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Quantification of Impact of Sowing Dates on Productivity of Rainfed Wheat

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Abstract: Field experiments conducted under rainfed agriculture for two consecutive years (2013-2015) revealed that temperature stress at the Anthesis and during grain filling duration is the most limiting factor for the productivity of spring wheat in rainfed regions of Pakistan. Four sowing dates **(**$SD_{1,}$ 21-30 Oct, SD_2, 11-20 Nov, SD_3, Dec 1-10 Dec and SD_4, Dec 21-30 Dec, during 2013-14 and 2014-15) were evaluated at three variable locations, Islamabad (Low temperature), URF-Koont (Medium temperature) and Talagang (High temperature) of rainfed Pothwar. Earlier sowing resulted in higher yield (3.04 t ha^{-1}), while advancing the sowing dates than optimum resulted to lower grain (1.44 t ha^{-1}). Similarly, higher biological yield (38%), plant height (41%), number of tillers (42%), spike length (20%), spikelet per spike (42%), grains per spike (36%), thousand grain weight (41%) was observed under early sowing dates than the later sowing dates. At Islamabad, where temperature was lower than URF-Koont and Talagang, spring wheat yield was higher (32%). Meanwhile, genotype Pak-13 produced better results than other genotypes. This study revealed that optimal timing for sowing and selection of suitable temperature resistant genotypes are good strategies to improve the productivity of rainfed crops in temperature stressed area.

Key words: Wheat, Sowing date, Biological yield, Grain yield, Harvest index, Climate change.

INTRODUCTION

Wheat *(Triticum aestivum* L.*)* is a staple food of most of the population over the globe. In the Mediterranean region, such as, rainfed areas of Pakistan, it is grown in late autumn or early winter to utilize maximum of monsoon water and harvested in the start of summer. It is a general practice of the rainfed region that the crop is planted when the temperature is lowered down after summer. The temperature higher than optimum during sowing (20 °C) and flowering (27 °C) period results in lower grain production in most of the rainfed areas of Pakistan (Ahmed and Hassan, 2015). Climate variability is certainly the result of climate change (IPCC, 2013). It had significant impressions on living systems of small land holders, communities, and in larger term the countries. The variation in rainfall and temperature has direct influence on climate variability. Changes in rainfall intensity and duration during the whole year have a relationship with the agricultural products (Thornton *et al*., 2014). Some positive impact of climate variability are also observed in parts of the world, located 55° northern widths (Ewert *et al*., 2015), while areas under hot and dry climate regions might see negative impact (Parry *et al*., 2005). Under-developed countries will be more affected due to less precipitation and a rise in temperature. Similarly, intensity and frequency of extremes climatic events, such as, heat, flood, drought and coldness, will be higher in future (Asseng *et al*., 2011). Change in any climatic event has direct positive impact on agriculture productivity, which could be due to alteration in the life cycle of crop. Critical growth stages of the crop particularly reproductive phase have severe negative impact due to high temperature, and Intergovernmental Panel on Climate Change (IPCC) has declared heat stress as an alarming threat to food production (IPCC, 2007). Since last three decades of 20th century, many areas of South Asia, Europe, Africa and Australia have been converted into arid zones due to climate variability (Dai, 2011). Climate change might negatively affect the farming community of Pakistan causing serious food security problems. Future projections suggest that by the years 2046-2065, the temperature of South Asia will rise by 2-3 °C (Gorst *et al*., 2015).

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The temperature higher than optimum negatively influences wheat crop and the wheat yield is observed to be reduced to 6% with an increase in 1°C average seasonal temperature (Asseng *et al*., 2015). While planning to get sustainable food, it is necessary to understand how different climate parameters affect food production. To apply such policies, the influence of different climatic factors on crop productivity needs to be divided and quantified. For example, variation in rainfall intensity is treated differently than a change in temperature (Reynolds *et al*., 2010). Among different climatic parameters, variation in temperature has significant damaging impact (Asseng *et al*., 2011) and many hotspot areas have been reported where wheat plants undergo high temperature problem (Gourdji *et al*., 2013; Teixeira *et al*., 2013). In Pakistan, wheat is sown over a wide range of sowing date in various cropping systems of rainfed and irrigated areas. This variation in sowing time is caused by various factors, such as, erratic rainfall in rainfed area, late planting or harvesting of preceding crop, lack or unavailability of farm machinery and inputs, etc. (Ahmed, 2011). The sowing time of wheat in Pakistan generally starts from mid of October and extends to the end of December. Delayed planting reduces wheat yield while delayed sowing of wheat crop suffers from heat stress during grain filling period. The reduction is almost linear (42 kg ha^{-1} day^{-1}) after optimum planting time (generally 10th November) (Khan, 2003; Ahmed, 2011).

