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EXPLORING THE TILLERING POTENTIAL IN WHEAT CULTIVARS AT DIFFERENT PLANTING GEOMETRY

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Abstract *A field experiment was conducted during rabi season 2017-18 to explore the tillering potential in wheat cultivars at different planting geometry at the research area of Lasbela University of Agriculture, Water and Marine Sciences, Uthal, Lasbela, Balochistan. The wheat cultivars "Zardana (Quetta region)" significantly produced 82.325 germination %, 292.00 tillers m^{-2}, 104.29 productive spikes m^{-2}, 71.958 non-productive spikes m^{-2}, 76.433 cm plant height, 12.892 cm spike length, 17.550 spikelets spike^{-1}, 54.233 grains spike^{-1}, 65.550 (g) 1000-grains weight, 4.3917 grain yield (t ha^{-1}), 37.333 cm Peduncle length, 5.3542 weight of straw (t ha^{-1}). The 30 cm (plant x plant distance) sowing method resulted in a maximum germination % of 91.050, 316.50 tillers m^{-2}, 120.43 m^{-2} productive spikes, 75.350 m^{-2} non–productive spikes, 89.650 cm plant height, 13.600 cm spike length, 22.283 spikelets spike^{-1}, 64.833 grains spike^{-1}, 78.483 g 1000-grains, 4.48 (t ha^{-1}) grain yield. The technique of seeding 20 cm (plant x plant) spacing 83.867 germination %, 297.17 tillers m^{-2}, and 104.77 productive spike m^{-2}, 69.050 non-productive spikes m^{-2}, 77.367 cm plant height 11.917 cm spike length, 18.867 spikelets spike^{-1}, 54.883 grains spike^{-1}, 68.700 (g) 1000 grains, 4.3 (t ha^{-1}) grain yield, 38.117 peduncle length, and 5.2 (t ha $^{-1}$) straw yield (t ha^{-1}). The technique of seeding 10 centimetres (p x p distance) resulted in a minimum of 74.150 germination %, 274.33 tillers m^{-2}, and 94.85 productive spikes m^{-2}, 65.633 non-productive spikes m^{-2}, 66.317 cm plant height, 10.450 cm spike length, 14.750 spikelets spike^{-1}, 47.650 grains spike^{-1}, 59.083 (g) 1000-grains, 3.9 (t ha^{-1}) grain yield, 33.967 Peduncle length, and 4.9 (t ha^{-1}) straw yield, while, the interaction between cultivars and sowing technique (C x S) revealed that the variety zardana and sowing method (C_2xS_4) interaction was more successful, achieving 93.667 germination %, 319.67 tiller (m^{-2}), 123.10 productive spikes(m^{-2}), and 78.83 non-productive spikes (m^{-2}), respectively, 92.00 cm plant height, 15.10 cm spike length, 23.03 spikelets spike^{-1}, 66.76 grains spike^{-1}, 80.8 g 1000 grains, 4.6 t ha^{-1} grain yield, 45.7 cm peduncle length, and 5.4 t ha^{-1} straw weight. It was indicated that the effective collaborating of cultivar Ujala × 30 cm (plant-to-plant distance) affects yield and yield components as compared to other cultivars and sowing methods. The present research revealed the effective performance of Zardana wheat cultivar (Quetta region) on all yielding parameters as compared to Ujala (Faisalabad region). After reviewing the data of this study, it was determined that sowing the crop at a Plant x Plant spacing of 30 cm resulted in the highest tillering growth and yield. When it came to cultivars, the "Zardana (Quetta region) cultivar" outperformed the "Ugala (Faisalabad region) cultivar" by a large margin.*

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Keywords: *Wheat Cultivars; Broadcast; Tillering Potential; Planting Geometry*

Introduction

Wheat (*Triticum aestivum* L.) is a staple food crop after rice, mostly used for food and animal feed. To keep up with the world's ever-increasing population, it is expected that global wheat demand will increase by 60% through 2050. Wheat grain output, however, is expected to plummet by 29 percent over this period due to a variety of biotic and abiotic stresses. (Manickavelu *et al*., 2012). Wheat, like other cereal crops, reacts differently to various agro-management activities, particularly planting techniques. Traditional sowing methods provide low crop production; however, line sowing by drilling on raised-up beds is further effective and produces greater crop production than broadcast and flat beds planting (Gupta, 2013). Carver (2016) studied the effects of several crop establishment methods, including the traditional line method, precision line method, and broadcasting. To construct the important efficient altitudinal arrangements, the broadcasting technique was applied. However, there was no visible association between any spatial layout and production efficacy. Line planting method has a higher production than conventional planting (Sobkowicz, 2016). The planting method has a considerable influence on seed placement at the optimum depth, which affects crop development. The optimal planting technique for wheat is influenced by the timing of sowing, the convenience of soil moisture during sowing time, the amount of remains in the region, and the convenience of a sowing apparatus (Abdelhadi *et al*. 2016). The planting of wheat and other cereal crops in line and ridge planting method is the most effective approach (Ghane *et al*. 2018). Line sowing is the favored method because it confirms dependable seed dissemination at the appropriate depth, resulting in greater seed emergence and crop stance consistency (Nasrullah *et al*. 2017). Subsequently being processed with rice and cotton, wheat is dispersed throughout Pakistan. Broadcasting not only necessitates a complex seed rate but also affects a smaller crop community, while line planting is preferred due to its consistent seed spreading and planting at the required deepness, which typically leads to improved emergence and a more uniform stance. Understanding early crop establishment is crucial for increasing wheat production. Planting method and proper Seed rate, in addition to other agronomic contemplations, are major factors of crop vigour and production. Considering the impact of and planting technique and proper seed rate, this study was laid out to establish the best planting technique and seed rate for optimum wheat production (Singh *et al*. 2015). Although the seedlings formed from drilled seeds outlived those developed from broadcast seeds, the plant stand developed from drilled seeds was well established, yielding more seed than the broadcast approach (Guy *et al*., 2017). Researchers Amoli *et al*. (2017) indicated that the most efficient no-till sowing technique for crop creation and production was employing an old-fashioned dual disc opener, which most producers in the region already peculiar. This saved growers money because they did not have to buy a no-till drill. The comparison of the existing study's findings with those of previous researchers revealed that the viewpoints of scientists who worked in the past were comparable to those of the present researchers and that their conclusions were consistent with the findings of the present research. Findings may vary owing to climate variance and other management elements that are specific to each researcher throughout conducting the experiments referred to in this chapter.

Wheat varieties have varying requirements for row spacing depending on their design and developmental trends. The crop canopy must capture a greater proportion of incoming radiation at the soil surface to provide a higher yield (Eberbach *et al*., 2005). Wheat yield may be significantly increased with improved planting geometry and proper tillage technique. Planting geometry with homogenous plant spatial distribution results in increased crop utilization of soil and environmental resources (Chen *et al*., 2008). Because row spacing impacts not just crop outlook but also the usage of inter-cultures and herbicides for actual and effective weed control, as well as the intercropping of other crops, row spacing influences crop yield. Aside from this, appropriate row spacing affects crop yield by boosting light interception and penetration, as well as light dispersion in the crop canopy and average leaf light utilization efficiency (Hussain *et al*., 2003). Proper spacing can help improve tillering capacity and increase the growth and yield components of wheat crops. (Thorsted *et al*., 2006). It is considered one of the cultivation practices that most influence grain yield and other agronomical principles. Changes in seeding density have special importance in wheat crops since they have a direct effect on grain yield and its components (Ozturk *et al*., 2006).

