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Evaluation of Sowing Density and Agro-Ecological Conditions on Wheat (*Triticum aestivum* L.) Yield and Components

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ABSTRACT

Wheat is the strategic crop in Afghanistan. Most wheat growers broadcast wheat seeds during sowing time, and sometimes the growers sow more seeds 3 to 4 times more than appropriate rate. Variety adaptation is another concern when releasing wheat varieties adapted to a broad environment. The main objective of this study was to evaluate the effects of sowing densities at the rate of 100, 110, and 120 kg ha^{-1} seed density on the total yield of three wheat varieties, Baghlan 09, Kabul 013, and Moqwim 09 under Kabul and Khost Agro-Ecological conditions, Afghanistan. The experiment was conducted using a randomized complete block design with three replications. The results indicated that seed rate at 110 kg ha^{-1} in Kabul province for Kabul 013 and Baghlan 09 varieties and 120 kg ha^{-1} in Khost province for all three varieties produced maximum grain yield. Ranking the three varieties, Kabul 013 and Moqwim 09 produced the highest grain yield while Baghlan 09 did not perform well in either of the two locations, Kabul and Khost. Interaction effects for all traits under evaluation in the two locations were also significant. Traits like days to heading, days to maturity, plant height, and grain yield were high in Kabul province compared to Khost. Correlation analysis revealed significant positive correlations among days to heading and days to maturity (r=0.98***), spikelets spike-1 and grain yield (r=0.88*** and r=0.75***) in Kabul and Khost provinces, respectively. Analysis indicated that the seed rate at 110 kg ha^{-1} for Kabul 013 and Baghlan 09 varieties in Kabul province and 120 kg ha^{-1} for all three varieties were optimum sowing density in Khost province.

Keywords: Agro-ecological conditions, grain yield, sowing density, varieties and wheat

Introduction

Wheat (*Triticum aestivum* L.) is globally cultivated on 222,27 million hectares with production and productivity of 779,29 million tons and 3.51 ton ha^{-1}, respectively (USDA 2022). The demand of the wheat crop is more than other major food crops and approximately 35% of the food of the world population is wheat product (Ali et al. 2016). Fortunately, wheat has wider adaptability to different agro-ecological conditions (Mirbahar et al. 2009). Wheat is the main cereal crop in Afghanistan which accounts for around 70% of total cereal consumption and 60% of the total intake of calories and is produced in both irrigated and rainfall conditions (MAIL 2013). The sowing of wheat variety in a perfect environment exploits the full genetic potential of a particular variety by providing optimum growth conditions such as temperature, light, humidity, and rainfall. Unfavorable environmental conditions, created by high temperature, mostly during reproductive stages, particularly the grain filling stage, could be minimized by adjusting the sowing time to an optimum time for different varieties (Gupta et al. 2020). Various agro-ecological conditions with varying climatic conditions may influence wheat grain yield and growth (Ahmadi et al. 2021).

Appropriate sowing density is an important factor for wheat grain yield. High seed density may lead to more crops per unit area which will induce competition among them for benefiting nutrients in the soil which will lead to low grain yield. Also, using

low seed density will produce less yield because of the less number of plants per unit area (Geravandi et al. 2011). Most farmers in Afghanistan broadcast seeds manually in wheat fields that generally affects the germination of wheat by the unsuitable depth of seeds (Ahmadi and Arian 2021). Research indicated that increased seed density can also lead to different wheat diseases (Kahrizi et al. 2010; Khan and Gul 2006). Using inappropriate sowing density can lead to weeds problems in wheat fields (Hameed et al. 2003; Fahad et al. 2015) and farmers with using optimum seed density can manage this problem.

Wheat yield is conditioned by many genes and therefore then can be affected by environmental effects. To understand the impact of the environment on wheat grain yield, wheat breeders need to conduct multi-environment trials in which the wheat varieties shall be evaluated for yield performance under different agro-ecological conditions. The presence of genotype x environment interactions is often an indication of a lack of stability of genotypes across the environments. Improved varieties play an outstanding role in exploiting the yield potential of the crop under specific agro-climatic conditions (Osmanzai et al. 2008; Gupta et al. 2020).

Osmanzai and Sharma (2008) found that the genetic by environmental interaction decreases correlation between phenotype and genotype making it hard to distinguish the genotypic effects of a variety. Thus, the current research was aimed at evaluating the effect of different environments and sowing densities on the growth and grain yield of wheat varieties.

Materials and Methods

Experimental site and treatments

Two individual field experiments were carried out at two dissimilar locations of Afghanistan (Experimental farm of the Agriculture Faculty, Kabul University, Kabul Province, and in Almara Village, Khost Province). Kabul is located at 1791 m above sea level with mean annual rainfall of 300 mm. Khost is lying at 1386 m above sea level with mean annual rainfall 650 mm. Both experiments were conducted during the 2018-2019 winter growing season. Data on monthly rainfall and mean temperatures over two environments and soil properties are provided in Table 1 and Figure 1, respectively.