Spring wheat is widely grown in most parts of Pakistan, especially, in rainfed areas of Pothwar. Spring wheat yield is highly variable depending upon the climatic conditions during growing season. In Pothwar, climatic conditions vary significantly from season to season and site to site, especially with regards to the onset of first and last rainfall (Stapper and Harris, 1989). In rainfed areas of Pakistan, higher temperature during anthesis and inadequate rainfall are the main issues for lower yield (Loss and Siddique, 1994). Wheat production in rainfed area of Pothwar, Pakistan, is highly vulnerable to higher temperature. Wheat growing season in these areas starts with the onset of winter and ends in April-May. Due to unavailability of moisture at the time of sowing, wheat sowing may be delayed, which resulted in crop exposure to higher temperature, particularly, during grain filling stage of the crop. This high temperature can reduce final wheat yield, which is badly affected by high temperature over the globe (Modarresi *et al*., 2010). Hussain and Mudasser (2007) conducted an experiment in rainfed area of Pakistan to investigate the higher temperature effect on growing season length and reported that an increase of 1.5 °C in temperature reduced crop life cycle as well as lowered 7% grain yield, while if temperature is increased upto 3 °C, the reduction in wheat yield was 24%. Climate change affects food production in different ways (Godfray *et al*., 2010). An increase in temperature is a major issue in crop production. Temperature higher than optimum negatively influence wheat crop as wheat yield reduces to 6% with an increase in 1°C average seasonal temperature (Asseng *et al*., 2015). While planning to get sustainable food, it is necessary to understand how different climate parameters affect food production. To apply such policies, the influence of different climatic factors on crop productivity needs to be divided and quantified. For example, variation in rainfall intensity is treated differently than a change in temperature (Reynolds *et al*., 2010). Among different climatic parameters, variation in temperature has significant damaging impact (Asseng *et al*., 2011) and many hotspot areas have been reported where crop plant undergo high temperature problem (Gourdji *et al*., 2013; Teixeira *et al*., 2013). So, keeping in view the above circumstances, current study was carried out during wheat growing season of 2013-14 and 2014-15, at low, medium and high temperature areas of rainfed Pothwar. The objectives of the study were: (i) to determine the impact of sowing time on wheat yield and (ii) to find out the best suitable genotype for rainfed areas of Pakistan.

MATERIALS AND METHODS

The current study was carried out during wheat growing season of 2013-14 and 2014-15 at high, medium and low rainfall areas of rainfed Pothwar. Recommended doses of fertilizer (N-P) 100-50 kg/ha were added at the time of sowing in the form of urea and DAP. Experiments, using Randomized Complete Block Design, were conducted using five wheat genotypes (Dharabi, NARC-2009, Pak-13, Chakwal-50, AUR-809), four sowing times **(**SD_1, 21-30 Oct, SD_2,11-20 Nov, SD_3, Dec 1-10 Dec and SD_4, Dec 21-30 Dec during 2013-14 and 2014-15), three varying environmental locations, Islamabad (Low temperature), URF-Koont (Medium temperature) and Talagang (High temperature), during 2013-14 and 2014-15. Individual plot size was 4m × 6m (24 m^2), the experiment was replicated three times and RCBD was used to carry out the field experiment. The average seasonal temperature, during both years for all the study sites under four sowing dates, has been presented in Table 1. At maturity, the number of fertile tillers per meter square was counted. Data, regarding plant height, spike length, number of spikelets per spike, were recorded for five plants per plot. This data was then averaged across the replicate plots. Biological yield was determined using the above samples per plot and then converted to biological yield in t ha^{-1}. Number of spikelets per spike and number of grains per spike were averaged from 50 spikes taken at random from each replication at harvest. Sample of thousand grain weight was taken at random from the seed lot of each plot and weighed in grams through electric balance. Grain yield was recorded from each sample from an area of 1 m^2 at random and then converted into t ha^{-1}.

Statistical analysis: Analysis of variance (ANOVA) was performed to test the significant differences between means of various parameters for five genotypes across four sowing dates (SDs) and three locations for the year 2013-2015 wheat growing seasons using R software.