Wheat is farmed in Pakistan with rice, maize, cotton, sugarcane, vegetables, and fodders in a varied cropping system. To date, zero tillage wheat is the most used resource conservation method in South Asia's Indo-Gangatic Plains, followed by rice (Erenstein and Laxmi, 2008). The introduction of short-statured wheat varieties aided with production and protection technology not only played a major role in boosting the overall productivity of wheat but also their competitive ability tilted the ecology balance in favour of weeds. As a result, there is an urgent need to solve the weed problem by creating effective and sustainable weed management methods. Agronomic changes, for example, can be extremely useful cultural methods. Some agronomic methods, such as variable plant density and crop geometrics, can be effectively combined with herbicides to allow crop-weed competition in favour of crops while minimizing pesticide load per unit area, hence improving agriculture sustainability (Dass *et al*., 2016). The wheat productivity, it is necessary to produce high-yielding wheat cultivars that are then matched with a more effective package of agronomic practices (Farooq *et al*., 2012; Hussain, Mehmood *et al*., 2012). Planting geometry increases wheat output while decreasing costs by maximizing tillering capacity and making optimum use of other available resources. It is one of the most significant agronomic techniques for boosting wheat production while decreasing expenses (Thorsted *et al*., 2006; Mehmood *et al*., 2012). To increase wheat tillering capacity, it is possible to utilize optimum row spacing to boost tillering capacity in the field (Kakar *et al*., 2001; Mehmood *et al*., 2012). However, Pakistan's wheat output remains fairly low when compared to the global average. Numerous factors contribute to Pakistan's poor wheat output. The primary causes for this include insufficient soil fertility, late planting, traditional sowing practices, a lack of irrigation water, weed infestation, and inadequate crop husbandry. Wheat production may be increased further by fine-tuning agronomic procedures (planting geometry) and managing weeds effectively. Furthermore, tight spacing may result in poorer output as a result of increased plant competition for nutrients and water as a result of greater plant rivalry as a result of higher plant competition (Das and Yaduraju, 2011). Genetically modified wheat genotypes are often chosen for several reasons, including increased yields, improved resistance to harsh environmental conditions, and earlier maturity, among others (Kumar *et al*., 2013). With these considerations in mind, the current experiment was designed to examine the tillering capacity of a wheat cultivar at various planting orientations to compare the yield and yield components of different wheat cultivars and to determine the effect of different planting distances on tiller production.

Materials and methods

Experiment Site

The experiment was carried out during the cropping season 2017-18 to explore the tillering potential in wheat under different planting geometry at the agronomic research area of Lasbela University of Agriculture, Water and Marine Sciences, Uthal, Lasbela, Balochistan.

Soil Analysis

For determining the fertility status of the experimental field before sowing and after harvesting the wheat ten composite soil samples were collected from the field during the year 2017-18. Furthermore, the soil samples were taken from a depth of 15 cm with the help of auger. All the obtained samples were analyzed for their physio-chemical properties as shown in table (1.1).

Table 1.1: Physio-Chemical analysis before and after sowing the wheat

Soil characteristics	Unit	Value before sowing	Value after sowing	Observation
Textural class		Silty clay loam	Silty clay loam	
pH		7.84	7.84	Alkaline soil
EC	(dsm^{-1})	0.772	0.772	Normal saline
Organic matter (O.M)	(%)	0.68	0.67	Organic matter is low
Total nitrogen	(%)	0.034	0.35	Soil total nitrogen is low
Available phosphorus	Mg kg^{-1}	3.89	1.18	Soil phosphorus is low
Available potassium	Mg kg^{-1}	116.3	98.4	Potassium is low

Experimental Design and Treatment

Experimental treatment consisting of two factors like two wheat cultivars (C_1= Ugala (Faisalabad region, C_2 = Zardana (Quetta region) and factor B treatment comprised the four different planting methods (Broadcast, 10, 20, 30 cm) with varied planting space. The experiment was sown in RCBD (randomize complete block design) with three replications and block size (3m x 5m) and having a row-to-row distance (15 cm) respectively.

The seedbed is prepared by one deep ploughing followed by two harrowing with disc plough and two planking given to prepare a well-pulverized seed bed. After pulverizing the soil, a simple cultivator was used for single ploughing and planking. After well-prepared seed bed, the seed was sown with the help of a dibbler. Dibblers have a wooden frame with pegs. The frame is pressed in the field and lifted and then one seeds are dropped by hand in each hole at the rate of 100 kg ha^{-1}seed rate. For the wheat crop, the recommended doses of nitrogen, phosphorus, and potassium fertilizer were sprayed at 75 kg ha^{-1}, 60 kg ha^{-1}, and 60 kg ha^{-1}, respectively. In the DAP and SOP farm, all phosphate and potash fertilizer was applied at the time of planting by drill. In the urea farm, nitrogen fertilizer was divided into two halves. The initial half is irrigated, while the second half is irrigated during important periods. Irrigation was applied as per schedule, First irrigation at crown root initiation (CRI) (21 days after sowing), second irrigation at late tillering (42 days after sowing), third irrigation (60 days after sowing), fourth irrigation at flowering (80 days after sowing), fifth irrigation at milk stage (95 days after sowing) and sixth irrigation at dough ripe (115 days after sowing). The seed was treated with an effective fungicide (Vitavex) before sowing crop to control the disease in wheat crop. The crop was harvested manually at maturity during March 2018 when grains had moisture (15-20%). All other cultural practices remain constant for all treatments. The following observations (Germination (%), Number of tillers (m^{-2}), Number of productive spikes (m^{-2}), Number of non-productive spikes (m^{-2})**,** Plant height at maturity (cm)**,** Spike length (cm)**,** Number of spikelets spike^{-1}**,** Number of grains spike^{-1}**,**1000-grain weight (g)**,** Grain yield (t ha^{-1})**,** Peduncle length (cm), Weight of straw (t ha^{-1}) relating to growth and yield of the crop was recorded. During the growing season 2017-18, meteorological data was collected at the Meteorological Department's observatory at Lasbela University of Agriculture, Water and Marine Sciences in Uthal, Balochistan. The obtained data on various yield and yield components of wheat varieties were statistically evaluated using Fisher's analysis of variance (ANOVA) methods, and the least significant difference (LSD) test at a 5% probability level will be used to test for differences between treatments means (Steel *et al*., 1997).