The treatments for this research were three sowing densities (100, 110, and 120 kg seeds ha^{-1}) and three facultative wheat (*Triticum aestivum* L.) varieties (Moqawim 09, Kabul 013, and Baghlan 09). The experiment was laid out in Randomized Complete Block Design, with three replications in a split-plot arrangement. Seed densities were the main plot and varieties were the sub plot. The combination of the treatments is presented in Table 2. The individual plot size was 6 m^2 (2 m x 3 m).

Sowing and measurements

According to the local time of environment for cultivation, wheat was sown on 24th October in Kabul Province and a month later (24th November) in Khost Province, respectively. Sowing was done with a hand drill method. A total of 120 kg ha^{-1} Nitrogen was applied three times, at sowing time, jointing, and flowering stages and Phosphorus fertilizer at 80 kg ha^{-1} was used at the time of cultivation. The data was recorded for the parameters of days to heading, days to maturity, plant height (cm), productive tillers (number m^{-2}), spikelets $spike^{-1}$ (no), grain yield (kg ha^{-1}), and harvest index (%). Harvest index (HI) was calculated using the following formula.

$$HI\,(\%) = \frac{\text{Grain yield}}{\text{Biological yield}}\, x\ 100$$

Statistical analysis

Data collected for each of the traits were subjected to analysis of variance (ANOVA), using Statistical Tool for Agriculture Research (STAR) software (version 2.0.1). To separate significant differences in the means of the treatments, Tukey's Honest Significant Difference (HSD) test was used at $p< 0.05\%$ probability level. To find the correlation among the yield and yield components of wheat varieties, the R software (R i386 4.0.2) was used.

Results and Discussion

Effects of sowing density: The effect of sowing density was not significant for the traits of days to heading, days to maturity, plant height, spikelets $spike^{-1}$, and harvest index in both provinces, while wheat crop sown at 120 kg seeds ha^{-1} performed outstandingly with respect to productive tillers (443.11m^{-2}) in Khost province as compared to 110 and 100 kg ha^{-1} but the values were not significant at any amount of sowing density in Kabul province, (Table 3 and Figure 2). The higher number of productive tillers may be due to the higher sowing density in Khost province. Our result is confirmed by (Goverdhan et al. 2018; Tilley et al. 2019) who found more number tillers in more seed rates compared to less.

In the case of grain yield, sowing density was significant in both provinces (Table 3). When the wheat crop was sown at 110 kg seeds ha^{-1} in Kabul province, the wheat produced the highest grain yield (5536.77 kg ha^{-1}) but in Khost province, the highest grain yield

(5472.28 kg ha^{-1}) was produced at 120 kg seeds ha^{-1} compare to others sowing density, Figure 2 (c) and (d). This amount of seeds rate may be the ideal seed rate for wheat cultivation in the mentioned provinces. It is in harmony with (Goverdhan et al. 2018) who found that optimum sowing density produced high yield compared to less and more.

Effects of varieties: Data concerning days to heading, days to maturity in Kabul province, while plant height, productive tillers, spikelets spike-1, and grain yield have significant differences between the varieties for both provinces. Harvest index was not significant in either of the two locations, Table 3. Among the varieties, Kabul 013 took more days to heading and days to maturity (195.26 and 246, respectively), Figure 3 (a) and (b).

The most productive tillers (456.56) were produced by Baghlan 09 in Kabul province, while Moqawim 09 (434.33) was at the top in Khost Province. Among the varieties, Kabul 013 produced less productive tillers in both provinces, Figure 3 (c) and (d).

Data regarding spikelets spike^{-1} also had significant effects for varieties, Table 3. Higher numbers of spikelets spike^{-1} among the varieties in both locations were produced by Kabul 013. Mean values of Kabul 013 variety (16.61 and 15.38) are at the top in both provinces (Kabul and Khost, respectively) while Baghlan 09 produced the minimum values (12.80 and 11.58), Figure 3 (e) and (f).

Grain yield, the main final product, was also significant among the varieties, Table 3. A higher yield was produced by Kabul 013 among the varieties. Figure 4 (g) and (h) revealed that the Kabul 013 variety is in first-class followed by Moqwim 09 while the Baghlan09 variety is in the low (c) class. The grain value of the Kabul 013 variety (5809.66 kg ha^{-1}), was 7.28% higher than Moqawim 09 and 13.39% higher than Baghlan 09, variety in Kabul province. Similarly in Khost province, the high grain yield of the Kabul 013 variety (5493.44 kg ha^{-1}) is 6.78% and 11.82% more than Moqawim 09 and Baghlan 09 varieties. Variations among the varieties for days to heading, days to maturity, productive tillers, spikelets spike-1, and grain yield may be the genetic make-up of varieties controlled by genes. It is similar to (Tolera et al. 2008; Abd El-Lattief 2014) who found the variation for agronomic traits among the varieties without the effects of examined factors.

