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Effect of row spacing on different wheat (*Triticum aestivum* L.) varieties in semi-arid region of Kandahar

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Abstract
A study was conducted during winter season of 2015 at Tarnak Research Farm of Afghanistan National Agriculture Science and Technology University (ANASTU), Kandahar, Afghanistan to find out suitable effect of row spacing on different varieties of wheat cultivation in the study region. The treatments comprised of three wheat varieties (PBW 154, Darulaman 07 and Herat 99) and three row spacing (20, 25 and 30 cm). The experiment was laid out in a (FRBD) with three replications. Consequences shown that among three wheat varieties, Herat 99 produced significantly taller plants (85.2 cm) than other varieties. Significantly higher number of tillers m^{-2} (304) and LAI (4.4) were recorded in Herat 99 than Darulaman 07. Herat 99 produced significantly greater dry matter accumulation m^{-2} (988 g m^{-2}) than other varieties. Significantly higher spike number m^{-2}, grain yield (3.71 t ha^{-1}) and straw yield (6.17 t ha^{-1}) were also recorded from Herat 99 than Darulaman 07. Planting at 20 cm row spacing resulted in significantly higher number of tillers (303) dry matter production (971 g m^{-2}) and LAI (4.4) number of spikes m^{-2} (285) as compared to 30 cm row spacing. However, spike length (12.1cm) and spikelets $spike^{-1}$ (20.9) were significantly greater with 30 cm row. The grain yield (3.71 t ha^{-1}) and straw yield (6.17 t ha^{-1}) were significantly higher with 20 cm row spacing than 30 cm row spacing

Keywords: Wheat varieties, Row spacing, Growth, Yield attributes and Yield

1. Introduction
Wheat (*Triticum aestivum* L.) belongs to *Poaceae* family which includes major cereal crops. Wheat is the most important staple food, it provides nearly 55% of the carbohydrates and 20% calories consumed globally (Breiman and Graur, 1995) [4].

Wheat is cultivated under a wide range of climates and soils, wheat can be grown on both irrigated and rainfed lands with rainfall between 300 and 900 mm, from sea level to plains of Tibet, approximately 4,000 m. above sea level conditions. In Afghanistan Agricultural production is highly dependent on rain and snowfall. Approximately, 45% of Afghanistan's wheat area in a normal year is irrigated, accounting for about 70% of production, while the remaining 55% depends entirely on rainfall and typically provides the remaining 30% of home production. Wheat production in 2014-15 was 5.4 million tonnes. Total wheat production increased by 3.9% over to 2013–14 production level. This increase in production was the result of increase in area under cultivation (MAIL, 2014–15) [17].

Row spacing affects crop yield as it not only determines the optimum crop stand, but also facilitates inter-culture and convenient herbicide application for effective and efficient weed control also facilitates the inter-cropping of other crops with it. In addition, proper row spacing is important for maximizing light interception, penetration, light distribution in crop canopy and average light utilization efficiency of the leaves in the canopy and, thus, affects yield of a crop (Hussain *et al.*, 2003) [12]. Row spacing requirements of wheat depend on architecture and growth pattern of the varieties. For higher yield, higher proportion of incident radiation at the soil surface must be intercepted by crop canopy (Eberbach *et al.*, 2005) [7]. In case of wider row spacing, solar radiation that falls between crop rows remains unutilized; plants become crowded and suffer from mutual shading if the row distance is too narrow.

Moreover, yield may be reduced in narrow spacing due to increased competition of plants for nutrient and moisture (Das and Yaduraju, 2011) [6]. The other essential factor is wheat genotypes are generally selected for higher yields and greater tolerance to adverse conditions and early maturity (Kumar *et al*. 2013) [16]. However, success of any crop production depends on the use of appropriate and selectivity of location-specific genotype/variety of high yield potential, and additionally improved cultural practices is an imperative part, may not be ignored. In recent past, wheat varieties developed by plant breeders have high yield potential. Cultural management plays a significant role in wheat production. Row spacing and optimum variety are of prime importance (Eissa *et al.*, 1995) [8], but all the varieties do not perform well in the same plant spacing, optimum plant densities vary greatly between areas, climatic conditions, soil and varieties (Darwinkel *et al*., 1977) [5].

