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Impacts of Temperature on Wheat Productivity in Rice-Wheat Cropping System of Punjab, Pakistan

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ABSTRACT

From 2011-12 to 2020-21, an experiment was conducted at the Adaptive Research Farm Sheikhupura, Punjab, Pakistan to test the adaptability of indigenous wheat cultivars in the rice-wheat cropping system of Pakistan. The selection of cultivars was based on their popularity among farmers and their ability to produce high yield. Each year, the experiment was set up using a Randomized Complete Block Design, with wheat cultivars as treatments randomized in plots measuring 3.15 m × 9.6 m. All experimental units were treated the same way in terms of agronomic practices, plant protection, harvesting, and post-harvesting techniques. Data was collected pertaining to number of tillers (m^{-2}), 1000-grain weight (g) and final grain yield (t ha^{-1}) for each cultivar, as well as the mean monthly minimum and maximum temperatures for each crop season recorded. The data was then analyzed statistically. It was found that temperature had a negative impact on the number of tillers, 1000-grain weight, and grain yield of wheat over the long term. Furthermore, the performance of wheat cultivars varied based on changes in temperature throughout the entire study period.

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INTRODUCTION

The term "yield stability" refers to the ability of a crop to maintain a consistent level of productivity over a prolonged period of time or in different regions with varying climatic conditions (Urruty *et al.*, 2016). This is a crucial challenge in modern agricultural production systems that are constantly evolving (Hufnagel *et al.*, 2020) and also an important adaptation strategy to cope with the changing climate (Olesen *et al.*, 2011). The dynamic nature of climate indicators has a negative impact on crop yields, which undermines the stability of agricultural production systems (Muller *et al.*, 2018; Najafi *et al.*, 2018; Ray *et al.*, 2015; Tigchelaar *et al.*, 2018). Farmers strive for consistent crop yields over time to secure a stable, long-term financial return on their investment and minimize risks of sudden drops in crop yield due to any production factor. Meanwhile, the breeding of crop cultivars focuses on ensuring broader yield stability by entertaining various climatic variables (Muhleisen *et al*. 2014). Yield stability is therefore crucial for both national and global food security, providing a sustainable source of income (Kalkuhl *et al*., 2016). Furthermore, significant spatio-temporal fluctuations in crop yield can lead to food insecurity or even famines in certain parts of the world, which cannot be immediately compensated (Abbo *et al*. 2010). Climate change is also having a severe impact on global crop yield (Porter and Gawith, 1999; Ottman *et al*., 2012). Over the past century, cereal-growing regions around the world have experienced a temperature increase of approximately 1°C, which has had a serious impact on crop production (Joshi and Joshi, 2019). The rising temperatures, combined with the increased concentration of greenhouse gases in the atmosphere, pose significant challenges to the agricultural productivity of developing countries due to lack of technological development and modern adaptations in these countries (Rosenzweig *et al*., 2014).

Moreover, the impact of unpredictable rainfall patterns on global crop productivity is equally devastating, with extreme precipitation causing floods and lack of rainfall causing drought stress to crops (Khan *et al*., 2016). The sharp rise in temperature, decreased water availability, and erratic rainfall patterns with fewer rainy days per year have all contributed to the significant decline in cereal production worldwide (Agarwal *et al*., 2000; Maharajan and Joshi, 2013). These abnormal changes in temperature and rainfall, along with extreme weather events, can have a severe impact on the yield of wheat crop (Harkness *et al*., 2020; Farhangfar *et al*., 2015; Hernandez-Ochoa *et al*., 2018) and result in a 10-50% loss in yield if mitigation strategies are not implemented (Ahmad *et al*., 2015; Hussain *et al*., 2018). To sustain production systems, it is necessary to develop climate-smart and heat-resistant crop cultivars (Wheeler and Braun, 2013).

The rice-wheat cropping system is the largest cropping system in the world, covering approximately 15.8 million hectares in India, Pakistan, Bangladesh, and Nepal, (Ladha *et al*. 2003; Timsina & Connor 2001). However, concerns have been raised about the sustainability of this system due to stagnant yields (Ladha *et al*. 2003; Busari *et al*. 2015), continuous soil degradation (Bhandari *et al*. 2002), water scarcity (Humphreys *et al*. 2010), and air pollution (Bijay *et al*. 2008). Furthermore, climate variability is posing a threat to the productivity of the entire agricultural system (Ghimire and Panday, 2016; Malla, 2008). In Pakistan, where the rice-wheat cropping system covers 2.1 million hectares, yield stagnation is occurring due to various factors (Regmi *et al*. 2002; Duxbury *et al*. 2000).

Pakistan's agricultural productivity is being severely affected by climate change, and the country is among the top five most vulnerable countries to this impact (Anwar *et al*., 2020). Rapid population growth and urbanization have only worsened this problem. By 2040, an estimated 8-10% loss in agricultural productivity is expected due to rising temperatures (Cradock-Henry *et al*., 2020). In order to mitigate these weather extremities, development of climate smart crop cultivars could be considered as a viable option. In Pakistan, over 100 wheat cultivars have been developed and released since 1971 to ensure food security by addressing issues such as rust, heat and drought stress, and enhancing nutrient uptake for higher grain yields (Ahmad, 2009). The present study focuses on long-term yield analysis of major wheat cultivars in Pakistan's rice-wheat cropping system to compare their yield stability and examine the effects of long-term temperature changes on wheat crop yield.

MATERIALS AND METHODS

Site Description

The experiment was conducted at the Adaptive Research Farm Sheikhupura, Punjab, Pakistan, spanning from 2011-12 to 2020-21. The experimental site is situated within the rice-wheat cropping system of Pakistan, with longitude N 31° 42' 36.57'' and latitude 73° 45' 45.00'' as depicted in Figure 1. This location is situated in a semi-arid agro-climatic zone and receives partial rainfall while relying mainly on irrigation. Rainfall occurs typically during the monsoon season in July and August, which necessitates for the area to be irrigated during the wheat season (Ghazala *et al*., 2009). Canal water and suitable groundwater are utilized for irrigation of wheat crop.