Effects of environments: Analysis of variance for combined data in Table 4 indicated that days to heading, days to maturity, plant height, and grain yield of the wheat crop were significantly affected due to different sowing environments. In Kabul province sowing of wheat significantly increased the days to heading (192.78 days), days to maturity (242.63 days), plant height (88.51 cm), and grain yield (5449.50 kg ha^{-1}) followed by Khost province (132.96 days, 190.8 days, 83.85 cm, and 5183.38 kg ha^{-1}, respectively) Figure 4. In Kabul province, the significantly higher of the mentioned parameters might be the accessibility of optimum environmental conditions for growth and development of the cultivated wheat varieties which could have boosted the accumulation of photosynthesis from the source of climate and land. This result is in harmony with Šíp et al. (2013) who reported the difference among the grain yield across the locations.

Interaction effects: A significantly higher number of productive tillers were observed in Khost province in all three wheat varieties when sown at 120 kg seeds ha^{-1}. The higher number of productive tillers on Moqawim 09 variety (450.33 a), closely followed by Kabul 013 (446 a) and Baghlan 09 (433 a) varieties. These varieties were top at the rate of 120 kg ha^{-1}, while at the seed rate of 100 kg ha^{-1} they produced few productive tillers, particularly Kabul 013 variety (381 b), and these differences for productive tillers in Kabul province were insignificant.

The interaction effects for grain yield among the sowing densities x varieties were significant in both provinces, Table 5. The most grain yield in Kabul province was observed on variety Kabul 013 (6017.00 a) when sown at 110 kg seeds ha^{-1}, similarly for Baghlan 09 but Moqawim 09 produced more grain yield at 120 kg seed ha^{-1} while in Khost province the most grain yield was produced when the wheat varieties were sown at 120 kg seed ha^{-1}. The Kabul 013 variety with (5845.33 kg ha^{-1} a) grain yield at 120 kg seed ha^{-1} is on the top but Baghlan 09 (4647.80 kg^{-1} c) produced the least grain yield on 100 kg ha^{-1}. The differential performance of wheat varieties for productive tillers and grain yield in different sowing densities and environments might be due to their genetic makeup and environmental effects.

Correlation among the yield and yield components of wheat varieties. The correlation among the yield and yield components of wheat varieties in this study is given in Figure 6. It is seen from the figure that there are positive and negative correlations within the yield and yield components in both provinces. There are strong positive correlations for both provinces (Kabul and Khost, respectively) among the days to heading and days to maturity (r= 0.98***, and r = 0.98***), plant height and spikelets spike^{-1} (r=0.72*** and r= 0.7^{2***}) plant height and grain yield (r= 0.64*** and r = 0.55***) and spikelets spike^{-1} with grain yield (r=0.88*** and r=0.75***) but just in Kabul province among the days

to heading with spikelets spike^{-1} (0.75***), days to heading with grain yield (r=0.83***), days to maturity with spikelets spike (r=0.69***) and days to maturity with grain yield (r=0.78***).

Conclusions

Research results indicated that the effects of sowing densities, varieties and environments were significant. The sowing of wheat with the seed rate at 110 kg ha^{-1} in Kabul province performed well for the grain yield, while in Khost province, the number of productive tillers and grain yield were maximum at 120 kg ha^{-1}. Among the varieties, the Kabul 013 variety was on the top for grain yield and its attribute (spikelets spike^{-1}). The interaction effects of densities x varieties and among the locations were also significant The most grain yield in Kabul province was observed on Kabul 013 variety (6017.00 kg ha^{-1}) when was sown at 110 kg seeds ha^{-1}, similarly for Moqawim 09 while Baghlan 09 produced more grain yield at 120 kg seed ha^{-1} while in Khost province the most grain yield was produced when the wheat varieties were sown at 120 kg seed ha^{-1}. Most days to heading and days to maturity, plant height, and grain yield were observed in Kabul province compared to Khost province. From the research results, we conclude and recommend that Kabul province is the suitable area for more grain yield of Kabul 013 and Baghlan 09 varieties at 110 kg ha^{-1} but 120 kg ha^{-1} sowing density is appropriate for Moqawim 09 while in Khost province for all three varieties, the 120 kg ha^{-1} density is suitable. Further research should be carried out in different provinces of Afghanistan besides Kabul and Khost to notice adaptation ability and appropriate sowing density for the mentioned varieties.

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Table 1. Soil and soil properties for the two environments (Kabul and Khost Provinces).

Environment		Kabul	Khost
Soil type	Property		
	Clay (%)	59.76	50.56
	Silt (%)	21	27
	Sand (%)	19.24	22.44
	Textural class	Sandy loam	Sandy clay loam
Soil analysis	pH (in water)	8.3	7.9
	N (%)	2.2	3
	P (mg kg^{-1})	6.9	7.5
	K (mg kg^{-1})	190	171
	OM (%)	0.91	0.93

Table 2. Combination of treatments from three sowing densities (S) and three wheat varieties (V).