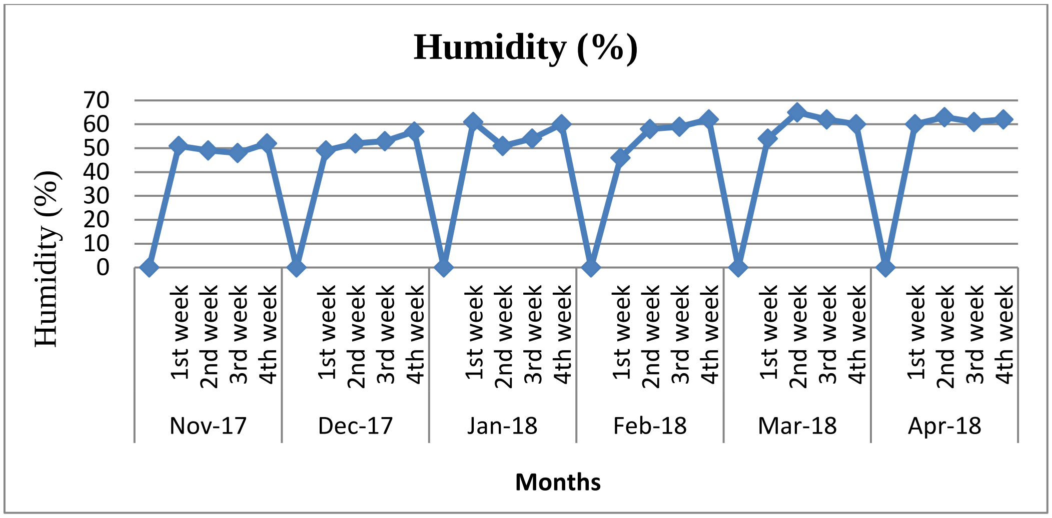

Figure 1.1: Relative humidity (%) of the experimental area during the cropping period

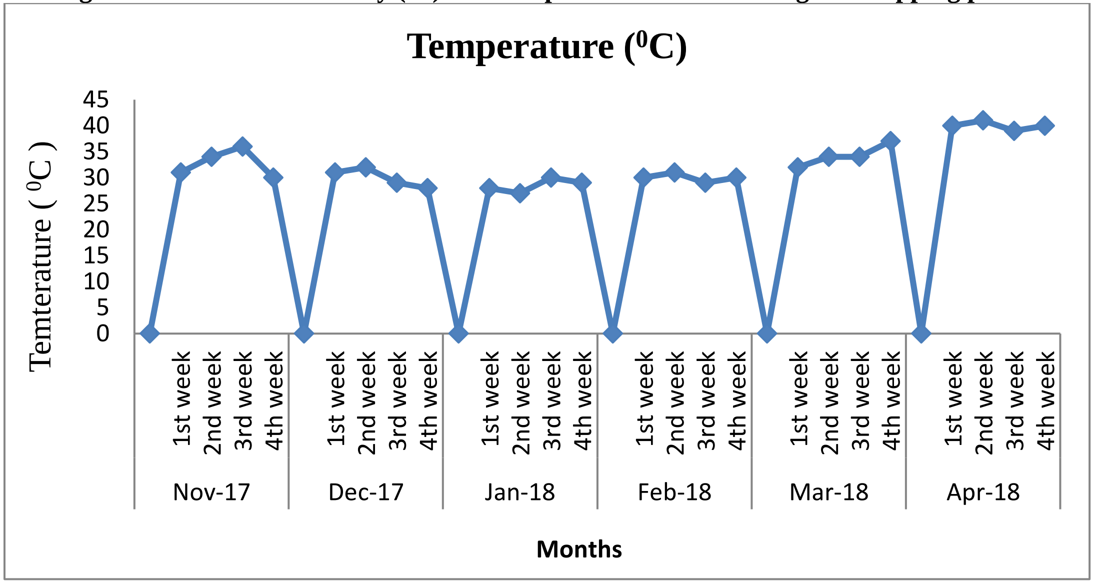

Figure 1.2: Temperature (°C) of experimental area during cropping period

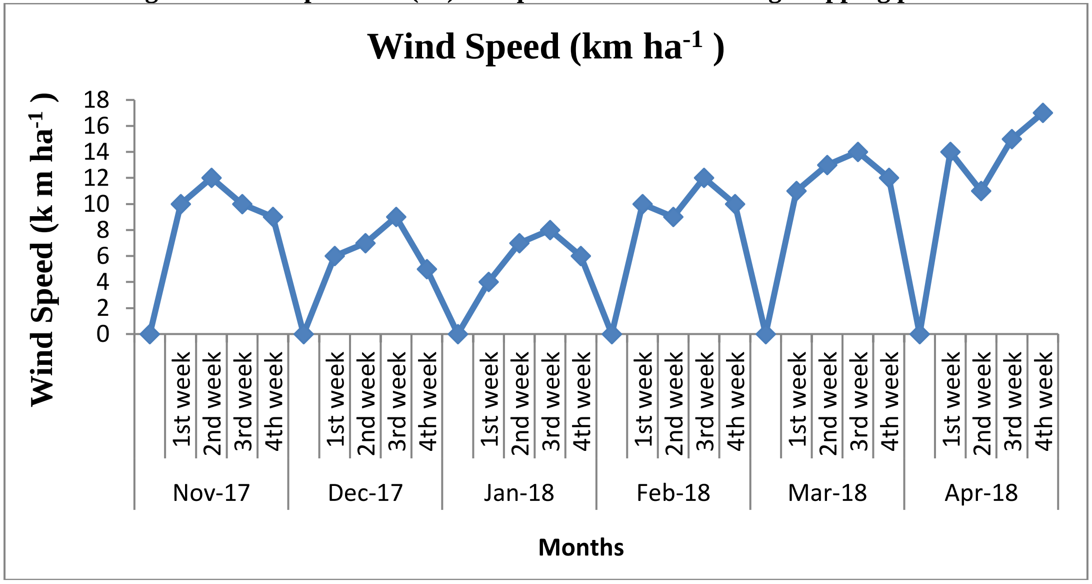

Figure 1.3: Wind speed (Km h^{-1}) of experimental area during cropping period

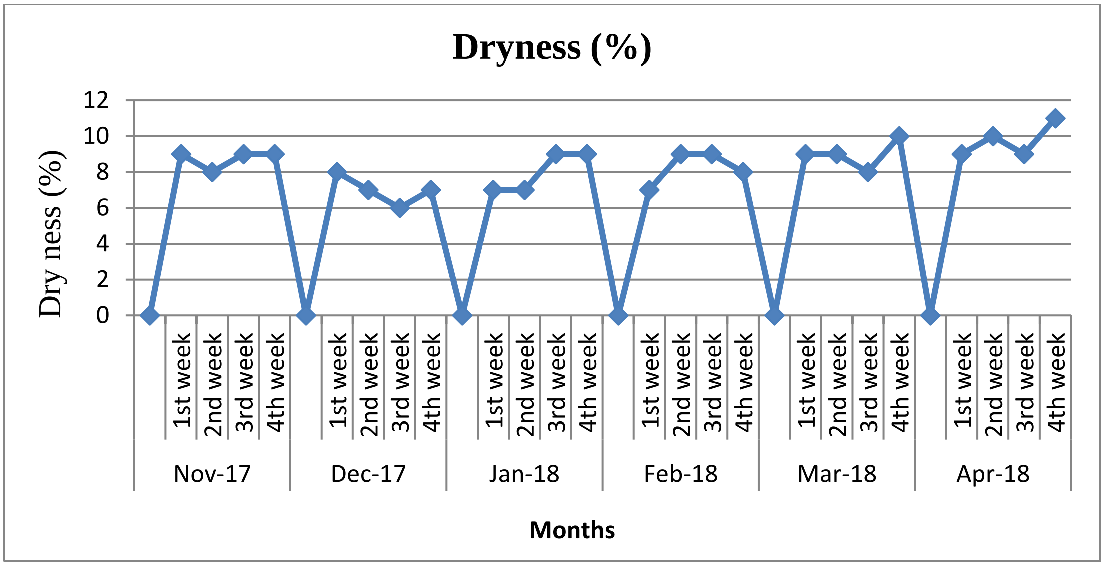

Figure 1.4: Dryness (%) of experimental area during cropping period 2017-18

Results

Germination (%)

Seed germination is a critical process that affects crop production and superiority. Understanding seed germination is so crucial for improving agricultural productivity and quality. Germination (%) of wheat cultivars under various sowing methods was observed statistically significant and the results are presented in table-1.2. The wheat cultivar Zardana (Quetta region) produced the highest germination (82.32%) as compared to (78.15%) Ujala (Faisalabad region). Whereas maximum germination (91.05%) was recorded when wheat crop was planted with 30 cm, followed by (83.86% and 74.15%) 20 cm and 10 cm, respectively. The minimum germination (71.90%) was noted with the broadcast planting method. The significant interactive effect indicated that the interaction of $C_2 \times S_4$ produced maximum germination (93.66%) and minimum germination (69.90%) was recorded with the interaction of $C_1 \times S_1$.