Soil Profile

The soil of the experimental site is clay loam in texture, slightly alkaline with a pH of 8, and had an electrical conductivity of 3.5 dS m^{-1} and a nutrient content of 8.3-9.5 mg g^{-1} dry soil. Every year, the soil analysis was conducted prior to crop sowing, and it showed that the soil had adequate amounts of phosphorus (P) and potassium (K), but there was always a deficiency of nitrogen (N) in the soil, which was supplemented by adding the recommended amount of nitrogen fertilizer.

Description of Wheat cultivars

The wheat cultivars used in the study were chosen based on their ability to adapt to the rice-wheat cropping system and were continuously selected based on farmer preference in terms of yield potential. Table 1 provides information on the pedigree, year of release, and growth habit of the selected cultivars used in the experiment.

Figure 1. Location of experimental site.

Table 1. Pedigree, growth habit and year of release of wheat cultivars.

No	Name of cultivar	Year of release	Pedigree	Growth habit
1	Chakwal-50	2008	ATTILA/3/HUI/CARC//CHEN/CHTO/4/ATTILA	Spring
2	Seher-06	2006	CHILL/2* STAR/4/BOW//BUC/PVN/3/2*VEE#10	Spring
3	Faislabad-08	2008	PBW65/2*Pastor	Spring
4	Lasani-08	2008	LUAN/KOH-97	Spring
5	Miraj-2008	2008	SPARROW/INIA//V.7394/WL711/13/BAUS	Spring
6	Punjab-11	2011	AMSEL/ATTILA//INQ-91/PEW'S'	Spring
7	Aas-11	2011	PRL/PASTOR//2236(V6550/SUTLEH-86)	Spring
8	Millat11	2011	CHENAB2000/INQ-91	Spring
9	AARI-11	2011	SH-88/90A-204//MH97	Spring
10	Galaxy-2013	2013	PUNJAB-96/WATTAN/MH-97	Spring
11	Johar-16	2016	KAUZ/PASTOT/V.3009	Spring
12	Borlogue-16	2016	SOKOLL/3/PASTOR/HXL7573/2*BAU	Spring
13	Gold-16	2016	PR32(BAU)/INQ-91	Spring
14	Akbar-19	2019	BECARD/QUAIU	Spring
15	Ghazi-19	2019	WBLL1*2/4/YACO/PBW.65/3/KAUZ*2/TRAP/KAUZ/5	Spring

Source: World Wheat Atlas. (http://wheatatlas.org/country/varieties/PAK/0).

Temperature Data

Data regarding the minimum and maximum temperatures was collected daily from a meteorological unit located at the Adaptive Research Farm Sheikhupura, Punjab, Pakistan. The collected data was then used to determine the monthly averages of minimum and maximum temperatures, which are summarized in Table 2.

Crop Husbandry

Each year, the wheat cultivars selected for adaptability trials or popular among farmers were planted during the second week of November. The seed drill was used to plant the seeds at a rate of 125 kg ha^{-1}, in the plot size of 3.15 m × 9.6 m, with three randomized replicates. Phosphatic fertilizer at a rate of 84 kg ha-1 and potash at a rate of 62 kg ha^{-1} were applied at the time of sowing using Diammonium Phosphate (DAP) and Murate of Potash (MOP) as source, respectively, each year. Nitrogen at the rate of 114 kg ha^{-1} was applied in three equal parts in the form of urea. The first 1/3rd of urea was applied at the time of sowing, while the remaining two splits each as 1/3rd of total N were applied in two equal halves with first and second irrigation each year. The nitrogen received from DAP was also considered when calculating the urea quantity fpr the nitrogen dose. The crop was Irrigated at all critical growth stages as and when needed.

Appropriate herbicides were used to achieve effective weed control based on the type of weed flora present in the experimental units.

Data collection and Statistical Analysis

The tillering data was collected at the end of December each year, and the crop was harvested and threshed manually at maturity to record grain yield. One thousand grains were counted and weighed from each experimental unit to find the grain weight index.

The collected data was then analyzed using analysis of variance. If there was a significant difference among crop cultivars in a particular year, the means were subjected to the least significant difference test with a probability of $p \leq 0.05$. Additionally, the impact of the mean monthly maximum and minimum temperature on tillering, 1000-grain weight, and final grain yield of wheat was assessed each year.

Table 2. Mean monthly minimum and maximum temperature (°C) in Sheikhupura from 2011-12 to 2020-21.

Months	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Maximum temperature (°C)										
November	31	30	29	30	29	29	28	29	30	29
December	27	28	25	27	26	26	26	26	24	26
January	22	24	24	23	22	23	24	22	21	22
February	26	25	23	28	28	29	29	23	28	31
March	35	32	32	35	34	37	38	33	31	34
April	38	39	43	40	41	45	41	41	37	41
May	46	47	45	44	46	45	44	46	44	42
Minimum temperature (°C)										
November	10	9	8	9	10	10	8	10	11	8
December	1	0	2	1	3	6	0	3	0	3
January	1	1	1	5	4	2	4	2	2	2
February	2	3	6	7	7	5	7	5	6	7
March	9	10	9	9	11	6	12	9	11	13
April	16	17	15	15	16	15	16	16	15	15
May	20	21	16	20	20	21	20	20	20	20

Source: Agrometeorology Cell, Adaptive Research Farm, Sheikhupura, Punjab, Pakistan

RESULTS

Number of Tillers (m^{-2})

Table-3 shows that tillering in wheat cultivars fluctuated significantly during all the years except 2016-17 and 2007-18. Faisalabad-08 and Galaxy-13 remained the part of study for most of the time and these varieties showed a variable behavior in tillering each year. Faisalabad-08 showed the best tillering ability during 20112-13 (230.33 m^{-2}) and 2020-21 (258.33 m^{-2}), whereas Galaxy-13 performed best during 2013-14 (356.33 m^{-2}), 2014-15 (255.67 m^{-2}), 2015-16 (264.67 m^{-2}) and 2018-19 (227.33 m^{-2}). During the year 2020-21, the highest tillering was found in Faisalabad-08 (258.33 m^{-2}) and Ujala-16 (256.33 m^{-2}) followed by Akbar-2019 (242.67 m^{-2}). As for the mean number of tillers are concerned over the years, the highest tillering was observed during 2013-14 (325.4 m^{-2}) and 2019-20 (329.598 m^{-2}) whereas the minimum tillering was found during 2012-13 (219.268 m^{-2}) (Fig-2-a). When the effect of minimum and maximum temperature on tillering was investigated, it was found that increase in both minimum (Fig-2-b) and maximum (Fig-2-c) temperature during the month of December decreased the tillering in wheat. However, the effect of maximum temperature on tillering was more visible and pronounced as the trend line for the effect of maximum temperature on tillering showed a greater slope than that of for the minimum temperature (Fig 2-b and 2-c).