Wheat is generally planted by broadcast method by most of the farmers in Afghanistan, though research scientists use line sowing and advise the same to the wheat farmers. Now-a-days due to infestation of weeds, it has become important to sow the crops in lines with suitable row spacing, which besides facilitating inter-culture and convenient herbicide application for effective and efficient weed control may also help in intercropping and reducing the seed rate per hectare without any adverse effect on the final grain yield.

There have been controversial reports in the literature regarding the role of row spacing in wheat production. Sharma and Thakur (1990) [24] reported that grain yield was non-significantly affected by sowing wheat either at 22 or 30 cm row spacing. Raj *et al.* (1992) [22] reported that row spacing (15, 22.5 or 30 cm) had no effect on grain yield, but the yields were lower in the wider row spacing (30cm). Singh and Srivastava (1991) [25] reported that tiller numbers, grains spike^{-1} and 1000-grain weight increased with increasing row spacing. Bakht *et al*. (2007) [3] reported that maximum grain yield was obtained when wheat was sown at row spacing of 30 cm. In India, recommended row spacing for most of the wheat cultivars is 22.5 cm. In Nepal, a hilly country, Pandey *et al* (2013) [20] did not find significant yield differences in studied row spacings of 15, 20 and 25 cm. These findings indicate that response of wheat to planting spacing is location and variety specific, and this need systematic evaluation across locations, environments and cultivars.

As in Afghanistan not enough research work has been done towards recommending most appropriate row spacing, it is necessary to conduct an experiment in order to make farmers and research workers to take a decision for row spacing of wheat. Hence, the present study was aimed to determine the influence of row spacing on growth and yield of wheat varieties in semi-arid region of Kandahar

2. Materials and Methods

A field research was held on “Effect of row spacing on different wheat varieties in semi-arid region of Kandahar” at Tarnak Research Farm of Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar Afghanistan, during winter of December 2014–May 2015. Geographically, the experimental field is located at longitude 65°52' 1″ East and latitude 31°26' 58″ North at an elevation of 986 m above the mean sea level. The Kandahar province is located in the southern region of Afghanistan. The climate of this place is tropical to sub-tropical of slightly semi-arid in nature.

According to agro-climatic conditions of Kandahar state, the seasonal rainfall of about 190.6 mm is received mostly in winter season. During experimentation, the crops received a total rainfall of 49.8 mm from December 2014 to May 2015. Therefore, in addition to the rainfall, irrigation was also provided for the proper growth and development of the crop. The maximum temperature varied between 12 ºC and 32 ºC while minimum temperature ranged between 0 ºC and 14.9 ºC during the cropping period of wheat.

The soil of the experimental site was sandy clay loam in texture, slightly alkaline in reaction having pH of 8.30, with a cation-exchange capacity of 80.58 meq/100g and electrical conductivity of 0.210 dSm-1. The initial N (0.06%) content of soil was low having P content of 1.23 mg/kg and K content of 1089 mg/kg.

The experimental included 9 treatments in a randomized complete block design with 3 replications and combinations of two factors, such as varieties (PBW-154, Darulaman-07 and Herat- 99) and different row spacing (20 cm, 25 cm and 30 cm).

Observations were recorded for different traits. In order to secure the effect of different treatments, the following observations such as plant population, Plant height, number of tillers per square meter, dry matter production per square meter, leaf area index, number of spikes per square meter, spike length, number of spikelets per spike, single spike weight, number of grains per spike, grain-weight per spike, 1000-grain weight, grain yield, straw yield and harvest index were recorded during the study.