Table 1: Mean maximum, minimum and average temperature at Islamabad, during 2013-14 and 2014-15 under four sowing dates (SD).

Locations	Years	Maximum Temperature		Minimum Temperature		Mean Temperature	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Islamabad	SD_1	22	22.4	6.7	7.3	14.3	14.8
	SD_2	21.6	21.8	6.7	6.8	14.1	14.3
	SD_3	21.5	22.1	6.8	7.5	14.2	14.8
	SD_4	22.5	23	8	8.8	15.3	15.9
URF-Koont	SD_1	24.2	26	7.8	10.1	16	18.1
	SD_2	23.5	25.8	7.7	10.2	15.6	18
	SD_3	23.5	25.5	7.8	10.1	15.6	17.8
	SD_4	24.1	26.8	7.9	11.3	16	19
Talagang	SD_1	26.4	27.1	11.2	10.2	18.8	18.7
	SD_2	25.9	27.7	11.4	11.3	18.6	19.5
	SD_3	25.8	28.2	11.5	12.1	18.7	20.1
	SD_4	26.3	29.3	11.9	13.1	19.1	21.2

RESULTS AND DISCUSSION

Number of tillers per square meter differed significantly under varying climatic locations (L) (Islamabad, URF-Koont, and Talagang) under four sowing dates (SD), while five wheat genotypes (G) were not statistically different during both years (Y). Statistical analysis of variance by ANOVA (Table 2) depicted that main effects of L and SD were significantly different at $p \leq 0.01$ (Table 2). Maximum number of tillers/m^2 (246.14) was counted at Islamabad, while the minimum value (177.07) was observed at Talagang followed by URF-Koont (196.72) (Table 3). Similarly, the highest number of tillers/m^2 was observed for early sowing dates, i.e., SD_1 (248.36) and SD_2 (251.51), while the lowest value was calculated for SD_4 (146.77). Number of tillers per m^2 was reduced by 42% in late sowing date (SD_4) as compared to early sowing date (SD_2). "Maximum" thousand grain weight was observed at Islamabad (33.53 g), while the minimum grain weight was recorded at Talagang (20.07 g). Forty percent reduction in thousand grain weight was noted at Talagang, as compared to Islamabad. Similarly, the highest thousand grain weight was observed for SD_2 (34.43 g), followed by SD_1 (34.11 g), while the lowest grain weight was observed under SD_4 (19.79 g). Thousand grain weight reduced by 41% was observed in late sowing date (SD_4), as compared to early sowing date (SD_1). Maximum thousand grain weight was recorded for Pak-13 (32.33 g), followed by AUR-809 (30.86 g) and NARC-2009 (29.46 g), while minimum thousand grain weight was observed for Dhurabi (23.15 g), followed by Chakwal-50 (25.00 g). Maximum thousand grain weight (31.19 g) was observed during 2013-14, while minimum thousand grain weight (25.13 g) was obtained during 2014-15. Maximum biological yield (8.10 t ha^{-1}) was observed during 2013-14, while minimum biological yield (6.69 t ha^{-1}) was obtained during 2014-15 (Table 3). A 17% reduction in biological yield was observed during 2013-14. The highest biological yield was recorded for Pak-13 (7.89 t ha^{-1}), followed by AUR-809 (7.75 t ha^{-1}) and NARC-2009 (7.65 t ha^{-1}), while the lowest biological yield was observed for Dhurabi (6.65 t ha^{-1}), followed by Chakwal-50 (6.95 t ha^{-1}). The percentage difference from the highest to the lowest biological yield among genotypes was 12%. Biological yield also differed considerably among study sites: the highest biological yield was observed in Islamabad (7.99 t ha^{-1}), while the lowest biological yield (6.73 t ha^{-1}) was noted at Talagang (10.2 t ha^{-1}). Similarly, the highest biological yield was detected under SD_2 (8.99 t ha^{-1}), followed by SD_1 (8.77 t ha^{-1}), while the lowest biological yield was observed under SD_4 (5.51 t ha^{-1}).