1000-Grain Weight (g)

During all the years, 1000-grain weight of different wheat cultivars remained significant except 2018-19 (Table-2). Faisalabad-08 showed the highest 1000-grain weight for 2012-13 (34.23 g) and 2020-21(40.73 g), whereas Galaxy-13showed highest 1000-grain weight during 2013-14(37.67 g), 2014-15 (38.40 g), 2015-16 (43.90 g) and 2019-20 (39.93 g). During 2011-12 (33.37 g) and 2013-14 (32.33 g), Faislabad-08 had the lowest 1000-grain weight. When the mean 1000-grain weight for year was calculated, maximum 1000-grain weight was found during 2019-20 (39.446 g) and 2020-21(39.672 g) and the minimum 1000-grain weight was recorded during 2018-19 (31.72 g) (Fig-3-a). When the effect of minimum and maximum temperature on 1000-grain weight was analyzed, it was found that both the minimum and maximum temperature affected the 1000-grain weight of wheat negatively (Fig-3-b and Fig-3-c). The effect of maximum temperature was more than that of minimum temperature on the 1000-grain weight of wheat.

Table 3. Number of tillers (m^{-2}) of different wheat cultivars in rice-wheat cropping system of Pakistan from 2011-12 to 2020-21

Cultivar	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Faisalabd-08	241.67bc*	230.33a	292.67d	236.00c	257.00b			217.67b	328.00ab	258.33a
Millat-11		215.67b	315.67c	246.67abc	248.00c					
Lasani-08	220.67d									
Sehar-06	238.33c									
Miraj-08	246.33ab									
Chakwal-50	238.33c									
Punjab-11		217.00b	325.33bc	253.00ab	250.67c					
AARI-11		216.67b	337.00b	243.33bc	247.00c					
Galaxy-13		216.67b	356.33a	255.67a	264.67a	224.00^{ns}	235.33	227.33a	322.33b	
Ujala-16						229.00	237.67	227.33a	328.33ab	256.33a
Borlog-16						223.00	227.00			
Golden -17						235.00	232.67			
Johar-16						223.67	178.33	228.67a	334.00a	
Anaj-17								228.00a	335.33a	243.67c
Ghazi-19										221.00c
Akbar-19										242.67b
LSD	6.854	6.499	17.188	11.287	5.617	NS	NS	4.625	7.843	9.182

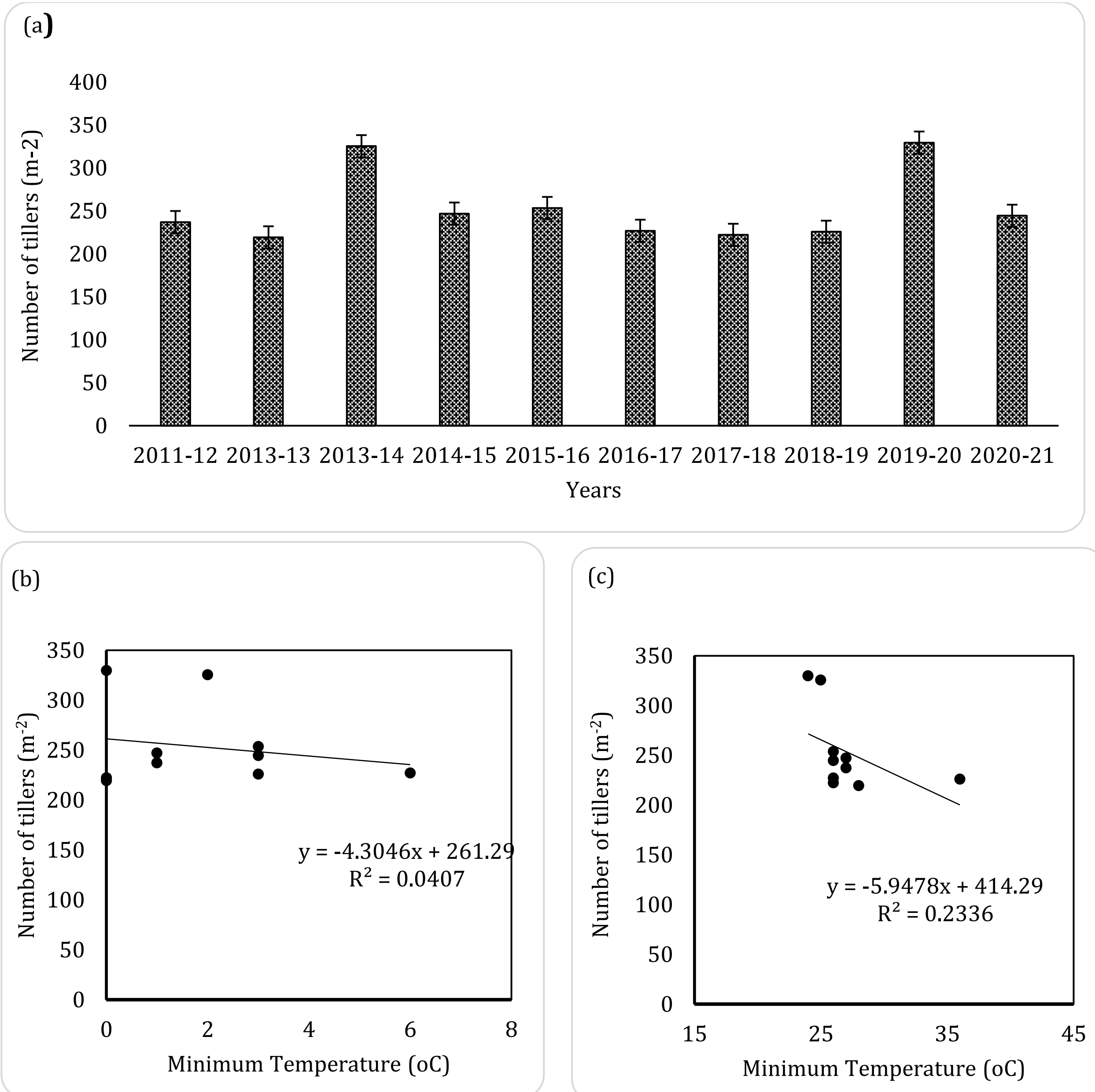

Figure 2. Mean number of tillers (m^{-2}) of wheat (a), Effect of minimum (b) and maximum (c) temperature on tillering of wheat in rice-wheat cropping system of Pakistan from 2011-12 to 2020-21.