3. Results and Discussion

3.1. Influence on growth parameters

3.1.1 Effect of varieties

Several researchers reported significantly different responses of different genotypes to various management variable and environments with respect to growth attributes due to inherent characteristics and efficiency of genotypes in terms of photosynthesis and dry matter portioning. Present experiment was also not an exception. However, in this study initial plant population did not differ significantly among treatments (Table 1). Because initial plant population was counted 20 days after sowing, and due to same seed rate, equality of germination percentage, and healthy seeds, plant population of all varieties was at same level and did not differ among varieties. These findings are in accordance with those of Abdul-Ghaffar *et al*. (2013) [1].

In this study Herat 99 variety was significantly taller than Darulaman 07 and PBW 154 (Table 1). The differences in plant height among various varieties are in general, due to genetic variance. These results are in line with the results of Nizamani *et al*. (2014) [19] and Suleiman *et al*. (2014) [27] who also reported that plant height significantly varied among different varieties. Variety Herat 99 also showed significantly higher tillers count than Darulaman 07 (Table 1). Variation in tillers count might be due to differences in genetic makeup of these wheat varieties. These results are in conformity with the findings of Rahman *et al*. (2010) [21], and Mali and Choudhary (2011) [18] who observed significant differences in the tillers count.

Likewise, higher dry matter accumulation was in Herat 99 than other varieties (Table 1). The difference in dry matter accumulation might be due to greater plant height and tiller count in this variety, dry matter is interrelated with plant height and number of tillers per unit area. These results are Mali and Choudhary (2011) [18] and Kumar *et al*. (2013) [16] who found significant difference in dry matter accumulation among different varieties. Herat 99 also showed higher leaf are index than other varieties (Table 1). In this variety higher LAI value might be due to its higher tillering capacity and taller nature. These findings are in accordance with those of Kalpana *et al*. (2014) [14] and Kaur *et al*. (2015) [15] who observed significant difference among the different varieties for LAI.

3.1.2. Effect of row spacing

Several researches have showed significant effect of row spacing on wheat growth parameters though the effects were varied under variable agro-ecologies. In the present experiment also different row spacing exerted significant effect on different growth parameters of wheat. However, different row spacing had non-significant effects on initial population (Table 1), these results agree with the findings of Abdul-Ghaffar *et al*. (2013) [1] who reported that row spacing did not affect the seedling density. Similarly plant height was not significantly influenced by different row spacing (Table 1). This result is in conformity with the finding of Hussain *et al.* (2012) [11] who reported that four row spacing *viz*. 15, 20, 25 and 30 cm had no effect on plant height.

Maintenance of optimum row spacing can help to optimize tillering capacity. Tiller count m^{-2} was influenced significantly due variable row spacing. In 20 cm row spacing plants utilized all available resources more efficiently including light, water, air and nutrients for producing more tiller per square meter than 30 cm row spacing but was at par with 25 cm row spacing (Table 1). These results are in consonance with the findings of Iqbal (2010) [13] and Ali *et al*. (2016) [2] who observed that narrow row spacing increased number of tillers per unit area significantly over wider row spacing.

The result of this experiment showed that significantly higher dry matter accumulation of wheat was recorded with 20 cm row spacing than 30 cm row spacing, which was at par with 25 cm row spacing at boot-leaf, flowering and maturity stages (Table 1). This difference in dry matter accumulation might be due to the fact that, dry matter is interrelated with plant height and number of tillers per unit area and the tillers count m^{-2} was higher under 20 cm row spacing. These finding are in conformity with the findings of Mali and Choudhary (2011) [18] who reported that among the different row spacing viz. 15, 17.5, 20 and 22.5 cm the 20 cm row spacing recorded the highest dry matter.

Significantly higher LAI was observed with 20 cm row spacing than 30 cm (Table 1). Leaf area index increased under narrower row spacing. This was mainly due to increase in number of tillers per unit area as well as increase in number of leaves per unit area. The similar findings were also reported by Kalpana *et al*. (2014) [14] who reported that different row spacing had significant influence on LAI.