Number of Tillers (m^{-2})

Tiller production influences the ultimate number of spikes and has a significant impact on wheat grain yield production. Optimizing tillering capacity can be aided by maintaining proper row spacing. Variable row spacing has a significant effect on tiller m^{-2}. To produce more tiller m^{-2}, plants hired all available resources more effectively in-row spacing, including light, water, air, and nutrients. Short row spacing significantly enhanced the number of tillers m^{-2} more than wider row spacing.

Data in Table 1.2 shows the results of observing wheat cultivar tillers (m^{-2}) under different seeding procedures were found to be significant. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) generated the most tillers (292.00 m^{-2}) as compared to (281.33 m^{-2}). Maximum tillers (316.50 m^{-2}) were reported when wheat crops were planted at a depth of 30 cm, followed by (297.17 m^{-2} and 274.33 m^{-2}) when wheat crops were planted at a depth of 20 cm and 10 cm, respectively. With the broadcast plant approach, the least tillers (258.67 m^{-2}) were recorded as significant. The interactive effects revealed that the interaction of $C_2 \times S_4$ generated maximum tillers (319.67 m^{-2}) while the interaction of $C_1 \times S_1$ produced the lowest tillers (250.00 m^{-2}).

Table 1.2: Influence of wheat cultivars and different planting geometry on germination (%), no. of tillers (m^{-2}) and no. of productive spike (m^{-2})

Treatments	Germination (%)	Number of Tillers (m^{-2})	Number of productive spike (m^{-2})
Factor - A Wheat Cultivars (C)			
C_1 = Ugala (Faisalabad region)	78.158 B	281.33 B	99.73 B
C_2 = Zardana (Quetta region)	82.325 A	292.00 A	104.29 A
SE	0.3613	0.9036	0.4696
LSD=0.5%	0.7748**	1.9380**	1.0072**
Factor - B Planting geometry (S)			
S_1=Broadcast	71.900 D	258.67 D	87.98 D
S_2=Plant X Plant distance (10 cm)	74.150 C	274.33 C	94.85 C
S_3=Plant X Plant distance (20 cm)	83.867 B	297.17 B	104.77 B
S_4=Plant X Plant distance (30 cm)	91.050 A	316.50 A	120.43 A
SE	0.5109	1.2779	0.6641

LSD 5%	1.0958 **	2.7407 **	1.4245 **
Interaction (Cultivars x Planting geometry (C x S)			
$C_1 \times S_1$	69.900 H	250.00 G	85.47 H
$C_1 \times S_2$	73.900 F	267.33 F	90.50 G
$C_1 \times S_3$	71.467 G	268.33 F	93.20 F
$C_1 \times S_4$	76.833 E	280.33 E	96.50 E
$C_2 \times S_1$	82.833 D	293.67 D	102.47 D
$C_2 \times S_2$	84.900 C	300.67 C	107.07 C
$C_2 \times S_3$	88.433 B	313.33 B	117.77 B
$C_2 \times S_4$	93.667 A	319.67 A	123.10 A
SE	0.7225	1.8072	0.9392
LSD (5%)	1.5496**	3.8760**	2.0145 ^{NS}

Mean column values not showing the same letter differ significantly at p=5%
** = highly significant at 0.05 level

Number of productive spike (m^{-2})

The number of fertile tillers number (FTN), demarcated as the tillers that produce spikes and seeds (having grains), is a key factor of grain production in wheat. Significant productive spikes (m^{-2}) of wheat cultivars were measured using different sowing techniques as shown in Table 1.2. When compared to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) produced the most productive spikes (104.29 m^2) (99.73 m^2). When wheat crops were planted at 30 cm, the most productive spikes (120.43 m^2) were reported, followed by (104.77 m^2) and (94.85 m^2) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the smallest number of productive spikes (87.98 m^2) was recorded. A significant interactive effect showed that the interaction of $C_2 \times S_4$ generated the highest number of productive spikes (123.10 cm) and the interaction of $C_1 \times S_1$ produced the lowest number of productive spikes (85.47 m^2).

Number of non-productive spike (m^{-2})

The formation of non-fertile spike greatly impacts wheat production. Significant tiller reduction from non-productive tillers frequently adds to low wheat production. In general, wheat crops with sufficient tillering numbers can produce high spikes due to a balanced dry weight (DW) distribution between productive and non-productive tillers, which is crucial to yield production

Table 1.3 showed that the number of non-productive spikes (m^{-2}) results presented in wheat cultivars was significant. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) generated the most non-productive spikes (71.958 m^2) (64.142 m^2). When wheat crops were planted with 30 cm, the highest number of non-productive spikes (75.350 m^2) was reported, followed by (69.050 m^2 and 65.633 m^2) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the lowest number of non-productive spikes (62.167 m^2) was recorded. Significant interactive effects showed that interaction between $C_2 \times S_4$ generated the highest number of non-productive spikes (78.833 m^2) while interaction of $C_1 \times S_1$ produced the lowest number of non-productive spikes (59.100 m^2).

Plant height at maturity (cm)

Plant height is an important morphological and developmental parameter that correlates substantially with total plant growth and is highly predictive of eventual grain production and biomass. Wheat plant height is an important agronomic characteristic that has a direct influence on crop yield. Although the dwarf phenotype is beneficial for wheat lodging, plants that are too tiny result in inadequate growth and, as a result, lower wheat output potential. As a result, increasing plant height is critical to increase output in the absence of lodging.

Significant plant height (cm) of wheat cultivars was measured using different sowing methods, and the results are shown in Table 1.3. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) generated the maximum plant height (76.433cm) (69.642cm). When wheat crops were planted with 30 cm, the largest plant height (89.650cm) was reported, followed by (77.367cm and 66.317cm) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the minimum plant height (58.817cm) was recorded. The significant effects showed that the interaction of $C_2 \times S_4$ caused maximum plant height (92.000cm) while the interaction of $C_1 \times S_1$ produced the lowest plant height (53.667cm).

Spike length (cm)

The morphology of the wheat inflorescence (also known as the spike) of small-grain cereals is important in affecting grain production. The number of spikes per square meter was considerably impacted by row spacing. When compared to other planting geometry at 30 cm line spacing found in substantially more spikes m^{-2} of wheat.

Data in Table 1.3 shows the significant results of the spike length (cm) of two wheat cultivars using different seeding techniques. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) achieved the longest spike length (12.892cm) (9.667cm). When wheat crops were planted with 30 cm, the largest spike length (13.600cm) was reported, followed by (11.917cm and 10.450cm) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the minimum spike length (9.150 cm) was recorded. Significant interactive effects revealed that the interaction of $C_2 \times S_4$ created a maximum spike length (15.100 cm) while the interaction of $C_1 \times S_1$ produced the lowest spike length (7.567cm).

