: Varieties

V_1 = Lasani-2008, V_2 = Faisalabad-2008, V_3 = Millat-2011, V_4 = Punjab-2011, V_5 = BARS-2009

(B) Sub Plot: Seed rates (kg ha^{-1})

S_1 = 60, S_2 = 80, S_3 = 100, S_4 = 120, S_5 =140

The soil profile was a sandy loam and the 0–30cm layer have0.27% organic matter, 0.014% nitrogen (N), 3.34ppm available phosphate (PO_4^{-3}) and 166ppm available potassium (K) with soilpH8.2. The experimental arrangement was 5 × 5 split-plot with four replications (split plot design) in which cultivar was the primary factor and seed rates (plant density) was the secondary factor. Each experimental plot consisted of six rows with 30 cm in-row spacing.

The experiment was conducted on a well-prepared seed bed during 2nd week of November during 2014-15.The recommended dose of N: P120:90 $kgha^{-1}$ was applied in the form of urea and triple super phosphate. All the phosphoric fertilizers were applied pre-seeding while half of the total nitrogenous fertilizer was applied at the time of first irrigation and 2nd dose of nitrogen (60 kg ha^{-1}) was applied at tillering stage.

Adequate plant protection measures were made during the crop growing period. Keeping in view the soil condition and physical appearance of the crop, six irrigations (75mm each) were applied to all the plots uniformly to avoid yield losses. Appropriate weedicides were used to keep the crop free of weeds. Following data were recorded from the said trial. All agronomic practices were carried out as per precise for high-yielding cultivation system.

Number of tillers m^{-2}

Data on a number of tillers m^{-2} were recorded by counting the number of tillers m^{-2}using quadrate in three central rows in each subplot and their mean was then calculated.

Average number of grains per spike

An average numberof grains $spike^{-1}$were recorded from five randomly selected spikes $treatment^{-1}$ in each sub plot and then their grains were counted and divided by five to get the average number of grains $spike^{-1}$.

Leaf area index (LAI)

Leaf area per plant calculated by formula suggested by Yoshida *et al.,* 1969. Functional leaf i.e. green leaves were counted on main shoot and on the other tillers of the tagged plant. Total length and width of flag leaf was multiplied by total number of leaves on plant, then again multiplied by factor of 0.67 for leaf area per plant. Leaf area index (LAI) was computed by using following formula as suggested by Watson (1947).

$$LAI = \frac{\text{Leaf area } (m^2)}{\text{Land area } (m^2)}$$

Leaf area duration`

Leaf area duration (LAD) describes the duration during which leaf remained green. Leaf area duration was estimated from LAI by Hunt (1978) method

$$LAD\ (days) = (LAI1 + LAI2) \times (t2 - t1)\ 1/2$$

Where$LAI_1$and $LAI_2$are leaf area indices at $t_1$and t_2, respectively. Cumulative LAD at final harvest was calculated by adding all LADs values.

Net assimilation rate ($g/m^2/day$)

The mean net assimilation (NAR) rate was determined by using the method of

Hunt (1978) as follow:

$$NAR\ (gm^{-2}day^{-1}) = \frac{TDM}{LAD}$$

TDM and LAD were the total dry matter and leaf area duration respectively at final harvest.

1000-grain weight (g)

The average weight of three samples was recorded for 1000 grains randomly taken from seed yield of each treatment.

Biological yield and grain yield

Four central rows were harvested, air dried and biological yield (kg ha^{-1}) was recorded whereas grain yield (kg ha^{-1}) was recorded on plot basis leaving the side rows as non-experimental.

Analysis of variance (ANOVA)

Data were subjected to analysis of variance (Steel *et al.,* 1997) to determine the significance of differences between treatments by using the software STATISTIX 8.1 at 1 % level of probability using LSD test for differences between the individual means.

Results and discussion

Tillers m^{-2}

Data presented in Table 1 (Fig.1) indicated that different wheat varieties had significant ($P \leq 0.01$) effect on tillers m^{-2}. Data showed that maximum tillers m^{-2}(380.35) were given byPunjab-2011 (V_4) followed by Millat-2011 and BARS-2009, which were statistically at par, while minimum tillers m^{-2}(266.55) were produced when plots were sown with Lasani-2008 (V_1).