3.2. Influence on yield attributes

3.2.1. Effect of varieties

The data regarding number of spikes m^{-2} are represented in table 2, which revealed that significantly higher number of spike m^{-2} were produced by Herat 99 than Darulaman 07. Variation in number of spikes m^{-2} might be due to their genetic make-up which is an inherent character of wheat varieties.

Spike length and number of spikelets showed non-significant difference among the different varieties (Table 2). Similar findings were also observed by Mali and Choudhary (2011) [18]. Number of grains per spike also did not differ significantly among the varieties (Table 2). The similar findings were also reported by Saeed *et al* (2012) [23] who found that effect of varieties on number of grains per spike was non-significant. Similarly, 1000-grain weight, grain weight per spike and single spike weight which is largely governed by genetic makeup of crop were statistically similar with tested varieties (Table 2).

3.2.2. Effect of row spacing

Yield parameters *viz.,* Spike number per square meter was significantly affected by different row spacing. Planting at 20 cm row spacing resulted in significantly more number of spikes m^{-2} of wheat as compared to 30 cm row spacing (Table 2). The increase in number of spikes at 20 cm row spacing might be due to better growth parameters and higher number of tillers. Similarly Ahmad *et al.* (2009) reported that number of spikes m^{-2} increased with narrow row spacing than wider row spacing.

Length of spike significantly increased with increasing row spacing and the maximum length of spike was observed at 30 cm row spacing (Table 2). It might be due to more inter-row with lower number of tillers m^{-2} leading to better space, light and nutrients availability to plants in wider row spacing. These findings are in conformity with the finding of Nizamani *et al.* (2014) [19] who reported that maximum spike length was observed in 30 cm row spacing than 15 and 22.5 row spacing.

Similarly, number of spikelets per spike of wheat significantly increased with increasing row spacing. Maximum number of spikelets was recorded with 30 cm row spacing (Table 2). Wider row spacing with relatively lower number of shoots m^{-2} might have decreased competition among plants for nutrient, water, space and light interception that contributed towards increased length of spike. These results are in conformity with those of Singh (2013) [26].

Number of grains per spike, thousand-grain weight, grain weight per spike and single spike weight were not significantly affected by different row spacing (Table 2). These results are in agreement with those of Pandey *et al.* (2013) [20] who reported that row spacing had non-significant effects on number of grains per spike, kernel weight per spike, spike weight, and 1000 kernel weight of wheat.

3.3. Influence on yield

3.3.1. Effect of varieties

The result of this study showed that different varieties significantly differed for grain yield. Variety Herat 99 showed higher grain yield than Darulaman 07 (Table 3). However, it was at par with PBW 154. The higher grain yield in Herat 99 was achieved due to more number of spike m^{-2}, LAI, and dry matter accumulation over other varieties. Saeed *et al.* (2012) [23] also reported significant differences among the varieties for grain yield.

Straw yield significantly varied among the varieties. Straw yield was significantly higher in Herat 99 compared to Darulaman 07 but was at par with PBW 154. Straw yield of wheat is the function of an accumulated effect of growth parameters like tillers per unit area, LAI and final height thus in Herat 99, higher straw yield was attributed mainly to higher values of growth parameters. These results are in conformity with the findings of Gawali *et al*. (2015) [9, 10] who reported straw yield of wheat was affected significantly by the different varieties.

Harvest index is the ratio of grain yield to biological yield. The result of this study showed that there were non-significant difference found among different varieties for harvest index (Table 3).

3.3.2. Effect of row spacing

The results of the investigation showed that different row spacing significantly influenced the grain yield of wheat. Higher grain yield was recorded from 20 cm row spacing than 30 cm. The higher grain yield in 20 cm row spacing was achieved mainly due to more number of spike m^{-2} over other row spacing. This was in conformity with the findings of Kalpana *et al*. (2014) [14] and Hussain *et al.* (2012) [11] who reported that grain yield increased as row spacing decreased.