Table 1.3: Influence of wheat cultivars and different planting geometry on number of non productive spike (m^{-2}), plant height (cm) and spike length (cm)

Treatments	Number of non productive spike (m^{-2})	Plant height at maturity(cm)	Spike length (cm)
Factor - A Wheat Cultivars (C)			
C_1 = Ugala (Faisalabad region)	64.142 B	69.642 B	9.667 B
C_2 = Zardana (Quetta region)	71.958 A	76.433 A	12.892 A
SE	0.4449	0.4009	0.1442
LSD=0.5%	0.9542 **	0.8599**	0.3094**
Factor - B Planting geometry(S)			
S_1 = Broadcast	62.167 D	58.817 D	9.150 D
S_2 = Plant X Plant distance (10 cm)	65.633 C	66.317 C	10.450 C
S_3 = Plant X Plant distance (20 cm)	69.050 B	77.367 B	11.917 B
S_4 = Plant X Plant distance (30 cm)	75.350 A	89.650 A	13.600 A
SE	0.6292	0.5670	0.2040
LSD 5%	1.3495**	1.2160 **	0.4375 **
Interaction (Cultivars x Planting geometry(C x S)			
$C_1 \times S_1$	59.100 G	53.667 G	7.567 F
$C_1 \times S_2$	65.233 E	63.967 F	10.733 D
$C_1 \times S_3$	61.767 F	62.633 F	8.767 E
$C_1 \times S_4$	69.500 D	70.000 E	12.133 C
$C_2 \times S_1$	63.833 E	74.967 D	10.233 D
$C_2 \times S_2$	74.267 B	79.767 C	13.600 B
$C_2 \times S_3$	71.867 C	87.300 B	12.100 C
$C_2 \times S_4$	78.833 A	92.000 A	15.100 A
SE	0.8898	0.8018	0.2885
LSD (5%)	1.9085*	1.7197**	0.6187^{NS}

Mean column values not showing the same letter differ significantly at p=5%

** = highly significant at 0.05 level

Number of spikelets spike^{-1}

The spikelets are determined may be regarded as one of the most critical periods of the wheat plant. Wider row spacing and fewer shoots per m^{-2} may have reduced plant competition for nutrients, water, space, and light interception, leading to spike length increase. The value of Table 1.3 showed that the results of observing the number of spikelets spike^{-1} of wheat varieties under different seeding methods were significant. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana generated the most spikelets spike^{-1} (17.550). (15.725). When wheat crops were planted at 30 cm, the highest spikelets spike^{-1} (22.283) were reported, followed by (18.867 and 14.750) at 20 cm and 10 cm, respectively. The spread plant approach yielded the lowest spikelets spike^{-1} (10.650). Interaction of $C_2 \times S_4$ generated the significant highest spikelets spike-1 (23.033), whereas interaction of C1 × S1 produced the lowest spikelets spike^{-1} (9.600).

Number of Grains spike^{-1}

The grains number (GN) is determined by spike growth rate (SGR) and spike growth period duration. However, because these three qualities are not independent of one another, assessing their relative contribution to grain number is critical for increasing yield potential. The planting density and number of spikelets plant^{-1}, which is the sum of the spikelets on each spike, determine the grains number spike^{-1}.

The result in table 1.4 was found significant for grain number spike^{-1} of wheat cultivars under different seeding procedures. When compared to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) produced the highest grains spike^{-1} (54.233), as compared (49.617). When wheat crops were planted with 30 cm, the greatest grains spike^{-1} (64.833) was reported, followed by (54.883 and 47.650) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the least grains spike^{-1} (40.333) was recorded. The interactive effects revealed significantly that the interaction of $C_2 \times S_4$ was found in the maximum grains spike^{-1} (66.767) and the lowest grains spike^{-1} (38.533) when compared to the interaction of $C_1 \times S_1$.

1000- grain weight (g)

The thousand-grain weight (TGW) is an important parameter for assessing a variety's background. The row spacing change did not influence the thousand-grain weight. The thousand-grain weight influences seedling vigour and growth, which affects yield indirectly.

The 1000-grain weight (g) of wheat cultivars was measured significantly under different sowing techniques, and the findings are listed in table 1.4. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) generated the greatest 1000-grain weight (65.550) and (60.775). When wheat crops were planted at 30 cm, the greatest 1000-grain weight (g) (78.483) was reported, followed by (68.700 and 59.083) at 20 cm and 10 cm, respectively. With the broadcast plant approach, the least 1000-grain weight (g) (46.383) was recorded. With significant interaction of C_2 x S_4, maximum 1000-grain weight (g) (80.833) and minimum 1000-grain weight (g) (45.233) were observed, whereas interaction of C_1 x S_1 generated highest 1000-grain weight (g) (80.833) and minimum seed weight (45.233).

Grain yield (t ha^{-1})

Grain yield was not reduced significantly by increasing row space, demonstrating that broader planting geometry technology may be used without fear of yield loss. Suitable varieties with optimum line spacing are crucial for optimal light, penetration, interruption, dissemination in the crop canopy, and average light use efficiency of the canopy leaves, all of which influence crop productivity.

The grain yield of wheat cultivars was measured using different planting techniques, and the findings provided in table 1.5 were significant. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) produced the greatest grain yield (4.3917) and (3.9442). When wheat crops were planted with 30 cm, the highest grain production (4.4850) was reported, followed by (4.3317 and 3.9717) with 20 cm and 10 cm, respectively. The spread plant approach had the lowest grain yield (3.8833). The interactive effects revealed that the interaction of $C_2 \times S_4$ generated the highest grain yield (4.6367) whereas the interaction of $C_1 \times S_1$ produced the lowest grain yield (3.6333).

Peduncle length (cm)

The peduncle, which is located at the first internode directly beneath the spike, performs several critical functions in crop productivity. To supply assimilates to the filled grain, the vascular system in the peduncle must grow.

The length of the peduncle in wheat cultivars was measured significantly using different sowing methods, and the findings are shown in table 1.5. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) generated the longest peduncle length (37.333) as compared (34.283). When wheat crops were planted with 30 cm, the largest peduncle length (43.500) was reported, followed by (38.117 and 33.967) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the shortest peduncle length (27.650) was recorded. The interactive effects revealed that the interaction of C_2 x S_4 created a maximum peduncle length (45.700) while the interaction of C_1 x S_1 produced the lowest peduncle length (26.700).

Straw yield (t ha^{-1})

Crop straw is a massive universal organic agricultural waste resource. Straw quantity and quality may be raised without having a significant detrimental impact on grain production. The presence of residues on the soil surface might have caused physical repression of weed seedlings and prevented the light from reaching them.

Value in table 1.5 showed that the results of observing the straw yield length of wheat cultivars under different seeding techniques were significant. In comparison to Ujala (Faisalabad area), the wheat cultivar Zardana (Quetta region) generated the greatest straw yield (5.3542) and (4.7317). When wheat crops were planted with 30 cm, the highest straw yield (5.2733) was obtained, followed by (5.200 and 4.9100) with 20 cm and 10 cm, respectively. With the broadcast plant approach, the minimal straw yield (4.7783) was recorded. A significant interactive effect revealed that the interaction of $C_2 \times S_4$ created the highest straw yield (5.4633) and the lowest straw yield (4.4233), whereas the interaction of $C_1 \times S_1$ produced the lowest straw yield (4.4233).