Table 4. 1000-grain weight (g) of different wheat cultivars in rice-wheat cropping system of Pakistan from 2011-12 to 2020-21.

Cultivars	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Faisalabad-08	33.37d*	34.23a	32.33c	37.80ab	38.20b			31.90	39.63a	40.73a
Millat-11		32.33c	33.67c	34.10c	38.17b					
Lasani-08	32.30cd									
Sehar-06	35.27bc									

Miraj-08	35.80ab									
Chakwal-50	37.70a									
Punjab-11		32.33b	34.33bc	32.00d	37.60b					
AARI-11		33.33b	36.33ab	35.10bc	35.73b					
Galaxy-13		33.57b	37.67a	38.40a	43.90a	33.47b	32.17ab	31.00ns	39.77a	
Ujala-16						32.07c	32.87a	29.67	39.93a	39.13cd
Borlog-16						34.20b	30.62c			
Golden -17						35.93a	31.80ab			
Johar-16						31.70c	31.66bc	31.00	38.37b	
Anaj-17								35.03	39.53a	38.70d
Ghazi-19										39.73bc
Akbar-19										40.07ab
LSD	2.089	0.377	2.063	2.721	3.223	0.843	1.080	NS	0.509	0.931

*= Means for a column/year not sharing the same letter differ from each other at p≤0.05, NS= non-significant

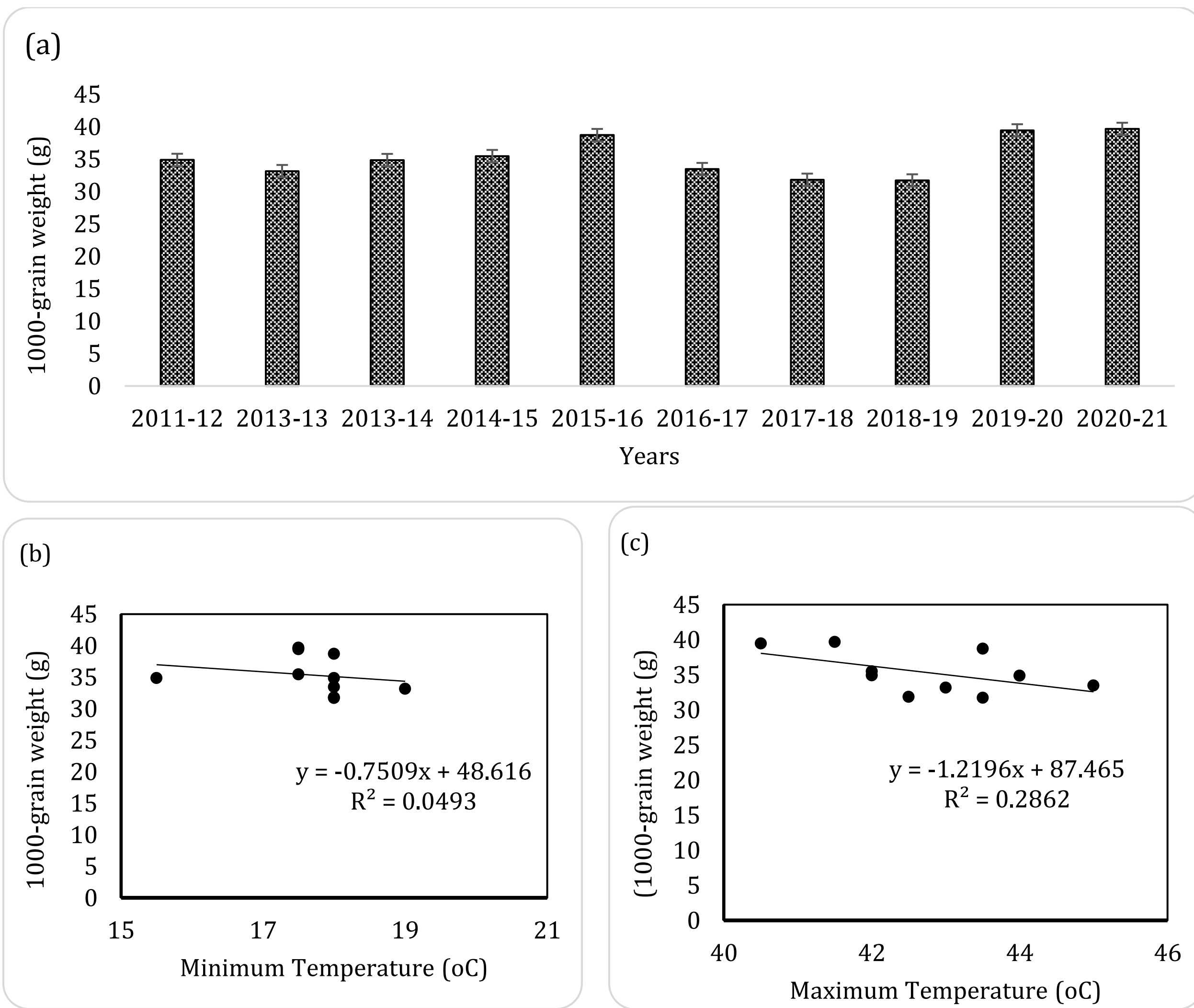

Figure 3. Mean 1000-grain weight (g) of wheat (a), Effect of minimum (b) and maximum (c) temperature on 1000-grain weight of wheat in rice-wheat cropping system of Pakistan from 2011-12 to 2020-21

Grain Yield (t ha^{-1})