These results are in agreement with Shah *et al.,* (2016). The differences among tillers m^{-2} of the varieties might be due to the inherent genetic potential for tillering.

Table 1. Tillers m^{-2} as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
	S_1(60)	S_2 (80)	S_3 (100)	S_4 (120)	S_5 (140)	Means
V_1 (Lasani-2008)	238.80	248.80	255.55	296.30	293.30	266.55
V_2 (Faisalabad-2008)	294.30	311.30	322.85	346.05	339.55	322.81
V_3 (Millat-2011)	360.30	371.80	375.80	398.05	370.80	375.35
V_4 (Punjab-2011)	349.30	368.05	371.80	423.30	389.30	380.35
V_5 (BARS-2009)	342.80	364.80	363.30	397.55	389.30	371.55
Means	317.1	332.95	337.86	372.25	356.45	

$LSD_{0.01}$ (Seed rates) = 11.65$LSD_{0.01}$ (Varieties) = 9.38

$LSD_{0.01}$ (Varieties × Seed rates) = 11.65.

The data further showed that different seed rates significantly affected tillers m^{-2}. It was evident from the data that maximum tillers m^{-2} (372.25) were noted when plots were seeded with 120 kg ha^{-1} (S_4), while minimum tillers m^{-2} (317.1) were recorded when60 kg seed rate ha^{-1} was used (S_1). These results are in concurrence with that of Khokar *et al.* (1985) who found maximum tillering at higher seed rates than at lower seed rates.

Table 2. Grains $spike^{-1}$as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	56.30	58.55	61.05	61.30	59.05	59.25
V_2 (Faisalabad-2008)	61.05	64.30	64.55	64.80	64.30	63.80
V_3 (Millat-2011)	72.30	69.30	70.05	62.55	59.30	66.70
V_4 (Punjab-2011)	71.80	71.05	73.30	77.05	71.30	72.90
V_5 (BARS-2009)	64.55	67.80	76.80	76.05	73.30	71.70
Means	65.20	66.20	69.15	68.35	65.45	

$LSD_{0.01}$ (Seed rates) = 3.31, $LSD_{0.01}$ (Varieties) = 2.83
$LSD_{0.01}$ (Varieties × Seed rates) = 6.35.

The tillering potential was much higher at optimum seed rate 120 kg ha^{-1}, when compared to lower or higher seed rate. It might be due to the fact that by increasing seed rate per unit area, the inter plant competition for space, nutrient, moisture and sun light increased which resulted in lower tillers m^{-2}.

Table 3. Leaf area index as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	3.20	3.51	3.88	4.18	4.02	3.76
V_2 (Faisalabad-2008)	3.37	4.69	5.09	4.99	4.39	4.51
V_3 (Millat-2011)	4.39	4.45	5.02	5.82	4.69	4.87
V_4 (Punjab-2011)	4.25	5.19	5.30	5.31	5.64	5.14
V_5 (BARS-2009)	4.54	4.82	4.81	5.02	3.92	4.62
Means	3.95	4.53	4.82	5.06	4.53	

$LSD_{0.01}$ (Seed rates) = 0.59, $LSD_{0.01}$ (Varieties) = 0.47

$LSD_{0.01}$ (Varieties × Seed rates) = 1.31.

The data also indicated that interaction between wheat varieties and seed rate was significantly affected. Data showed that maximum tillers m^{-2}(423.30) were noted when variety Punjab-2011 sown at the seed rate of 120 kg ha^{-1}(V_4S_4), while minimum tillers m^{-2} were recorded in variety Lasani-2008sown at seed rate of 60, 80 and 100 kg ha^{-1} (238.8, 248.80 and 255.55), which were statistically similar. Najma (2004) also reported similar results.

Table 4. Leaf area duration as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	255.5	286.7	309.3	281.7	273.2	281.3
V_2 (Faisalabad-2008)	260.1	282.5	322.2	305.0	282.3	290.4
V_3 (Millat-2011)	269.7	277.7	285.0	288.6	285.2	281.2
V_4 (Punjab-2011)	274.8	278.3	337.4	314.4	312.3	303.4
V_5 (BARS-2009)	279.2	283.6	285.1	290.4	281.5	284.0
Means	267.9	281.8	307.8	296.0	286.9	

$LSD_{0.01}$ (Seed rates) = 15.6, $LSD_{0.01}$ (Varieties) = 9.7

$LSD_{0.01}$ (Varieties × Seed rates) = 18.3.