Treatments	Description
S1 V1	100 kg seed ha^{-1} and Moqawim 09 variety
S1 V2	100 kg seed ha^{-1} and Kabul 013 variety
S1 V3	100 kg seed ha^{-1} and Baghlan 09 variety
S2 V1	110 kg seed ha^{-1} and Moqawim 09 variety
S2 V2	110 kg seed ha^{-1} and Kabul 013 variety
S2 V3	110 kg seed ha^{-1} and Baghlan 09 variety
S3 V1	120 kg seed ha^{-1} and Moqawim 09 variety
S3 V2	120 kg seed ha^{-1} and Kabul 013 variety
S3 V3	120 kg seed ha^{-1} and Baghlan 09 variety

S: Sowing densities, V: Variety.

Table 3. Analysis of variance (ANOVA) for growth, yield and yield attributes of wheat on two environments (Kabul and Khost provinces).

Source of Variance		DH	DM	PH	SS	PT	GY	HI
	DF	MS	MS	MS	MS	MS	MS	MS
Kabul								
Replication	2	0.11	0.03	0.10	0.01	843.44	235.59	0.00
Seed Density (SD)	2	0.77	0.70	1.53	1.33	1420.33	151724.59**	3.36
Error (a)	4	0.55	0.20	0.61	0.12	365.11	16.81	1.48
Variety (V)	2	124.33**	258.92**	398.79**	34.41**	6627.11**	1068153.03**	0.70
SD x V	4	0.11	0.25	0.00	0.58	1156.61	42774.25**	2.73
Error (b)	12	0.12	0.09	0.49	0.79	394.33	13.57	2.02
CV (%)		**0.25**	**0.14**	**0.81**	**5.47**	**4.57**	**6.95**	**3.53**
Khost								
Replication	2	0.70	0.25	3.26	4.85	67.44	576.29	0.019
Seed Density (SD)	2	18.03	7.37	1.53	2.24	3444.77**	697107.73**	6.67
Error (a)	4	18.03	6.53	0.61	1.04	20.88	883.80	3.57
Variety (V)	2	0.14	0.25	398.79**	34.25**	1864.77**	769710.28**	0.85
SD x V	4	18.14	5.20	0.00	0.07	609.22**	7091.35*	2.41
Error (b)	12	11.70	3.27	0.49	0.50	50.85	2066.69	2.89
CV (%)		**2.74**	**1.06**	**0.86**	**6.03**	**1.56**	**0.81**	**4.58**

Note:* and ** Significant at p< 0.05 and p<0.01 levels, respectively, DF: Degrees of freedom, MS: Mean sum of squares, DH: Days to heading, DM: Days to maturity, PH: Plant height, SS: Spikelets spike^{-1}, PT: Productive tillers, GY: Grain yield and HI: Harvest Index.

Table 4. Analysis of variance (ANOVA) for Combine data of wheat growth, yield and yield attributes.

Source of Variance		DH	DM	PH	PT	SS	GY	HI
	DF	MS	MS	MS	MS	MS	MS	MS
Location	1	48300.46**	36244.46**	294.00**	1093.50	20.41	954620.88**	6.06
Rep within location	4	0.40	0.14	1.68	455.44	3.50*	405.94	0.00
Seed Density (SD)	2	8.46	4.05	3.07*	2718.05**	2.66*	674547.47**	9.64
L x SD	2	10.35	4.01	0.00	2147.05**	0.91	174284.85**	0.39
Error (a)	8	9.29	3.37	0.61	193.00	0.58	450.31	2.52
Variety (V)	2	65.01**	130.72**	797.58**	6493.16**	68.67**	1825257.99**	1.55
SD x V	4	8.65	3.27	0.01	480.80	0.43	15259.08**	5.09
L x V	2	59.46**	128.46**	0.00	1998.92**	0.00	12605.32**	0.00
L x SD x V	4	9.60	2.18	0.00	1285.02**	0.22	34606.53**	0.05
Error (b)	24	5.91	1.68	0.49	222.59	0.64	1040.13	2.46

Note:* and ** Significant at p< 0.05 and p<0.01 levels, respectively, DF: Degree of freedom, MS: Mean sum of squares, DH: Days to heading, DM: Days to maturity, PH: Plant height, SS: Spikelets spike^{-1}, PT: Productive tillers, GY: Grain yield and HI: Harvest Index.

Table 5. The interaction effects of sowing density, variety and environments.

Environment		Productive tillers (m^{-2})			Grain yield (kg ha^{-1})		
		Varieties					
	Sowing Density	V1	V2	V3	V1	V2	V3
Kabul	S1	411.66	408.66	434.66	5260.00 c	5609.00 c	5031.33 c
	S2	432.33	415.00	482.66	5385.00 b	6017.00 a	5208.33 a
	S3	450.33	383.33	452.33	5600.00 a	5803.00 b	5130.00 b
Khost	S1	425.00 b	381.00 b	411.00 b	4898.33 c	5205.00 c	4647.80 c
	S2	427.66 b	390.33 b	425.66 a	5137.00 b	5430.00 b	4915.40 b
	S3	450.33 a	446.00 a	433.00 a	5397.20 a	5845.33 a	5174.33 a

Note: S1, S2 and S3 describe the 100, 110 and 120 kg ha^{-1} amount of sowing density, respectively and V1, V2 and V3 show the name of varieties respectively: Moqawim 09, Kabul 013 and Baghlan 09.