Table 1.4: Influence of wheat cultivars and different planting geometry on spikelets Spike $^{-1}$, number of Grains spike^{-1} and 1000-grain weight (g)

Treatments	**Number of spikelets Spike $^{-1}$**	**Number of Grains spike^{-1}**	**1000-grain weight (g)**
Factor - A Wheat Cultivars (C)			
C_1 = Ugala (Faisalabad region)	15.725 B	49.617 B	60.775 B
C_2 = Zardana (Quetta region)	17.550 A	54.233 A	65.550 A
SE	0.2488	0.2182	0.3574
LSD=0.5%	0.5337**	0.4680**	0.7666**
Factor - B Planting geometry(S)			
S_1 = Broadcast	10.650 D	40.333 D	46.383 D
S_2 = Plant X Plant distance (10 cm)	14.750 C	47.650 C	59.083 C
S_3 = Plant X Plant distance (20 cm)	18.867 B	54.883 B	68.700 B
S_4 = Plant X Plant distance (30 cm)	22.283 A	64.833 A	78.483 A
SE	0.3519	0.3086	0.5054

LSD 5%	0.7547 **	0.6619 **	1.0841 **
Interaction (Cultivars x Planting geometry(C x S)			
$C_1 \times S_1$	9.600 H	38.533 H	45.233 H
$C_1 \times S_2$	11.700 G	42.133 G	47.533 G
$C_1 \times S_3$	13.667 F	45.033 F	54.833 F
$C_1 \times S_4$	15.833 E	50.267 E	63.333 E
$C_2 \times S_1$	18.100 D	52.000 D	66.900 D
$C_2 \times S_2$	19.633 C	57.767 C	70.500 C
$C_2 \times S_3$	21.533 B	62.900 B	76.133 B
$C_2 \times S_4$	23.033 A	66.767 A	80.833 A
SE	0.4977	0.4364	0.7148
LSD (5%)	1.0674 ^{NS}	0.9361**	1.5331**

Mean column values not showing the same letter differ significantly at p=5%
** = highly significant at 0.05 level

Table 1.5: Influence of wheat cultivars and different planting geometry on Grains spike^{-1}, grain yield (t ha^{-1}), peduncle length (cm) and straw yield (tha^{-1})

Treatments	**Number of Grains spike^{-1}**	**Grain yield (t ha^{-1})**	**Peduncle length (cm)**	**Straw yield (t ha^{-1})**
Factor - A Wheat Cultivars (C)				
C_1 = Ugala (Faisalabad region)	49.617 B	3.9442 B	34.283 B	4.7317 B
C_2 = Zardana (Quetta region)	54.233 A	4.3917 A	37.333 A	5.3542 A
SE	0.2182	0.1257	0.1272	0.1667
LSD=0.5%	0.4680**	0.2696**	0.2729**	0.3575 ^{NS}
Factor B Planting geometry(S)				
S_1=Broadcast	40.333 D	3.8833 C	27.650 D	4.7783 B
S_2=Plant X Plant distance (10 cm)	47.650 C	3.9717 BC	33.967 C	4.9100 B
S_3=Plant X Plant distance (20 cm)	54.883 B	4.3317 AB	38.117 B	5.2100 A
S_4=Plant X Plant distance (30 cm)	64.833 A	4.4850 A	43.500 A	5.2733 A
SE	0.3086	0.1777	0.1799	0.2357
LSD 5%	0.6619 **	0.3812 **	0.3859 **	0.5056 **
Interaction (Cultivars x Planting geometry (C x S)				
$C_1 \times S_1$	38.533 H	3.6333 H	26.700 H	4.4233 H
$C_1 \times S_2$	42.133 G	4.1333 F	28.600 G	5.1333 E
$C_1 \times S_3$	45.033 F	3.6533G	31.600 F	4.4767 G
$C_1 \times S_4$	50.267 E	4.2900 D	36.333 E	5.3433C
$C_2 \times S_1$	52.000 D	4.1567 E	37.533 D	4.9433 F
$C_2 \times S_2$	57.767 C	4.5067 B	38.700 C	5.4767 A
$C_2 \times S_3$	62.900 B	4.3333 C	41.300 B	5.0833 D
$C_2 \times S_4$	66.767 A	4.6367 A	45.700 A	5.4633 A
SE	0.4364	0.2514	0.2545	0.3334
LSD (5%)	0.9361**	0.5391**	0.5458**	0.7150*

Mean column values not showing the same letter differ significantly at p=5%
** = highly significant at 0.05 level

Discussion

Wheat, like other cereal crops, reacts differently to various agro-management activities, particularly planting techniques. Traditional sowing methods provide low crop production; however, line sowing by drilling on raised-up beds is further effective and produces greater crop production than broadcast and flat beds planting (Gupta, 2013). Carver (2016) studied the effects of several crop establishment methods, including traditional drilling, precision drilling, and broadcasting.

Statistical analysis showed that the wheat variety "Zardana (Quetta region)" ranked first produced 82.325 germination, 292.00 tillersm^{-2}, 104.29 productive spikem^{-2}, 71.958 non-productive spikem^{-2},76.433 cm plant height, 12.892 cm spike length, 17.550 spikelets spike^{-1}, 54.233 grains spike^{-1}, 65.550

(g)1000-grain weight, 4.39 grain yield (tha^{-1}), 37.333 cm Penduncle length as compare to the other wheat variety Ujala for different trait like 78.158 germination %, 69.642 cm plant height, 281.33 tillersm^{-2}, 99.73 productive spikem^{-2}, 64.142 non-productive spikem^{-2}, 9.667 cm spike length, 15.725 spikelets spike^{-1}, 49.617 grains spike^{-1}, 60.775 (g) 1000-grains weight, 3.94 grain yield (t ha^{-1}), 34.283 cm Penduncle length; and 3.73 straw weight (t ha^{-1}) were achieved.

Wheat crop planted with plant × plant distance (30 cm) produced maximum 91.050 germination %, 316.50 tillersm^{-2}, 120.43 productive spikem^{-2}, 75.350 non-productive spikem^{-2},89.650 cm plant height, 13.600 cm spike length, 22.283 spikelets spike^{-1}, 64.833 grains spike^{-1}, 78.483 (g) 1000-grains weight, 4.48 grain yield (t ha^{-1}), 43.500 cm Peduncle length, 5.27 straw weight (t ha^{-1}) as compared to the remaining other three sowing method (Broad cost, planting at 10 cm and planting at 20 cm). A significant effect on the wheat crop was the distance between the plants (20 cm).