A significant difference in grain yield of wheat cultivars was observed from 2012-13 to 2020-21 and during 2011-12 there was no statistically significant difference among wheat cultivars in terms of their grain yield (Table-5). Wheat cultivar Galaxy-13 remained the highest yielding cultivar from 2012-13 to 2016-17 statistically (Fig-4). During 2016-17 (3.90 t ha^{-1}) and 2017-18 (3.54 t ha^{-1}), wheat cultivar Ujala-16 was the highest yielding wheat cultivar and during 2018-19, Anaj-17 (3.90 t ha^{-1}) was the best performing wheat cultivar. During 2019-20, Faisalabad-08 (4.01 tha^{-1}) performed as the best cultivar in terms of grain yield (Table-5). During 2020-21, Ghazi-19 (4.93 t ha^{-1}) was the highest yielding wheat cultivar. Moreover, Akbar-19 (4.43 t ha^{-1}), Anaj-17 (4.33 t ha^{-1}) and Faisalaabd-08 (4.07 t ha^{-1}) were also statistically at pat with Ghazi-19. When the mean yield for year was calculated, it showed that highest grain yield of wheat was recorded during 2020-21(4.136 t ha^{-1}) followed by the year 2013-14 (4.01 t ha^{-1}), while the minimum grain yield of wheat was observed during 2012-13 (2.424 t ha^{-1}) (Fig-4). Temperature also affected the grain yield of wheat in a negative fashion (Fig-5-a and Fig-5-c). The effects of minimum temperature during the months of April and May had more drastic effects on the grain yield of wheat.

Table 5. Grain yield (t ha^{-1}) of different wheat cultivars in rice-wheat cropping system of Pakistan from 2011-12 to 2020-21.

Cultivars	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Faisalabad-08	3.51^{ns}	2.17b*	3.57d	2.57c	3.64b			3.88ab	4.01a	4.07a
Millat-11		2.33ab	3.87c	3.26b	3.12d					
Lasani-08	3.42									
Sehar-06	3.87									
Miraj-08	3.72									
Chakwal-50	3.63									
Punjab-11		2.52ab	4.05bc	3.38ab	3.28c					
AARI-11		2.52ab	4.15b	2.80c	3.21cd					
Galaxy-13		2.58a	4.42a	3.63a	4.12a	3.87a	3.5b	3.80 b	3.93ab	
Ujala-16						3.90a	3.54a	3.70c	3.86b	2.92b
Borlog-16						3.62b	3.27d			
Golden -17						3.68b	3.41c			
Johar-16						3.76ab	3.18e	3.33d	3.84b	
Anaj-17								3.90a	3.9ab	4.33a
Ghazi-19										4.93a
Akbar-19										4.43a
LSD	NS	0.350	0.256	0.287	0.142	0.170	0.033	0.077	0.127	0.926

*= Means for a column/year not sharing the same letter differ from each other at p≤0.05, NS= non-significant

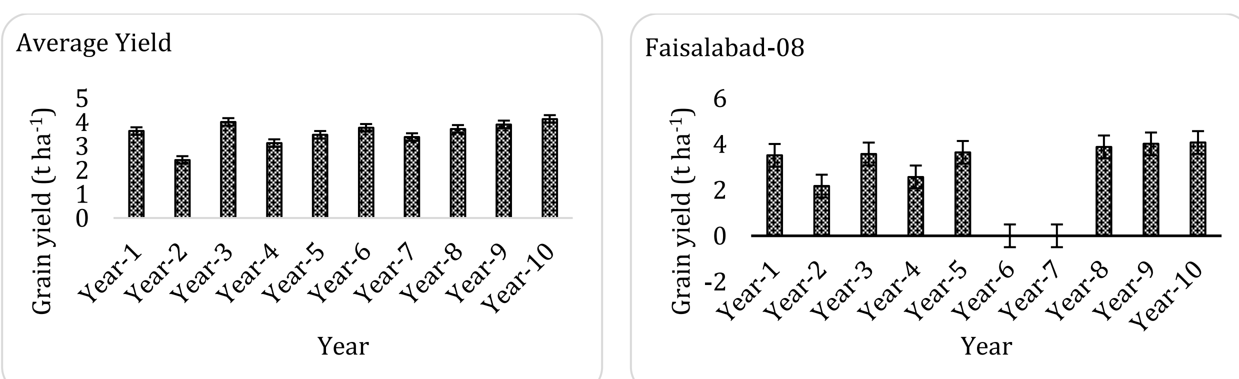

Figure 4 (a). Variations in average grain yield as well as grain yield of some wheat cultivars.