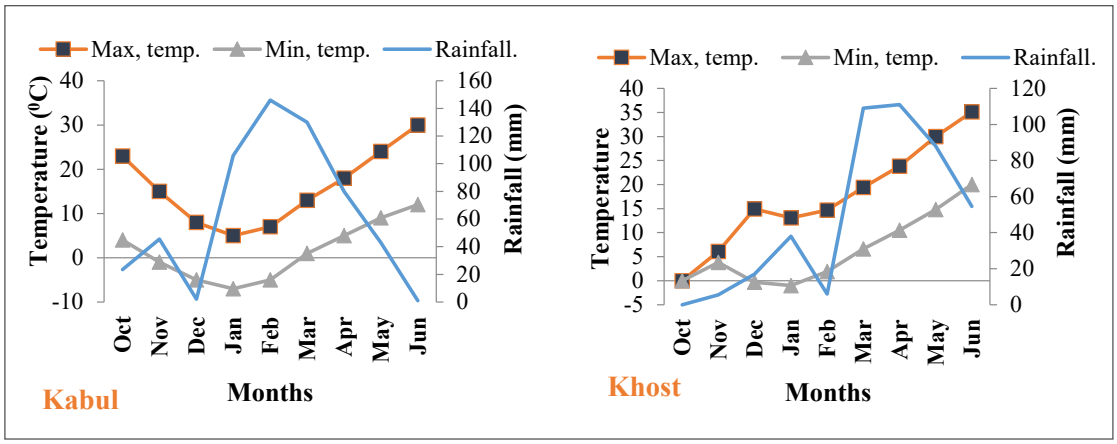
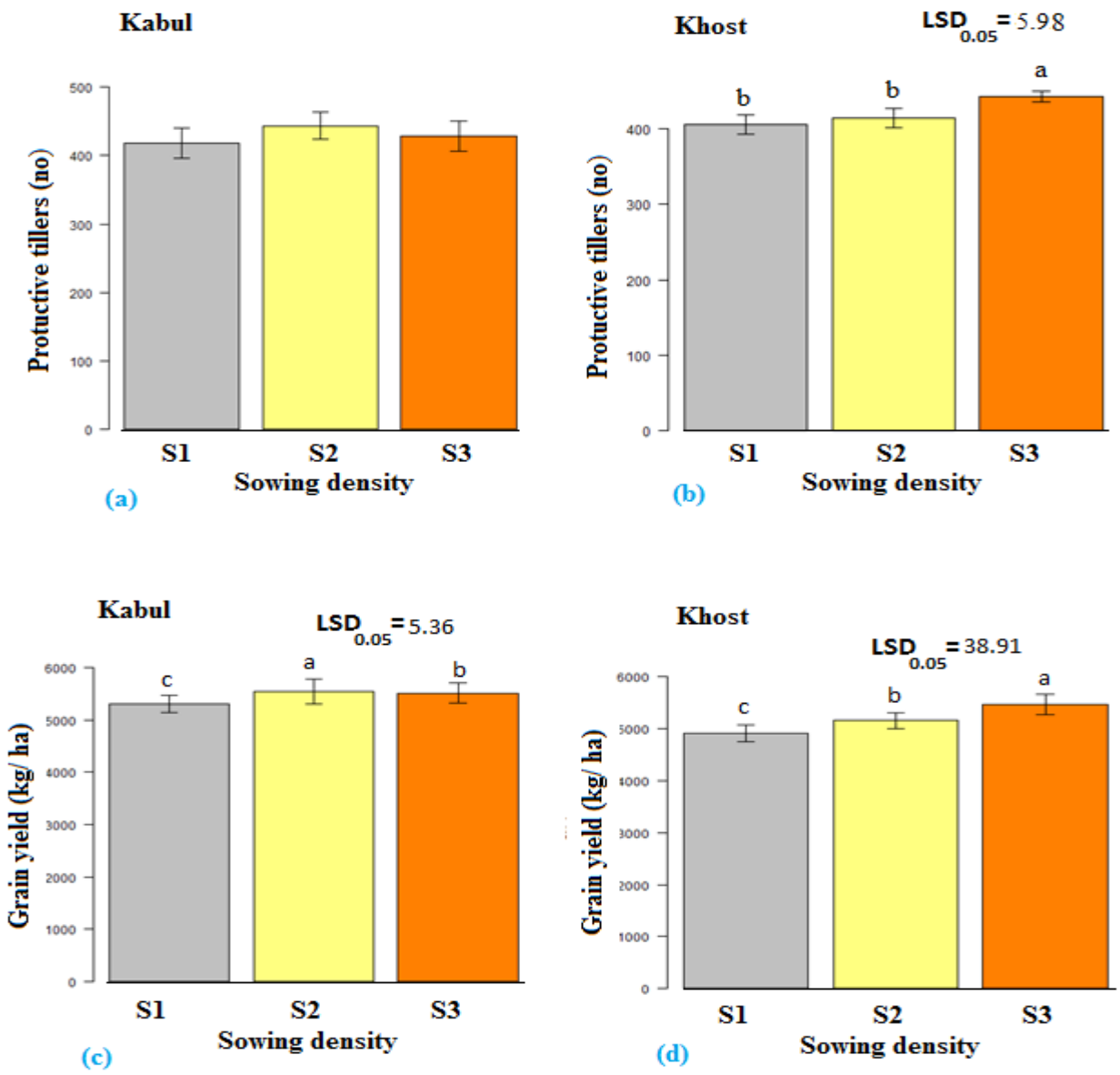