Broad cost sowing method produced the lowest 71.900 germination %, 258.67 tillersm^{-2}, 87.98 productive spikem^{-2}, 62.167 non-productive spikem^{-2}, 58.817 cm plant height 9.150 cm spike length, 10.650 spikelets spike^{-1}, 40.333 grains spike^{-1}, 46.383 (g) 1000-grains weight, 3.88 grain yield (t ha^{-1}), 27.650 cm Peduncle length, and 4.77 straw weight (t ha^{-1}). A significant interaction was observed between wheat cultivars and different sowing method. Interaction $C_2 \times S_4$ produced maximum yield and yield component for all traits as compared to the minimum value noted in C_1xS_1 interaction. According to Ashraf *et al.* (2018), the technique of sowing has a substantial impact on wheat yields, and the crop planted by the drilling method outperformed the crop sown by traditional methods. These findings are completely confirmed by the literature. Using three different planting strategies, Khan *et al.* (2016) discovered that each of the growth and yield characteristics was substantially impacted by the planting method utilized. Quanqi *et al.* (2015) discovered that crop production increased when the crop was seeded using the drilling technique. Compared to traditional broadcasts of seeds, direct drilling yielded reduced straw yields and nutrient absorption; as a result, direct drilling was effective and recommended for wheat production. Wheat is farmed in Pakistan with rice, maize, cotton, sugarcane, vegetables, and fodders in a varied cropping system. To date, zero tillage wheat is the most commonly used resource conservation method in south Asia's Indo-Gangatic Plains, followed by rice (Erenstein and Laxmi, 2008). The introduction of short-statured wheat varieties aided with production and protection technology not only played a major role in boosting the overall productivity of wheat but also their competitive ability tilted the ecology balance in favour of weeds. As a result, there is an urgent need to solve the weed problem by creating effective and sustainable weed management methods. Agronomic improvements, for example, can be extremely useful cultural methods. Some agronomic methods, such as variable plant density and crop geometrics, can be effectively paired with herbicides to allow crop-weed competition in favour of crops while minimizing pesticide load per unit area, hence aiding in agriculture sustainability (Dass *et al.*, 2016). Planting techniques were investigated in detail by Gupta (2016), who conducted tests to determine the effect that planting methods had on wheat crop growth attributes and grain production. If a plant is planted close enough to another, it may compete with the other plant to alter its soil or air habitat, thus slowing the pace of growth of both plants. Crop population structure and production are said to be affected by row width (Zhou *et al.*, 2010). Wheat varieties have varying requirements for row spacing depending on their design and developmental trends. The crop canopy must capture a greater proportion of incoming radiation at the soil surface to provide a higher yield (Eberbach and Pala, 2005). According to several studies done in different climes, crop productivity increased when the rows were spaced closely together as opposed to when the rows were spaced far apart (Chen *et al.*, 2008). According to some researchers, wider row spacing in wheat either delivers higher yields or yields that are comparable to tighter row spacing (Hiltbrunner *et al.*, 2005). In addition to row spacing, many additional agronomic techniques may be used to improve wheat drought resilience. Because the quantity of bare soil exposed to the sun determines the amount of evaporation from the soil, narrow row spacing improves drought tolerance by lowering evaporation losses from the soil (Farooq *et al.*, 2015). Planting wheat varieties, on the other hand, should be done with the plant's height and tillering potential in mind as it grows. Dwarf cultivars with limited tillering capacity, for example, produced better yields when planted in tightly spaced rows than dwarf cultivars with lower tillering capability when planted in medium row spacing (Hussain *et al.*, 2013). Using a medium row spacing of 20 cm, it was discovered that a greater number of grains per spike could be obtained (Lasani 2008). In this attribute, genetic variety and the availability of necessary nutrients play a major role. It has been observed that when spacing is limited in the field, the number of grains spike^{-1} drops because of light and nutrition deficiency, as well as a lack of available space (Naseri *et al.*, 2012).

According to Hussain *et al.* (2016), the drilling technique of sowing simplifies the implementation of other agricultural cultural practices and increases crop yields. Seed production was increased, according to Faraji *et al.* (2016), who claimed that field management measures increased seed output. The drilling technique has major benefits in terms of soil moisture management, and it may be modified to allow for narrower row spacing when associated with other planting geometry (Mascagni *et al.*, 2017). Carver (2016) studied the effects of several crop establishment methods, including traditional drilling, precision drilling, and broadcasting. To construct the most efficient spatial arrangements, the broadcasting technique was applied. Broadcast sowing, as opposed to planting in rows by drilling the seeds, often produces a lower crop yield Plants that are produced in agricultural communities compete with one another for resources and nutrients. It is vital to engage in this kind of competition when the immediate supply of a single essential element falls below the aggregate demands of all plants. If a plant is planted close enough to another, it may convince the other plant to alter its soil or air habitat, thus slowing the pace of growth of both plants. Researchers Amoli *et al*. (2017) found that using a conventional dual disc opener, which already existing the grower's region, was one of the most effective no-till sowing methods for crop formation and production. This saved growers money because they did not have to purchase a no-till drill. The comparison of the present study's findings with those of previous researchers revealed that the viewpoints of scientists who worked in the past were comparable to those of the present researchers and that their conclusions were consistent with the findings of the present research. Findings may vary owing to climate variance and other management elements that are specific to each researcher throughout conducting the experiments referred to in this chapter. Wheat varieties have varying requirements for row spacing depending on their design and developmental trends. The crop canopy must capture a greater proportion of incoming radiation at the soil surface to provide a higher yield (Eberbach *et al*., 2005).

Conclusions

It was concluded that different sowing methods significantly increased wheat production. Wheat cultivar Zardana (Quetta region) performed best regarding all traits (germination %, number of tillers m^{-2}, number of spikelets $spike^{-1}$, spike Length, number of grains $spike^{-1}$, 1000-grain weight, number of grains $spike^{-1}$, grain yield and straw yield) under 30 cm plant to plant distance as compared to Ujala wheat cultivar (Faisalabad region).

References

Abdelhadi, M., de Solan, B., & Andrieu, B. (2016). Architectural response of wheat cultivars to row spacing reveals altered perception of plant density. *Frontiers in plant science*,**10**, 999. https://doi.org/10.3389/fpls.2019.00999

Amoli, M., Roche, J., Bouniols, A., Cerny, M., Mouloungui, Z .,& Merah, O. (2017). Effects of genotype and sowing date on phytostanol–phytosterol content and agronomic traits in wheat under organic agriculture. *Journal of Food Chemistry*. **117**(2), 219–225. https://doi.org/10.1016/j.foodchem.2009.03.102

Ashraf, M., Ali, M., Din, Q. M., Akram, M., & Ali, L. (2018). Effect of different seed rates and row spacings on the growth and yield of wheat. *Journal of Animal and Plant Science*, 13(3), 161-163.

Carver, B. F., Smith, C. M., Chuang, W. P., Hunger, R. M., Edwards, J. T., Yan, L. & Bowden, R. L. (2016). Registration of OK05312, a High-Yielding Hard Winter Wheat Donor of Cmc4 for Wheat Curl Mite Resistance. *Journal of Plant Registrations*, **10**(1), 75-79. https://doi.org/10.3198/jpr2015.04.0026crg

Chen, C., Neill, K., Wichman, D., & Westcott, M. (2008). Hard red spring wheat response to row spacing, seeding rate, and nitrogen. *Agronomy Journal*, **100**(5), 1296-1302. https://doi.org/10.2134/agronj2007.0198

Chen, S., Zhang, X., Sun, H., Ren, T., & Wang, Y. (2011). Effects of winter wheat row spacing on evapotranpsiration, grain yield and water use efficiency. *Agricultural Water Management*, **97**(8), 1126-1132. https://doi.org/10.1016/j.agwat.2009.09.005

Das T. K., & Yaduraju, N. T. (2011). Effects of missing- row sowing supplemented with row spacing and nitrogen on weed competition and growth and yield of wheat. *Crop and Pasture Science*, **62**(1), 48-57. https://doi.org/10.1071/CP10203

Dass, A., Shekhavat, K., Choudhary A.K., Sepat, S.,Rathore, S. S., Mahajan, G. & Chauhan, B. S. (2016). Weed management in direct seeded rice using crop competition- A review. *Crop Protection*, https://doi.org/10.2016/J.croppro.2016.08.005.