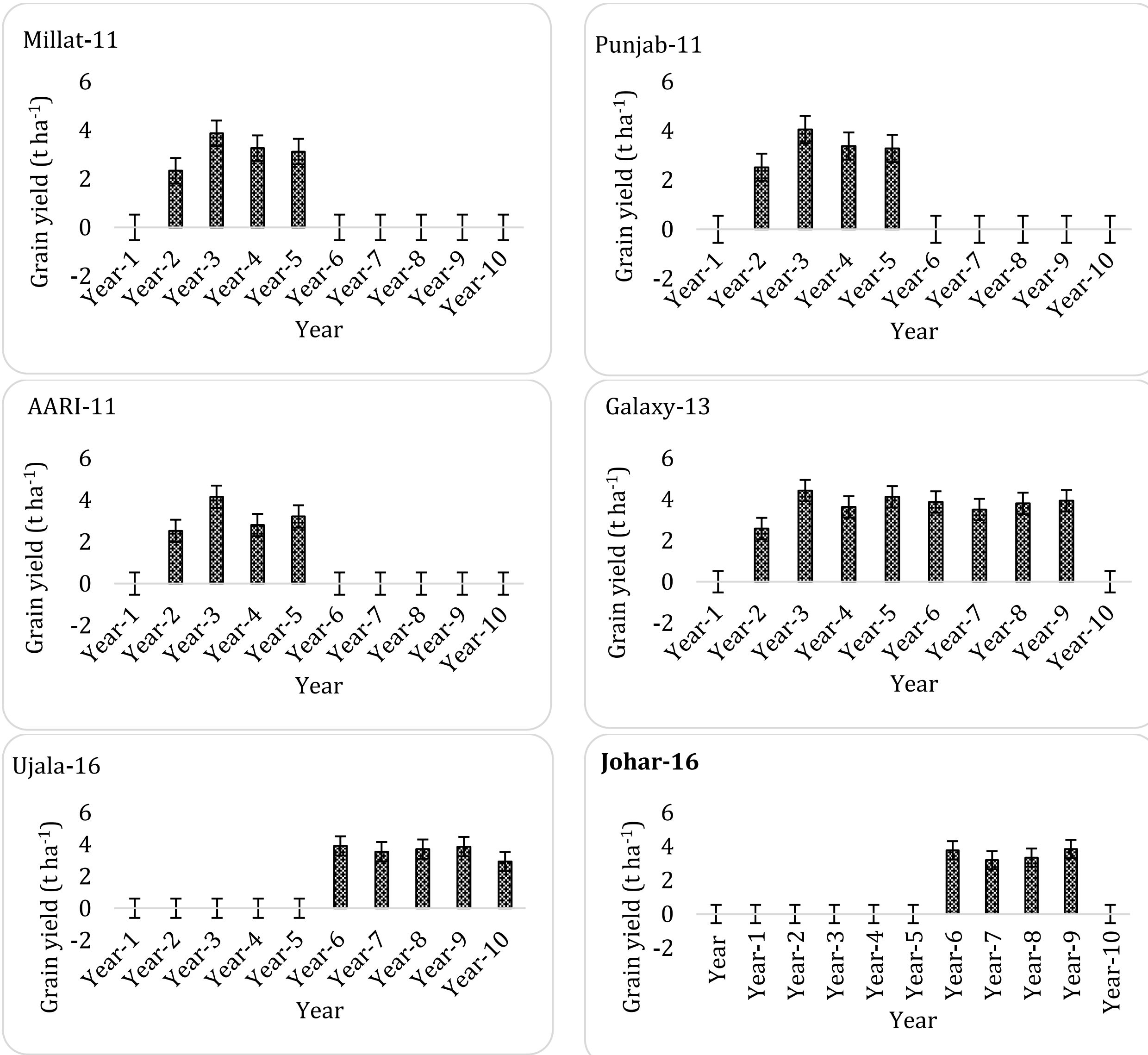

Figure 4 (b). Variations in average grain yield as well as grain yield of some wheat cultivars from 2011-12 to 2020-21 in rice-wheat cropping system of Pakistan, Year-01= 2011-12, Year-02= 2012-13, Year-03= 2013-14, Year-04= 2014-15, Year-05= 2015-16, Year-06= 2016-17, Year-07= 2017-18, Year-08, 2018-19, Year-09= 2019-20 and Year-10= 2020-21.

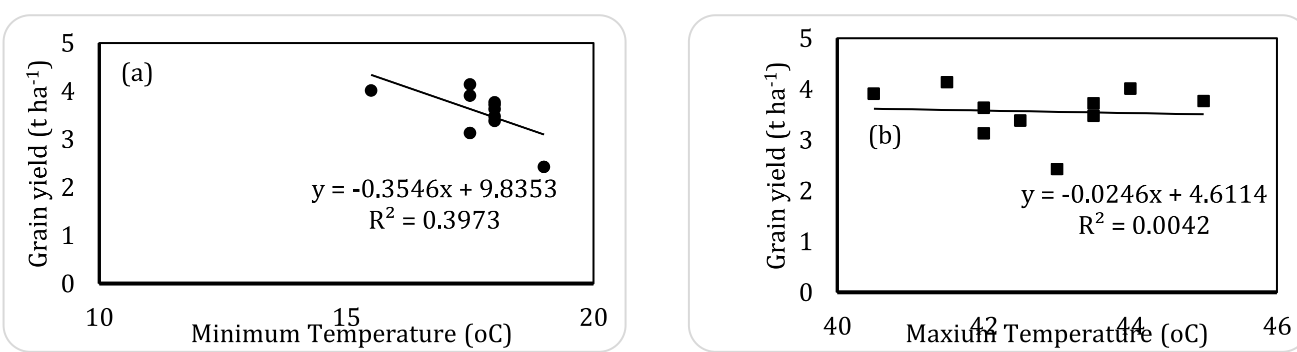

Figure 5. Effect of minimum (a) and maximum (b) temperature during December on grain yield (m-2) in wheat in rice-wheat cropping system of Pakistan.

DISCUSSION

According to Hsu and Walton (1971), tillering, leaf area, and spikes per plant are important factors that significantly affect the final yield of wheat. While high tillering is beneficial, the ideal temperature for tillering in wheat is between 13-18°C; any temperature increase during this stage can inhibit tillering and lead to lower crop yield (Li *et al*., 2010; Liu *et al*., 2018). Studies have also shown that high temperatures can shorten the duration of all growth stages in wheat (Blum *et al*., 2011). The varying tillering capabilities of different wheat cultivars are attributed to both genetic differences and the negative impact of temperature constraints.

Table-2 presents clear evidence that the maximum temperature in December exceeded 25°C, which resulted in a shortened tillering period and decreased tillering in wheat cultivars. Additionally, the minimum temperature in December was also unfavorable for tillering in wheat, dropping to 0°C in some years. Therefore, the variations in tillering and low tillering in Pakistan's rice-wheat cropping system may be attributed to higher temperature fluctuations during the month of December. Wollenwebe *et al*. (2003) reported that the reproductive stages of wheat are more sensitive to heat and temperature stress than the vegetative stages. Stone and Nicolas (1998) found that high temperature from anthesis to maturity can reduce wheat grain weight by up to 20%. Warrington *et al*. (1977) showed that high temperature reduces the size of endosperm cell reducing starch deposition in wheat grain. Grain filling duration is also affected by temperature, with an increase in night temperature from 14°C to 20°C causing 3 days less duration for grain filling, whereas at 23°C, it causes 7 days less duration for grain filling in wheat (Parsad *et al*., 2008). In addition to grain filling duration, grain filling rate is important, as it compensates for the shorter duration (Dias and Lidon, 2009). The grain filling rate depends on leaf and spike photosynthesis rates as well as the availability of food reserves in the plant stem (Sofield *et al*., 1977).