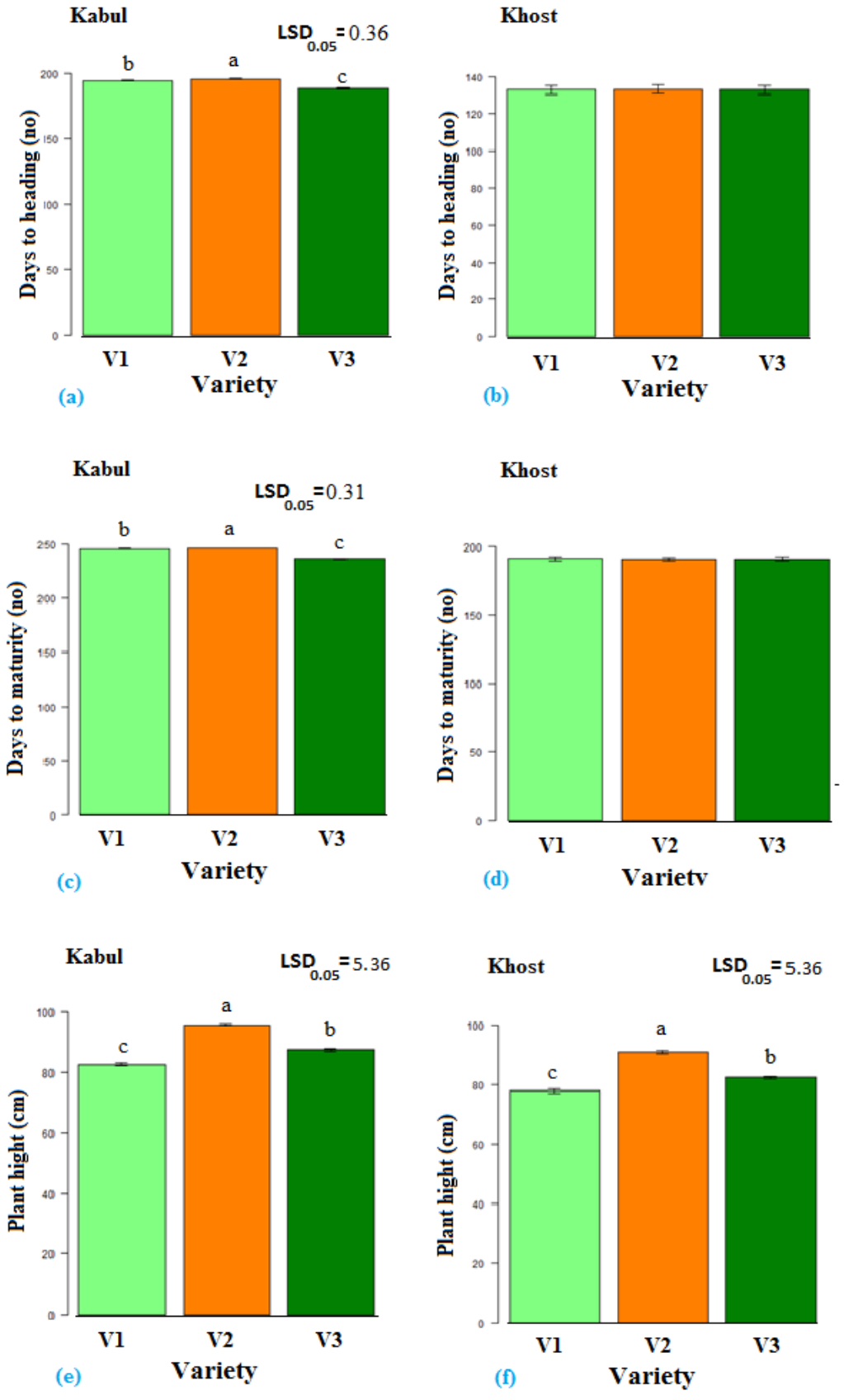