Grain yield varied considerably among five wheat genotypes at varying locations under four sowing dates, while during both years thousand grains weight did not differ statistically. ANOVA table defined the main effects of G, L and SD at $p \leq 0.01$ (Table 2). Economic yield differed considerably among varying study sites (Table 3). Maximum grain yield observed in Islamabad (2.40 t ha^{-1}), while minimum grain yield recorded at Talagang (2.18 t ha^{-1}). 32% reduction in grain yield noted at Talagang as compared that in Islamabad. Similarly, the highest grain yield was observed for SD_2 (3.04 t ha^{-1}), while the lowest grain yield was observed under SD_4 (1.44 t ha^{-1}). Economic yield reduced by 52% in late sowing date (SD_4) as compared with early sowing date (SD_2). Maximum grain yield was recorded for Pak-13 (2.63 t ha^{-1}), while minimum grain yield was observed for Dhurabi (1.88 t ha^{-1}). The percentage difference from maximum to minimum level of grain yield among genotypes was 23%. Maximum grain yield (2.39 t ha^{-1}) was observed during 2013-14, while minimum grain yield (2.19 t ha^{-1}) was obtained during 2014-15.

Table 2: SS and DF for number of tillers, 1000 grain weight, biological yield, grain yield and harvest index during 2013-14 and 2014-15 for five wheat genotypes under four sowing dates at three study sites.

Source	DF	Number of tillers	1000 grain weight	Biological yield	Grain yield	Harvest index
R	2	63734	2309.2	217.77	56.931	217.77
Y	1	22074^{NS}	40.8^{NS}	184.58**	4.043**	0.1774
L	2	304012***	7331.4***	95.52**	46.161**	0.05955**
SD	3	724650***	14369.1***	840.1**	171.357**	0.33602**
G	4	280129***	4746.8***	84.74**	29.295**	0.24147**
YxL	2	11261^{NS}	18.4^{NS}	0.05^{NS}	0.88**	0.11811**
YxSD	3	1585^{NS}	105.4^{NS}	2.96^{NS}	0.284^{NS}	0.03678**
YxG	4	24135^{NS}	30.2^{NS}	2.26^{NS}	1.139**	0.00436^{NS}
LxSD	6	66884^{NS}	1613.3***	7.64^{NS}	3.4**	0.01483^{NS}
LxG	8	71217^{NS}	260.3^{NS}	5.35^{NS}	2.247**	0.04057*
SDxG	12	48015^{NS}	113.3^{NS}	26.71*	0.993*	0.00892^{NS}
YxLxSD	6	2045^{NS}	286.1^{NS}	16.25^{NS}	0.456^{NS}	0.03347^{NS}
YxLxG	8	64619^{NS}	37.5^{NS}	8.35^{NS}	0.483^{NS}	0.02467^{NS}
YxSDxG	12	29105^{NS}	35.8^{NS}	14.37^{NS}	1.963**	0.03714^{NS}
LxSDxG	24	59565^{NS}	107.4^{NS}	38.36^{NS}	3.51**	0.02201^{NS}
YxLxSDxG	24	54984^{NS}	71.6^{NS}	22.96^{NS}	1.729*	0.10346^{NS}
Error	238	1798867	17761.3	248.6	10.392	0.05755^{NS}
Total	359	3626883	49238	1816.57	335.264	0.67593

Where DF=Degree of freedom, Y= Years, G= Genotypes, L= Locations, SD= Sowing dates, NS=Non Significant, Alphabets sharing same letters are non-significant at $p \leq 0.05$, and ***=significant at ≤0.01, **=significant at ≤0.055 and *=significant at ≤0.1 significance level.

Table 3: Yield and yield components for five wheat genotypes at three study sites under four sowing dates during two years.

	Number of tillers	1000 grain weight	Biological yield	Grain yield	Harvest index
Year					
2013-14	214.47^{NS}	36.49^{NS}	8.10^{A}	2.39^{A}	0.26^{B}
2014-15	198.81	35.82	6.66^{B}	2.19^{B}	0.29^{A}
LSD	18.053	1.79	0.21	0.04	0.01
Location					
Islamabad	246.14^{A}	41.75^{A}	7.99^{A}	2.73^{A}	0.32^{A}
URF-Koont	196.72^{B}	36.03^{B}	7.42^{B}	2.29^{B}	0.28^{B}
Talagang	177.07^{B}	30.698^{C}	6.73^{C}	1.85^{C}	0.24^{C}
LSD	22.11	2.19	0.25	0.051	0.01
Sowing Date					
SD_1	248.36^{A}	40.98^{A}	8.77^{A}	2.89^{B}	0.29^{A}
SD_2	251.51^{A}	42.85^{A}	8.99^{A}	3.04^{A}	0.31^{A}
SD_3	179.93^{B}	33.98^{B}	6.25^{B}	1.79^{C}	0.27^{B}
SD_4	146.77^{C}	26.83^{C}	5.52^{C}	1.44^{D}	0.24^{C}
LSD	25.531	2.53	0.30	0.06	0.02
Genotypes					
NARC-2009	206.57^{B}	38.03^{A}	7.65^{A}	2.39^{C}	0.29^{A}
AUR-809	221.1A^{B}	38.61^{A}	7.75^{A}	2.50^{B}	0.29^{A}
Pak-13	242.51^{A}	40.42^{A}	7.89^{A}	2.63^{A}	0.30^{A}
Dhurabi	157.72^{C}	31.01^{B}	6.65^{B}	1.88^{E}	0.25^{B}
Chakwal-50	205.31^{B}	32.73^{B}	6.96^{B}	2.03^{D}	0.26^{B}
LSD	28.54	2.84	0.33	0.0686	0.02