Table-2 clearly shows that the temperature changes over time or even within a single crop season are responsible for variations in the 1000-grain weight of wheat. Abrupt temperature changes during the grain formation and filling stages, as seen in Table 4, can cause significant losses in the 1000-grain weight of wheat. If the temperature changes smoothly during the months of March and April, it can benefit the grain filling stage of wheat. The genetic composition of each wheat cultivar is also a significant factor in determining the 1000-grain weight, as evidenced by Table-1, which shows that each cultivar has unique combinations of parent lines.

The final yield of a crop depends on its ability to efficiently carry out photosynthesis, reproductive success, allocation of dry matter to the edible parts, and plant architecture. High temperature stress negatively impacts all of these attributes in wheat crop, as noted by Driedonks *et al. (*2016). Even a slight increase of 1% in minimum or maximum temperature during wheat growth can result in a 5-6% decrease in grain yield, and if this temperature increase occurs during the reproductive phase, it can lead to a 21% reduction in yield (Berkley *et al*., 2011; Lobell and Field, 2007). High temperature stress also has a significant impact on leaf photosynthesis, leading to stunted growth during earlier stages and poor development during the later stages of crop development (Wahid *et al*., 2007). Additionally, high temperature causes the accelerated production of reactive oxygen species (ROS), leading to membrane damage in the wheat plant (Djanaguiraman *et al*., 2018; Narayanan *et al*., 2016).

CONCLUSION

The study indicates that high temperatures have a detrimental impact on wheat yield stability, as evidenced by a decrease in tillering and 1000-grain weight. Differences in grain yield among wheat cultivars may be attributed to genetic variation. Consequently, the development of heat-resistant wheat cultivars that can adapt to sudden temperature fluctuations is critical for achieving sustainable wheat yields in heat striken areas of the world.

REFERENCES

Abbo S., Lev-Yadun S., Gopher A., 2010. Yield stability: an agronomic perspective on the origin of near Eastern agriculture. Vegetation History and Archaeobotany. 19(2), 143–150.

Aggarwal P.K., Bandyopadhyay S.K., Pathak H., Kalra N., Chander S., Kumar S., 2000. Analysis of Yield Trends of the Rice-Wheat System in North-Western India. Outlook on Agriculture. 29, 259–268.

Ahmad F.,2009. Food security in Pakistan. Pakistan Journal of Agriculture Sciences. 46, 83–89.

Ahmad A., Ashfaq M., Rasul G., Wajid S.A., Khaliq T., Rasul

F., Saeed U., Rahman M. H. Hussain J., Ahmad Bai;g I., 2015. Impact of Climate Change on the Rice–Wheat Cropping System of Pakistan. In Series on Climate Change Impacts, Adaptation, and Mitigation; Imperial College, ASA, CSSA, and SSSA Publication: Madison, WI, USA, 2015; Volume 4, pp. 219–258.

Anwar A., Younis M., Ullah I., 2020. Impact of urbanization and economic growth on CO2 emission: A case of far east Asian countries. International Journal of Environmental Research. 17, 25-31

Barkley A., Tack J., Nalley L., Bergtold J., Bowden R., Fritz A.,2011. Weather, disease, and wheat breeding effects on Kansas wheat varietal yields, 1985–2011.Agronomy Journal. 227-35.

Bhandari AL, LadhaJ.K., Pathak H., Padre A.T., Dawe D., Gupta R.K., 2002. Yield and soil nutrient changes in a long-term rice–wheat rotation in India. Soil Science Society of American Journal, 66, pp. 162-170

Bijay S., Shah Y.H., BeeboutJ., Singh Y., BureshR. J., 2008. Crop residue management for low land rice based cropping systems in Asia. Advances in Agronomy, 98, 117-199.

Blum A., Klueva N., Nguyen HT.,2011. Wheat cellular thermotolerance is related to yield under high temperature stress. Euphytica. 117(2), 117–123.

Busari M.A., Kukal S.S., Kaur A., Bhatt R.,Dulazi A.A.,2015. Conservation tillage impacts on soil, crop and the environment. International Soil and Water Conservation Research.

Cradock-Henry N.A., Blackett P., Hall M., Johnstone P., Teixeira E., Wreford A., 2020. Climate adaptation pathways for agriculture: insights from a participatory process. Environmental Science Policy. 107, 66–79

Dias A.S., Lidon F.C., 2009. Evaluation of grain filling rate and duration in bread and durum wheat, under high temperature stress after anthesis. Journal of Agronomy and Crop Science.195(2), 137–147.

Djanaguiraman M., Boyle D.L., Welti R., Jagadish S.V.K., Prasad P.V.V., 2018. Decreased photosynthetic rate under high temperature in wheat is due to lipid desaturation, oxidation, acylation, and damage of organelles. BMC Plant Biology.18-55.

Driedonks N., Rieu I., Vriezen WH.,2016. Breeding for plant heat tolerance at vegetative and reproductive stages. Plant Reproduction.29, 67–79.

Duxbury J.M., Abrol I.P., Gupta R.K., Bronson K.F., 2000. Analysis of long-term soil fertility experiments with rice-wheat rotations in South Asia. In: Abrol, I.P. Bronson, K.F. Duxbury, J.M. and Gupta, R.K. (eds.) Long-term soil fertility experiments in ricewheat cropping systems. RiceWheat Consortium Paper Series No. 6. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India. p. 7-22.

Farhangfar S., Bannayan M., Khazaei H.R., Baygi M.M., 2015. Vulnerability Assessment of Wheat and Maize Production Affected by Drought and Climate Change. International Journal of Disaster Risk Reduction. 13, 37–51.

Ghazala N., Rasul G., 2009. Water Requirement of Wheat Crop in Pakistan, Pakistan Journal of Meteorology. 6(11), 89–97.

Ghimire D., Panday D., 2016. Interconnection of Climate Change, Agriculture and Climate Justice: Complexities for Feeding the World under Changing Climate. Development, Palgrave Macmillan Society for International Deveopment. 59(3), 270–273.

Harkness C., Semenov M.A., Areal F., S;enapati N., Trnka M., Balek J., Bishop J., 2020. Adverse Weather Conditions for UK Wheat Production under Climate Change. Agriculture and Forest Meteorology. 282–283, 107862.

Hernandez-Ochoa I.M., Asseng S., Kassie B.T., Xiong W., Robertson R., Luz Pequeno D.N., Sonder K., Reynolds M., Babar M.A., Molero Milan A.,2018. Climate Change Impact on Mexico Wheat Production. Agriculture and Forest Meteorology. 263, 373–387.