Figure 1. Rainfall and temperature during the growing period.



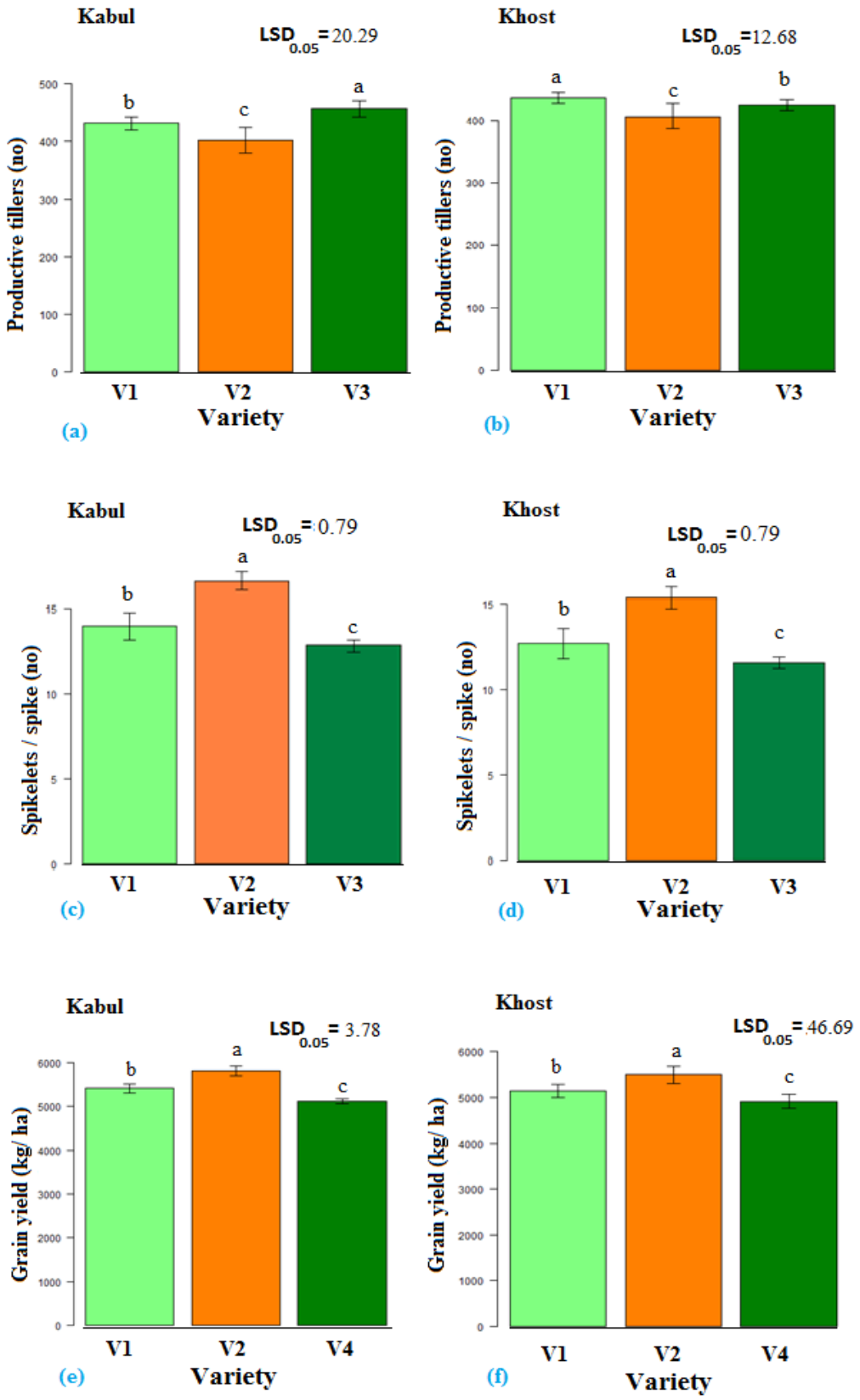
Note: S1, S2 and S3 describe the 100, 110 and 120 kg seeds ha^{-1}, respectively.

Figure 2. Effects of sowing density on productive tillers and grain yield of wheat.



Note: V1, V2 and V3 describe the name of varieties Moqawim 09, Kabul 013 and Baghlan 09, respectively.

Figure 3. Effects of varieties for days to heading, days to maturity and plant height.



Note: V1, V2 and V3 describe the name of varieties Moqawim 09, Kabul 013 and Baghlan 09, respectively.

Figure 4. Effects of varieties for productive tillers, Spiklets spike^{-1} and grain yield.