Number of grains spike^{-1}

The potential of wheat spike is determined by the number of grains spike^{-1} which is an important yield component of grain yield. Statistical analysis of the data presented in Table 2 (Fig.2) revealed that different wheat varieties significantly affected number of grains spike^{-1}. Punjab-2011 (V_4) gave the highest number of grains spike^{-1} (72.9) closely followed by BARS-2009 (71.7 grains spike^{-1}), and the lowest number of grains spike^{-1}(59.25) were produced byLasani-2008 (V_1). The greater differences in number of grains spike^{-1} of the five varieties showed greater genetic variability among the varieties for higher sink capacities of the varieties and differences in ear size (Khakkar, 2003).

Data further revealed that different seed rates had a significant effect on number of grains spike^{-1}. It was evident from the data that, maximum number of grains spike^{-1}(69.75) were noted in seed rate sowing@ 120 kg ha^{-1} (S_4), while minimum grains spike^{-1} (65.2) were recorded, when 60 kg seed rate ha^{-1} was used and grains spike^{-1} were also decreased when seed rate was increased to 140 kg ha^{-1}. Similar results were also reported by Chatha *et al.* (1986), Nazir *et al.* (1987) and Marwat *et al.* (1989), who reported that lower or higher seed rates produced significant decrease in the number of grains spike^{-1}.

Table 5. Net assimilation rate (g/m^2/day) as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	2.98	3.02	3.12	3.60	3.62	3.27^{NS}
V_2 (Faisalabad-2008)	3.05	3.01	3.00	3.51	3.55	3.22
V_3 (Millat-2011)	3.0	3.02	3.05	3.60	3.63	3.26
V_4 (Punjab-2011)	3.01	3.22	3.33	3.65	3.70	3.38
V_5 (BARS-2009)	2.95	2.99	3.05	3.55	3.60	3.23
Means	3.00	3.05	3.11	3.58	3.62	

$LSD_{0.01}$ (Seed rates) = 0.55

$LSD_{0.01}$ (Varieties × Seed rates) = 0.65.

The increase in number of grains spike^{-1} with a decrease in seed rate might be due to less competition among the plants for nutrients present in the soil, higher light use efficiency thereby better light penetration has increased photosynthetic activity resultantly better vegetative growth and grain formation.

The data also indicated that interaction between wheat varieties and seed rate significantly affected the grains spike^{-1}. Maximum grains spike^{-1}(77.05) were recorded in variety Punjab-2011 sown at a seed rate of 120 kg ha^{-1} (V_4S_4), while minimum grains spike^{-1}were observed in treatment combination of Lasani-2008 × 60 seeding rate.

Table 6. 1000-grain weight as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	39.30	41.35	42.03	43.20	41.00	41.38
V_2 (Faisalabad-2008)	42.18	44.73	44.78	46.25	44.20	44.43
V_3 (Millat-2011)	41.98	45.75	45.23	46.80	46.33	45.22
V_4 (Punjab-2011)	43.15	46.40	46.80	48.28	46.33	46.19
V_5 (BARS-2009)	45.41	45.98	46.48	46.73	44.65	45.85
Means	42.40	44.84	45.06	46.25	44.50	

$LSD_{0.01}$ (Seed rates) = 1.17, $LSD_{0.01}$ (Varieties) = 0.52.

$LSD_{0.01}$ (Varieties × Seed rates) = 2.28.

These results are in agreement with Li *et al.,* (2016) who stated that plant density affected the yield by controlling the seed-setting characteristics in the tiller spike.

Leaf area index

Analysis of data presented in Table 3 (Fig. 3) showed that different wheat varieties had significant effects on leaf area index. Maximum leaf area index (5.14) was recorded from plots sown with variety Punjab-2011 (V_4), while minimum leaf area index (3.76) was recorded when plots were sown with Lasani-2008 (V_2). These results were also reported by Shah., (2016).