Eberbach, P., & Pala, M. (2005). Crop row spacing and its influence on the partitioning of evapotranspiration by wintergrown wheat in Northern Syria. *Plant and Soil*, **268**(1), 195-208. https://doi.org/10.1007/s11104-004-0271-y

Erenstein, O., & Laxmi, V. (2008). Zero tillage impacts in India's rice–wheat systems: a review. *Soil and Tillage Research*, **100**(1-2), 1-14. https://doi.org/10.1016/j.still.2008.05.001

Faraji, M., Soomro, Z. A., Qamar,, M. & Gurmani, Z. A. (2006). Effect of nitrogen and phosphorus on yield and yield-contributing characteristics of wheat. *Sarhad Journal of Agriculture*, **21**, 651-653.

Farooq, H., Shabir, G., Khan, M.B., & Zia, A. B. (2012). Delay in planting decreases wheat productivity. *International Journal of Agriculture & Biology*, 14(4), 533–539.

Farooq, S., Shahid, M., Khan, M. B., Hussain, M., & Farooq, M. (2015).Improving the productivity of bread wheat by good management practices under terminal drought. *Journal of Agronomy and Crop Science*, **201**(3), 173-188. https://doi.org/10.1111/jac.12093

Ghane, M., Rasekhi Nejad, A., Blanke, M., Gao, Z., & Moan, T. (2018). Narrow spacing insures higher productivity of low tillering wheat cultivars. *Wind Energy*, **21**(7), 575-589.

Gupta, P. K., Sahai, S., Singh, N., Dixit C. K., Singh, D.P., Sharma, C., Tiwari, M .K., Gupta, R.K., &

Garg, S.C.(2016). Residue burning in rice–wheat cropping system: Causes and implications. *Current Science*, **87**(12),1713-1717.

Guy Jr, G. P., Zhang, K., Bohm, M. K., Losby, J., Lewis, B., Young, R., & Dowell, D. (2017). Wheat cultivar yield response to some organic and conventional farming conditions and the yield potential of mixtures. *The Journal of Agricultural Science*, **66**(26), 697-704. https://doi.org/10.1017/S00218596170001x

Hiltbrunner, J., Liedgens, M., Stamp, P., Streit, B. (2005). Effects of row spacing and liquid manure on directly drilled winter wheat in organic farming. *European Journal of Agronomy*, **22**(4), 441-447. https://doi.org/10.1016/j.eja.2004.06.003

Hussain, M., Farooq, S., Jabran, K., Ijaz, M., Sattar, A., & Hassan, W. (2016). Wheat sown with narrow spacing results in higher yield and water use efficiency under deficit supplemental irrigation at the vegetative and reproductive stage. *Agronomy*, **6**(2),22. https://doi.org/10.3390/agronomy6020022

Hussain, M., Khan, M. B., Mehmood, Z., Zia, A. B., Jabran, K., & Farooq, M. (2013). Optimizing row spacing in wheat cultivars differing in tillering and stature for higher productivity. *Archives of Agronomy and Soil Science*, **59**(11), 1457-1470. https://doi.org/10.1080/03650340.2012.725937

Hussian I, Khan M. A.,& Ahmad K. (2003) Effect of row spacing on the grain yield and yield component of wheat (*Triticum aestivum* L.). *Pakistan Journal of Agronomy*, **2**(3), 153-59.

Kakar, K. M., Arif, M., & Ali, S. (2001). Effect of NP levels, seed rate and row spacing on wheat. *Pakistan journal of Biological. Science*, **4**, 1319-1322.

Khan, I. A., Ihsanullah, A. J., Taj, F. H.,& Khan, N. (2016). Effect of sowing dates on yield and yield components of Mash bean. *Asian Journal of Plant Science*, **1**, 622-624.

Lasani, J., Manent, J., Viudas, J., López, A., & Santiveri, P. (2008). Seeding rate influence on yield and yield components of irrigated winter wheat in a Mediterranean climate. *Agronomy Journal*, **96**(5), 1258-1265. https://doi.org/10.2134/agronj2004.1258

Manickavelu, A., Kawaura, K., Oishi, K., Shin-I, T., Kohara, Y., Yahiaoui, N ., & Yano, K. (2012). Comprehensive functional analyses of expressed sequence tags in common wheat (*Triticum aestivum* L.). *DNA research*, 19(2), 165-177. https://doi.org/10.1093/dnares/dss001

Mascagni, S .S., Lemke, R., Wang, Z. H., & Chhabra, B. S. (2017). Tillage, nitrogen and crop residue effects on crop yield, nutrient uptake, soil quality, and greenhouse gas emissions. *Soil and Tillage Research*, 90(1-2), 171-183. https://doi.org/10.1016/j.still.2005.09.001

Mehmood, N., Ahmad, B., Hassan, S., & Bakhsh, K. (2012). Impact of temperature ADN precipitation on rice productivity in rice-wheat cropping system of Punjab province. *Journal Animal Plant Science*, *22*(4), 993-997

Naresh, R. K., Gupta Raj, K., Gajendra Pal, D. S., & Kumar Dipender, K. V. (2015). Tillage crop establishment strategies and soil fertility management: resource use efficiencies and soil carbon sequestration in a rice-wheat cropping system. *International Journal of Plant Production*, **21**, 121-128.

Naseri, R., Soleymanifard, A., Khoshkhabar, H., Mirzaei, A., & Nazaralizadeh, K. (2012).Effect of plant density on grain yield, yield components and associated traits of three durum wheat cultivars in Western Iran. *International Journal of Agriculture and Crop Science*, ***4***(2), 79-85.

Nasrullah, H. M., Aslam, M., Akhtar, M., Ali, B., Majid, A., Akram, M., & Farooq, U. (2017). Relay cropping of cotton in standing wheat: an innovative approach for enhancing the productivity and income of small farm. *Romanian Agricultural Research*, **34**, 87-195. https://hdl.handle.net/20.500.11766/67223

Ozturk, A., Caglar, O., &Bulut, S. (2006). Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. *Journal of Agronomy and Crop Science*, **192**(1), 10-16. https://doi.org/10.1111/j.1439-037X.2006.00187.x

Quanqi, Q., Bian, C., Liu, X., Ma, C., & Liu, Q. (2015). Winter wheat grain yield and water use efficiency in wide-precision planting pattern under deficit irrigation in North China Plain. *Agricultural Water Management*, ***153***, 71-76. https://doi.org/10.1016/j.agwat.2015.02.004

Singh, B., Singh, J., Singh, G., & Kaur, G. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Agronomy*, ***5***(2), 220-238. https://doi.org/10.3390/agronomy5020220

Steel, R. G. D., Torrie, J. H. and Dicky, D. A. 1997. Principles and procedures of Statistics. A biometrical Approch 3rd Ed. McGraw Hill Book Cooperation International New York, 400-428.

Thorsted, M. D., Olesen, J. E., & Weiner, J. (2006). Width of clover strips and wheat rows influence grain yield in winter wheat/white clover intercropping. *Field Crops Research*, **95**(2-3), 280-290. https://doi.org/10.1016/j.fcr.2005.04.001

Zhou, X. B., Li, Q. Q., Yu, S. Z., Wu, W., & Chen, Y. H. (2010). Row spacing and irrigation effects on water consumption of winter wheat in Taian, China. *Canadian journal of plant science*, **87**(3), 471-477. https://doi.org/10.4141/P06-035

Declarations

Declaration of Interest Statement

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work.

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Author's contributions

MH and MW conducted the field trials and planned the experiment. SA, QS, AS analyzed the data. GK and HTA assisted with data collection. All authors proofread the manuscript. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable

Consent for Publication

Not applicable