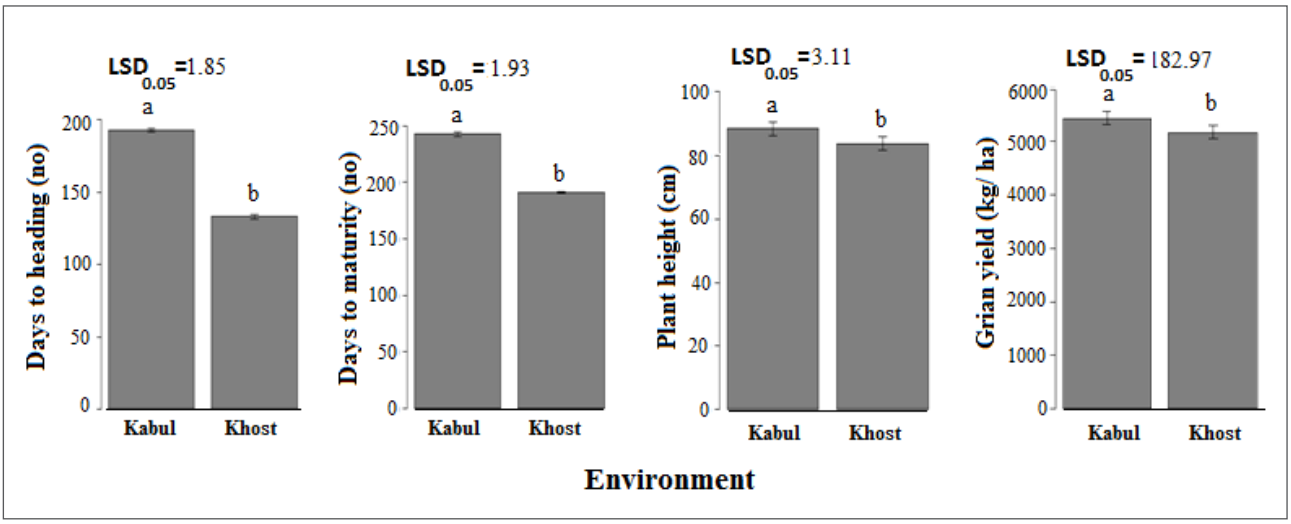
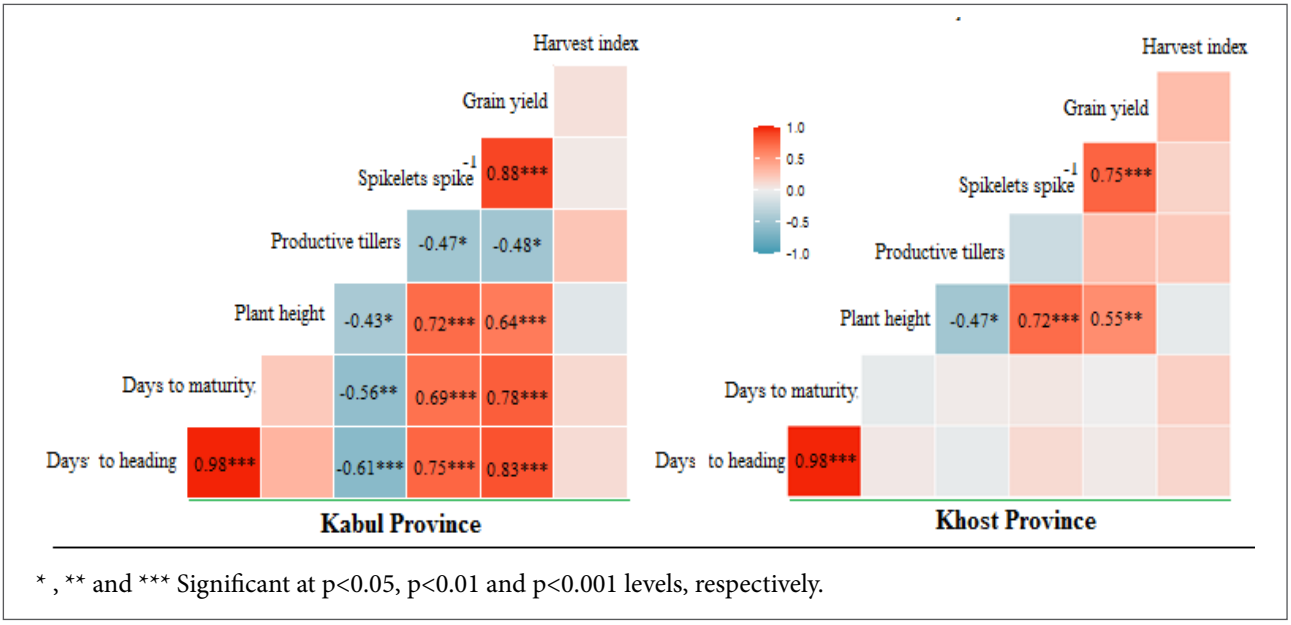


Figure 5. Effects of environments for days to heading, days to maturity, plant height and grain yield on wheat crop.



* , ** and *** Significant at p<0.05, p<0.01 and p<0.001 levels, respectively.

Figure 6. Correlation among the yield and yield components of wheat varieties on two different provinces.

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