The data further showed that different seed rates had significant effect on leaf area index. It was evident from the data that maximum leaf area index (5.06) was observed when plots were sown with 120 kg ha^{-1} (S_4), while minimum leaf area index (3.95) was recorded when 60 kg seed rate ha^{-1} was used (S_1). Similar results were also reported by Ibrar (1999). Yoshida (1981) also reported that dense planting maximizes the leaf area index (LAI), ensuring that plant photosynthesis meets the high yield requirements.

Table 7. Biological yield as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	7640.7	8657.9	9649.9	10140.9	9891.5	9196.2
V_2 (Faisalabad-2008)	7932.4	8813.9	9665.1	10704.8	10022.2	9427.7
V_3 (Millat-2011)	8090.5	8388.1	8692.6	10390.5	10353.1	9183.0
V_4 (Punjab-2011)	8271.8	8960.9	11235.1	11474.0	11553.6	10299.1
V_5 (BARS-2009)	8236.6	8478.6	8694.3	10308.4	10135.1	9170.6
Means	8034.4	8659.9	9587.4	10603.7	10391.1	

$LSD_{0.01}$ (Seed rates) = **715**, $LSD_{0.01}$ (Varieties) = 682.

$LSD_{0.01}$ (Varieties × Seed rates) = 801.

This might be due to more vegetation growth in low seeded plots than higher seeded ones. The seeding rate at 140 kg ha^{-1} decreased the leaf area index due to greater competition among the plants for the limited sunlight and available nutrients in the soil.

Data also indicated that interaction between wheat varieties and seed rate was significantly affected. Maximum leaf area index (5.82) was observed when variety Millat-2011 sown at 120 kg seed rate ha^{-1}(V_3S_4), while minimum leaf area index (3.20) was noted in variety Lasani-2008 sown at 60 kg ha^{-1} (V_1S_1). It might be due to greater competition among the plants for sunlight and available nutrients in the soil. Leaf area index depends upon tillers m^{-2} and leaf area tiller^{-1}, the differences in leaf area in different varieties × seed rates might be due to the mutual interaction of genetic and environmental factors especially light and water status of the soil.

Table 8. Grain yield as affected by various wheat varieties and different seed rates.

Varieties	Seed rates (kg ha^{-1})					
					S_5 (140)	Means
V_1 (Lasani-2008)	3132.70	3506.45	3956.45	4259.20	3857.70	3742.50
V_2 (Faisalabad-2008)	3172.95	3437.45	3817.70	4388.95	3808.45	3725.10
V_3 (Millat-2011)	3236.20	3397.20	3563.95	4363.95	4037.70	3719.80
V_4 (Punjab-2011)	3391.45	3673.95	4550.20	4876.45	4621.45	4222.70
V_5 (BARS-2009)	3253.45	3391.45	3477.70	4226.45	3952.70	3660.35
Means	3237.35	3481.30	3873.2	4423	4055.6	

$LSD_{0.01}$ (Seed rates) = **357.65**, $LSD_{0.01}$ (Varieties) = 331.31

$LSD_{0.01}$ (Varieties × Seed rates) = 799.62.

Leaf area duration (days)

Leaf area duration (LAD)expresses the magnitude and persistence of the leaf area during crop growth period and presented in Table 4 (Fig.4) was considerably maximum(303.4) in Punjab-2011as compared to other varieties while minimum leaf area duration (281.2) was recorded when plots were sown with Millat-2002 (V_3). In relation to seeding rates means showed significant effect on leaf area duration and maximum leaf area duration (307.8) was observed when plots were sown with 100 kg ha^{-1} (S_3), while minimum leaf area duration (276.9) was recorded when 60 kg seed rate ha^{-1} was used (S_1). The increase in LAD might be due to increased nutrient translocation from source to sink, enhanced leafiness which enhanced photosynthetic efficiency.

Increased LAD ensured that leaf stay green for longer period, resultantly more period availability for photosynthesis and higher grain yield. The seeding rate at 140 kg ha^{-1} decreased the leaf area duration due to greater competition among the plants for the limited sunlight and available nutrients in the soil.

Table 9. Economic analysis of wheat as affected by various irrigation and nitrogen levels.