Where Y= Years, G= Genotypes, L= Locations, SD= Sowing dates, NS=Non-Significant, Alphabets sharing same letters are non-significant at $p \leq 0.05$.

Harvest index significantly differed for five wheat genotypes under four sowing dates at varying locations during both years. Analysis of variance showed that main effects of Y, G, L and SD were significantly different at $p \leq 0.01$ (Table 2). Maximum harvest index (0.29) was observed during 2014-15, while minimum harvest index (0.27) was obtained during 2013-14 (Table 3). During 2013-14, a 9% reduction in harvest index was observed. Harvest index also changed considerably among study sites. The highest harvest index was observed at Islamabad (0.32), while the lowest was noted at Talagang (0.24). A 32% reduction in harvest index was recorded at Talagang. Similarly, the highest harvest index observed under SD_2 (0.31), followed by SD_1 (0.29), while the lowest harvest index was observed under SD_4 (0.25). Harvest index was reduced by 21% late sowing date (SD_4), as compared to early sowing (SD_2). Maximum harvest index was recorded for Pak-13 (0.30), followed by AUR-809 (0.29), while the lowest harvest index was observed for Dhurabi (0.25). The percentage difference among genotypes for harvest index was 15%.

Number of tillers per unit area has a direct influence on final economic yield. The higher the number of tillers, the higher will be the grain yield. Change in number of tillers per unit area among study sites might be due to higher seasonal temperature at URF-Koont (4.6 °C) and Talagang (4.8 °C), as compared to Islamabad, where temperature was optimum. These results were in line with Nawaz *et al.* (2013), who reported that high temperature during crop life cycle reduces yield and yield components. In our study under later sowing dates, there was higher temperature, which resulted in reduction in the number of tillers per unit area. Sial *et al.* (2005) concluded that higher temperature under late sowing dates resulted in decreased number of tillers per unit area for wheat crop.

Thousand grain weight is a very crucial varietal character contributing towards final yield. This variation might be due to increase in temperature and moisture stress during later growth stages of wheat crop and ultimately it had marked influence on grain yield of crop (Table 3). The crop sown during early seasons utilized available resources but during late sowing by the occurrence of high temperature crop growth and development retarded. Schlenker and Lobell (2010) reported the adverse effects of higher temperature on wheat kernel yield. Andarzian *et al.* (2015) depicted that high temperature reduces grain weight more significantly than rainfall. The variation in thousand grain weight among study sites was due to variation in seasonal temperature. For example, Hlavinka *et al*. (2009) reported strong correlation among climatic parameters and yield attributes. Variation among different wheat genotypes for thousand grain weight was due to their potential against varying climatic conditions. Qadir *et al*. (1999) pointed out the variation of genotypes for thousand grain weights under varying climate. Increasing temperature adversely affected crop biomass. At Talagang, there was higher temperature during wheat growing seasons than URF-Koont and Islamabad, which resulted in early maturity and low biomass production as compared to Islamabad, where climatic conditions were favorable for better crop stand. White *et al*. (2011) pointed that crop dry-matter was affected due to change in environments. Change in sowing time significantly influenced wheat biomass production. The crop sown during October and November utilized the available resources but during late sowing by the occurrence of high temperature retarded crop growth and development was observed. Schlenker and Lobell (2010) reported the adverse effects of higher temperature on wheat biomass and grain yield. Andarzian *et al.* (2015) reported that it is the high temperature that reduced crop biomass rather than the rainfall. Current studies report that a decrease in biomass due to higher temperature confirms the earlier researchers' findings, who concluded that heat stress accelerates crop phenology and crop senescence, which results in earlier crop maturity, lesser biomass and crop yield (Zhao *et al*., 2007; Prasad *et al*., 2008; Hatfield and Prueger, 2015; Prasad and Jagadish, 2015). Increased temperature in future will have negative impact on crops and Piao *et al*. (2010) reported that some varieties will be fitted from warmer climate, while other might disappear. Since, phenological characteristics are highly related to the biomass production therefore, cultivars, which can sustain higher temperature should be used in future.