Straw yield showed significant differences under different row spacing. Higher straw yield was recorded with 20 cm row spacing as compared to 30 cm row spacing. This was closely followed by 25 cm row spacing (Table 3). This higher straw yield in 20 cm and 25 cm row spacing occurred mainly due to higher number of tillers, greater leaf area index and plant height. Such finding were supported by Ali *et al.* (2010) [13] who reported that narrow row spacing recorded higher straw yield than wider row spacing.

The result of this study showed that there were non-significant differences among different row spacing for harvest index (Table 3). Similarly non-significant effect of row spacing on harvest index was reported by Bakht *et al.* (2007) [3]

Table 1: Effect of row spacing on the growth attributes of wheat varieties

Treatment	Initial Plant population m^{-2}	Plant height (cm)	Tiller count m^{-2}	Dry matter accumulation (gr m^{-2})				LAI		
				Tillering stage	Boot-leaf stage	Flowering stage	Harvesting stages	Tillering stage	Boot-leaf stage	Flowering stage
Varieties										
PBW 154	120	74.9	290	53	268	772	934	2.2	3.2	4.3
Darulaman 07	119	73.2	272	50	261	718	885	2.1	2.9	3.8
Herat 99	121	85.2	304	54	282	788	988	2.4	3.3	4.4
SEm (±)	1.6	2.61	4.9	2.0	5.2	11.5	16.0	0.08	0.11	0.16
CD (P=0.05)	NS	7.82	14.8	NS	15.7	34.6	48.1	0.24	0.34	0.47
Row spacing (cm)										
20	122	78.1	303	53	280	787	971	2.4	3.4	4.6
25	121	77.1	295	52	277	779	960	2.3	3.2	4.2
30	118	78.2	269	51	255	712	876	2.0	2.8	3.8
SEm (±)	1.6	2.6	4.9	2.0	5.2	11.5	16.0	0.08	0.11	0.16
CD (P=0.05)	NS	NS	14.8	NS	15.7	34.6	48.1	0.24	0.34	0.47

Table 2: Effect of row spacing on the yield attributes of wheat varieties

Treatment	Number of spikesm^{-2}	Spike length (cm)	Spikelets $spike^{-1}$	Grains $spike^{-1}$	1000-grain weight (g)	Grain weight $spike^{-1}$(g)	Single spike weight(g)
Varieties							
PBW 154	271	11.0	19.6	43.3	37.68	1.62	2.36
Darulaman 07	251	11.0	19.5	43.2	38.20	1.65	2.40
Herat 99	285	11.6	19.8	44.6	36.61	1.62	2.44
SEm (±)	5.2	0.43	0.62	1.15	1.409	0.033	0.087
CD (P=0.05)	15.7	NS	NS	NS	NS	NS	NS
Row spacing (cm)							
20	285	10.4	18.5	43.0	37.54	1.60	2.27
25	274	11.1	19.5	43.6	37.61	1.63	2.39
30	249	12.1	20.9	44.5	37.33	1.65	2.54
SEm (±)	5.2	0.43	0.62	1.15	1.409	0.033	0.087
CD (P=0.05)	15.7	1.30	1.87	NS	NS	NS	NS

Table 3: Effect of row spacing on the yield of wheat varieties

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Varieties			
PBW 154	3.61	5.75	38.4
Darulaman 07	3.38	5.47	38.2
Herat 99	3.71	6.17	37.7
SEm (±)	0.053	0.142	0.62
CD (P=0.05)	0.160	0.426	NS
Row spacing (cm)			
20	3.73	6.00	38.3
25	3.64	5.96	37.9
30	3.33	5.43	38.0

SEm (±)	0.053	0.142	0.62
CD (P=0.05)	0.160	0.426	NS

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