Treatments	Wheat Yield (kg ha-1)		Income (Rs. ha-1)		Gross Income (Rs. ha-1)	Total Expenditure (Rs. ha-1)	Net Income (Rs. ha⁻¹)	BCR	MRR %
	Grain	Straw	Grain	Straw					
A: Varieties									
V1	3742	5454	112260	27270	139530	87053	52477	1.60	160.28
V2	3725	5703	111750	28515	140265	87053	53212	1.61	161.13
V3	3720	5463	111600	27315	138915	87053	51862	1.60	159.58
V4	4223	6076	126690	30380	157070	87053	70017	1.80	180.43
V5	3660	5511	109800	27555	137355	87053	50302	1.58	157.78
B: Seed rate (kg ha-1)									
S1 (60)	3237	4797	97110	23985	121095	84653	36442	1.43	143.05
S2 (80)	3481	5179	104430	25895	130325	85453	44872	1.53	152.51
S3 (100)	3873	5714	116190	28570	144760	86253	58507	1.68	167.83
S4 (120)	4423	6181	132690	30905	163595	87053	76542	1.88	187.93
S5 (140)	4056	6335	121680	31675	153355	87853	65502	1.75	174.56
C: Interaction (A x B)									
V1S 1	3133	4508	93990	22540	116530	84653	31877	1.38	137.66
V1S2	3506	5152	105180	25760	130940	85453	45487	1.53	153.23
V1S3	3956	5694	118680	28470	147150	86253	60897	1.71	170.60
V1S4	4259	5882	127770	29410	157180	87053	70127	1.81	180.56
V1S5	3858	6034	115740	30170	145910	87853	58057	1.66	166.08
V2S1	3173	4759	95190	23795	118985	84653	34332	1.41	140.56
V2S2	3437	5377	103110	26885	129995	85453	44542	1.52	152.12
V2S3	3818	5847	114540	29235	143775	86253	57522	1.67	166.69
V2S4	4389	6316	131670	31580	163250	87053	76197	1.88	187.53
V2S5	3808	6214	114240	31070	145310	87853	57457	1.65	165.40
V3S1	3236	4855	97080	24275	121355	84653	36702	1.43	143.36
V3S2	3397	4991	101910	24955	126865	85453	41412	1.48	148.46
V3S3	3564	5129	106920	25645	132565	86253	46312	1.54	153.69
V3S4	4364	6027	130920	30135	161055	87053	74002	1.85	185.01
V3S5	4038	6315	121140	31575	152715	87853	64862	1.74	173.83
V4S1	3391	4881	101730	24405	126135	84653	41482	1.49	149.00
V4S2	3674	5287	110220	26435	136655	85453	51202	1.60	159.92
V4S3	4550	6685	136500	33425	169925	86253	83672	1.97	197.01
V4S4	4876	6598	146280	32990	179270	87053	92217	2.06	205.93
V4S5	4621	6932	138630	34660	173290	87853	85437	1.97	197.25
V5S1	3253	4984	97590	24920	122510	84653	37857	1.45	144.72
V5S2	3391	5087	101730	25435	127165	85453	41712	1.49	148.81
V5S3	3478	5216	104340	26080	130420	86253	44167	1.51	151.21
V5S4	4226	6082	126780	30410	157190	87053	70137	1.81	180.57
V5S5	3952	6183	118560	30915	149475	87853	61622	1.70	170.14

Data also indicated that interaction between wheat varieties and seed rate was significantly affected. Maximum leaf area duration (337.4) was observed when variety Punjab-2011 sown at 100 kg seed rate ha^{-1} (V_4S_3) which resulted increased NAR better accumulation of photo-assimilate in plant, while minimum leaf area duration (255.5) was noted in variety Lasani-2008 sown at 60 kg ha^{-1} (V_1S_1). Leaf area duration depends upon tillers m^{-2} and leaf area $tiller^{-1}$, the differences in leaf area in different varieties × seed rates might be due to the mutual interaction of genetic and environmental factors especially light and water status of the soil.

Net assimilation rate (g/m²/day)

The average net assimilation rate (NAR)of a crop indicates the net photosynthetic production per unit leaf area duration (LAD).NAR was non- significant for varieties whereas seeding rates and interaction showed significance. Maximum NAR (3.38) was recorded from plots sown with variety Punjab-2011 (V_4), while minimum NAR (3.22) was recorded when plots were sown with Faisalabad-2008 (V_2) and the varieties were statistically at par.