Grain yield is the final produce of the crop. Climatic parameters had great influence on the production of wheat crop. Varying climatic parameters have critical impact on decision making to adapt to global food production (Godfray *et al*., 2010). The temperature has significant impact on crop yield as higher temperature resulted in less production of assimilate due to earlier crop maturity, which ultimately reduces assimilates partitioning to the grains. During current studies, a higher temperature has negative correlation with grain yield under all treatments, however, temperature before anthesis showed strong influence on grain yield, which could be due to its impact on fertilization, and further, grain development stages of the crop. Changes in environmental conditions resulted in reduced wheat yield. Grain yield was higher under early sowing dates (Porter and Semenov, 2005), while reduced under later sowing dates due to higher temperature (Hurkman *et al*., 2009). Matching the critical growth stages of the crop with optimum environmental conditions is the best way to surpass the effect of heat stress and to have higher grain yield (Slafer *et al*., 2009). Prolonged crop foundation phase resulted in the reduced grain yield in earlier sown crops, while extended construction phase increased the grain yield as concluded by Miralles *et al.* (2000). Any change in seasonal temperature has great impact on wheat production. For SD_2, the highest wheat yield was produced at all the study sites emphasizing that in rainfed areas early November sowing of spring wheat could be better option under changing climatic conditions. Harvest index is the ratio between grain yield to biological yield. The first and prime focus of a crop plant is to convert maximum photosynthate into its economic yield. Variation in harvest index during growing seasons was observed due to changing climate during both years. At Islamabad, there was low temperature than URF-Koont and Talagang, and climatic conditions were favorable for better crop stand which resulted in proper translocation of photosynthate into grains. Andarzian *et al.* (2015) reported that under favorable climate wheat crop translocated a photosynthate into grains. Variation in climatic conditions such as lower rainfall and higher temperature gave rise to lower harvest index in cereals (Quiring and Papakryiakou, 2003).

The increase in temperature resulted into lower grain yield in later sowing dates. Akram *et al*. (2008) reported that grain yield has considerably positive association with yield parameters. Negative correlation of sowing dates to the yield and yield parameters illustrated the potential negative impact of higher temperature. Riazuddin *et al*. (2010) reported the negative impact of higher temperature on spring wheat yield and yield parameters. Among later sowing dates, the temperature was higher than the early sowing dates resulted to reduce grain yield. Similar to present findings, Khan *et al*. (2010) reported reduced wheat grain yield due to stresses like high temperature and drought. In present study, wheat productivity was affected by abiotic factors, like temperature and rainfall (Atkinson and Urwin, 2012). At Talagang, temperature was higher than other locations which resulted in heat stress, due to which crop water status lowered. Reconnoitering the relationship of different biotic and abiotic factors by correlation, as documented by Hlavinka *et al*. (2009) and Kolář *et al*. (2014) could help to explain yield variability with better understanding.

CONCLUSION

Current study revealed the impact of changing climate on wheat productivity for rainfed areas of Pothwar, Pakistan, in the multi-site field experiment of wheat crop. Under varying climatic study sites, the response of changing the sowing dates as adaptation strategies was identified. These results showed that a climate change influenced wheat production while increased temperature reduced wheat yield. For sowing dates, SD_1 and SD_2, there was no temperature stress and the average seasonal temperature remained lower than the later sowing dates, which led to higher wheat yield. Wheat growth and development is highly vulnerable to climate change. A shift from optimum sowing time to later sowing may significantly reduce wheat yield. Meanwhile, the atmospheric parameters especially rainfall and temperature had their impact on wheat yield. It is the need of the day that adaptation strategies should be adopted to increase wheat yield, which will ultimately help in securing food security of under developing countries like Pakistan. Based on current study, it is recommended that sowing of wheat should be done in early November to get maximum yield, and Genotype Pak-13 and AUR-809 must be planted in rainfed areas of Pothwar, Pakistan. Similarly, such genotypes should be developed, which will be tolerant to higher temperature to feed the increasing population of the globe, particularly Pakistan.

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