Different seed rates had significant effect on NAR and maximum NAR (3.62) was observed when plots were sown with 140 kg ha^{-1} (S_5), while minimum NAR (3.00) was recorded when 60 kg seed rate ha^{-1} was used (S_1). Interaction between wheat varieties and seed rate significantly affected NAR and maximum value (3.70) was observed when variety Punjab-2011 was sown at 140 kg seed rate ha^{-1} (V_4S_5), while minimum NAR (2.98) was noted in variety Lasani-2008 sown at 60 kg ha^{-1} (V_1S_1). These results are in accordance with that of Aziz *et al.,* (2017) who measured maximum NAR at higher seeding density of 150 kg/ha. Similar results were also reported by Aziz *et al.,* (2017) reported that dense planting maximizes the net assimilation rate (NAR).

1000-grain weight (g)

Different wheat varieties showed a significant ($P \leq 0.01$) effect on 1000-grain weight presented in Table 6 (Fig.6). Maximum 1000 grain (46.19 g) was recorded in case of variety Punjab-2011 (V_4), statistically at par with variety BARS-2009 (45.85 g), while minimum 1000 grain (41.38 g) was recorded in varietyLasani-2008 (V_1).

The differences in varieties may be due to variation in the potential grain size of the varieties, variation in leaf area especially of flag leaf and might be due to variation in reproductive sink intensity as a result of physiological parameters that determined seed size in different varieties.

Analysis of variance further revealed that different seed rates had significant effect on 1000 grain weight. Maximum 1000 grain weight (46.25 g) was recorded when plots were sown@ 120 kg seed rate ha^{-1} (S_4), while minimum 1000-grain weight (42.40 g) was recorded when 60 kg seed rate ha^{-1} was used (S_1). These results were agreed with findings of Man sab*et al.,* (1985) who also reported that 1000 grain weight varied with increasing/decreasing the seeding densities.

The data also indicated that interaction between wheat varieties and seed rate was significantly affected1000-grains weight. Maximum 1000-grains weight (48.28 g) was obtained when variety Punjab-2011 sown at the rate of 120 kg ha^{-1} seed rate (V_4S_4), while minimum 1000-grains weight (39.30 g) was noted from variety Lasani-2008 and seeded with 60 kg ha^{-1} (V_1S_1).

Biological yield (kg ha⁻¹)

Statistical analysis of data given in Table 7 (Fig.7) showed that biological yield was significantly affected by different wheat varieties. It was clear that maximum biological yield (10299.1 kg ha^{-1}) was recorded from plots sown with variety Punjab-2011 (V_4), while minimum biological yield (9170.6 kg ha^{-1}) was givenbyBARS-2009 (V_5).

The differences in biological yield of varieties might be due to variation in their genetic potential for dry matter accumulation.The data further showed that different seeding rates significantly affected the biological yield.

It was evident from the data that maximum biological yield (10603.7 kg ha^{-1}) was given by treatment of 120 kg seed rate ha^{-1} (S_4), while minimum biological yield (8034.4 kg ha^{-1}) was recorded when 60 kg seed rate ha^{-1} was used (S_1). These results were in agreement with Marwat *et al.,* (1989) who stated that the increase in biological yield with higher seed rate might be due to more number of plants per unit area despite reduced tillers per plant.

Data also indicated that interaction between varieties and seed rate was significantly affected the biological yield. Data showed that maximum biological yield (11553.6 kg ha^{-1}) was noted when variety Punjab-2011 sown at the rate of 140 kg seed rate ha^{-1} (V_4S_4), while minimum biological yield (7640.7 kg ha^{-1}) was produced by variety Lasani-2008at seed rate of 60 kg ha^{-1} (V_1S_1). The differences in biological yield might be due to variation in tillers m^{-2} and tiller grain weight. Both of these have been differentially affected by the soil and environmental conditions.

Grain yield (kg ha^{-1})

Statistical analysis of the data perused in Table 8 (Fig.8) revealed that different wheat varieties had significant effects on grain yield. Highest average grain yield (4223 kg ha^{-1}) was given by variety Punjab-2011 (V_4), while all other varieties produced lowest grain yield being statistically at par. Similar results were also reported by Ijaz *et al.,* (2002), Azra and Shah (2000) and Kamal *et al.,* (2003).

The differences among grain yields of the 5-varieties may be due to the variation in genetic makeup of the varieties and may have resulted from differences in yield components and partitioning of assimilates to grains. Data further revealed that different seed rates had significant effect on grain yield. It was evident from the data that maximum average grain yield (4423.00 kg ha^{-1}) was recorded when plots were sown with 120 kg ha^{-1} (S_4), while minimum grain yield (3237.35 kg ha^{-1}) was recorded when 60 kg ha^{-1} seed rate was used (S_1).

These results were in agreement with Mujahid *et al.* (1972), Chatta *et al.* (1986), Nazir *et al.* (1987), Ibrar (1999), Hameed *et al.* (2003) and Ijaz *et al.* (2002), reported that grain yield increased as seed rate increased and the highest grain yield was noted in plots seeded @ 120 kg ha^{-1}.

The data also indicated that interaction between wheat varieties and seed rate significantly affected the grain yield. Data showed that maximum grain yield (4876.45 kg ha^{-1}) was obtained when variety Punjab-2011 was sown at the seed rate of 120 kg ha^{-1} (V_4S_4), while minimum grain yield (3132.70 kg ha^{-1}) was recorded from variety Lasani-2008planted with 60 kg seed rate ha^{-1}.

Economic analysis

Data presented in Table 9indicated that economic analysis of wheat was significantly affected by various varieties and different seeding rates.

Wheat varieties displayed a significant increase in net monetary gain presented in Fig 9. It was clear from the data that when plots were sown with variety Punjab-2011 produced maximum net income (Rs. 70017.00 ha^{-1}), while variety BARS-2009 gave minimum net profit (Rs. 50302.00 ha^{-1}). When plots were seeded with 120 kg ha^{-1} produced maximum net income (Rs. 76542.00ha^{-1}), while plots in which seed rate was used @ 60 kg ha^{-1}gave minimum (Rs. 36442.00 ha^{-1}) net profit. Interaction between varieties and seed rate displayed maximum net profit (Rs. 92217.00) in the combination of variety Punjab-2011 and 120 kg ha^{-1} seed rate, while minimum net income (Rs. 31877.00 ha^{-1}) was obtained from plots in which variety Lasani-2008was sown with 60 kg seed rate ha^{-1}.

The data also revealed that BCR (benefit-cost ratio) was higher (1.80) when variety Punjab-2011 was sown, while varietiesLasani-2008 and Millat-2011gave minimum BCR (1.60). When seeding rate was kept 120 kg ha^{-1}, gave maximum BCR (1.88), while minimum BCR (1.43) was recorded in plots where seed rate was used 60 kg ha^{-1}.

The interaction of Punjab-2011and 120 kg seed rate ha^{-1}gave the maximum BCR of 2.06, while minimum (1.38) BCR was noted when plots were seeded with 60 kg ha^{-1} with variety Lasani-2008.

Highest (180.43%) marginal rate of return was noted from variety Punjab-2011, while lowest (159.58) marginal rate of return was recorded by variety Millat-2009. Similarly when plots were sown with 120 kg ha^{-1}, the maximum marginal rate of return (187.93), whiletheminimum marginal rate of return (143.05) was obtained from those pots where seed rate was used 60 kg ha^{-1}. The data further revealed that interaction displayed a significant variation among varieties and seed rate.

The maximum marginal rate of return (205.93) was achieved from the combination of variety Punjab-2011 and 120 kg seed rate ha^{-1}, while theminimum marginal rate of return (137.66) was recorded in treatment combination of variety Lasani-2008and seed rate of 60 kg ha^{-1}.

Conclusion

From the foregoing discussions, it may be concluded that variety Punjab-2011sown at 120 kg seed rate ha^{-1}positively affected yield and yield components such as spikes m^{-2}, seeds spike^{-1} and 1000 seed weight which ultimately contributed to increased grain yield with BCR of 2.06. Therefore, variety Punjab-2011 with a seeding rate of 120 kg ha^{-1} is recommended to obtain the maximum grain yield in wheat.

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