Hira G.S., JalotaS.K., Arora V.K., 2004. Efficient management of water resources for sustainable cropping in Punjab Research Bulletin. Department of Soils, Punjab Agricultural University, Ludhiana p. 20

Hsu P., Walton P.D., 1971. Relationships between Yield and Its Components and Structures above the Flag Leaf Node in Spring Wheat. Crop Science, 2, 190-193.

Hufnagel J., Reckling M., Ewert F., 2020. Diverse approaches to crop diversification in agricultural research. A review. Agronomy for Sustainable

Development. 40(2):14.

HumphreysE., KukalS.S., Christen E.W., Hira G.S., Singh B., Sudhir Y., Sharma R.K., 2010. Halting the groundwater decline in north-west India-which crop technologies will be winners? Advances in Agronomy, 109, 156-199

Hussain J., Khaliq T., Ahmad A., Akhter J., Asseng S., 2018. Wheat Responses to Climate Change and Its Adaptations: A Focus on Arid and Semi-Arid Environment. International Journalof Environmental Research. 12, 117–126.

Joshi G.R., Joshi B.,2019. Climate Change Impact on Agricultural Sector of Nepal: Implications for Adaptation and Resilience Building. In Agricultural Transformation in Nepal: Trends, Prospects, and Policy Options; Thapa, G., Kumar, A., Joshi, P.K., Eds.; Springer: Singapore, pp. 119–155

Porter, J.R., Gawith M., 1999. Temperatures and the growth and development of wheat: A review. *European Journal of Agronomy.* 10, 23–36.

Kalkuhl M., von Braun J., Torero M.,2016. Volatile and extreme food prices, food security, and policy: an overview. Food price volatility and its implications for food security and policy. In: Kalkuhl M, von Braun J, Torero M (eds) Food Price Volatility and Its Implications for Food Security and Policy. Springer Open, New York City, pp 3–31

Khan A., Ijaz M., Muhammad J., Goheer A., Akbar G., Adnan M. 2016. Climate Change Implications for Wheat Crop in Dera Ismail Khan District of Khyber Pakhtunkhwa. Pakistan Journalof Meteorology.13, 17–27.

LadhaJK D. Dawe, H. Pathak, A.T. Padre, R.L. Yadav, S. Bij ay, Singh Yadvinder, Y. Singh, P. Singh, A.L. Kundu, R. Sakal, N. Ram, A.P. Regmi, S.K. Gami, A.L. Bhand ari, R. Amin, C.R. Yadav, E.M. Bhattarai, S. Das, H.P. Aggarwal, R.K. Gupta, P.R. Hobbs How extensive are yield declines in long-term rice–wheat experiments in Asia? Field Crops Research, 81 (2003), pp. 159-180

LI Q.Y., Nian L., Liu W.D., Li L., Zhou S.M., Jun Y., 2010. Effects of accumulated temperature before winter on Growth and Development of Wheat in Henan Province. Chinese Journal of Agro-meteorology. 31, 563–569. (In Chinese)

Liu L., Ji H., An J., Shi K., Yan Z., 2018. Response of biomass accumulation in wheat to low-temperature stress at jointing and booting stages. Environmental and Experimental Botany. 157, 46–57.

Lobell D.B., Field C.B., 2007. Global scale climate-crop yield relationships and the impacts of recent warming. Environmental Research Letters. 2:011002.

Maharjan K.L., Joshi N.P., 2013. Effect of Climate Variables on Yield of Major Food-Crops in Nepal: A Time-Series Analysis. In Climate Change, Agriculture and Rural Livelihoods in Developing Countries; Maharjan, K.L., Joshi, N.P., Eds.; Advances in Asian Human-Environmental Research; Springer: Tokyo, Japan, pp. 127–137.

Malla G., 2008. Climate Change and Its Impact on Nepalese Agriculture. Journal of Agriculture and Environment. 9, 62–71.

OttmanM.J., Kimball B.A., White J.W.,Wall G.W., 2012. Wheat growth response to increased temperature from varied planting dates and supplemental infrared heating. Agronomy Journal. 104, 7–16

Mühleisen J., Piepho H.P., Maurer HP., Longin C.F.H., Reif J.C., 2014. Yield stability of hybrids versus lines in wheat, barley, and triticale. Theoretical and Applied Genetics. 127(2), 309–316.

Müller C., Elliott J., Pugh T.A.M., Ruane A.C., Ciais P., Balkovic J., Deryng D., Folberth C., Cesar Izaurralde R., Jones C.D., Khabarov N., Lawrence P., Liu W., Reddy A.D., Schmid E., Wang X., 2018. Global patterns of crop yield stability under additional nutrient and water inputs. PLoS One 13(6):e0198748.

Najafi E., Devineni N., Khanbilvardi R.M., Kogan F.,2018. Understanding the changes in global crop yields through changes in climate and technology. Earth's Future 6(3), 410–427.

Narayanan S., Tamura P.J., Roth MR., Prasad P.V.V., Welti R., 2016. Wheat leaf lipids during heat stress: I. high day and night temperatures result in major lipid alterations. Plant, Cell and Environment.39, 787–803.

Olesen J.E., Trnka M., Kersebaum K.C., Skjelvåg AO., Seguin B., Peltonen-Sainio P., Rossi F., Kozyra J., Micale F., 2011. Impacts and adaptation of European crop production systems to climate change. European Journal of Agronomy. 34(2), 96–112.

Prasad P.V.V., Staggenborg S.A., Ristic Z., 2008. Impacts of drought and/or high temperature stress on physiological, developmental, growth and yield processes of crop plants. In: Ahuja LM, *et al*., editors. Responses of crops to limited water: Understanding and modeling water stress effects on plant growth processes. Advances in Agricultural Modeling Series, USA p. 301–355.

Ray D.K., Gerber J.S., MacDonald G.K., West P.C., 2015. Climate variation explains a third of global crop yield variability. Nature Communications. 6:5989.

Regmi A.P., Ladha J.K., Pasuquin E.M., Pathak H., Hobbs P.R., Shrestha M.L., Ghauti D.B., Duveiller E., 2002. Potassium in sustaining yields in a long-term rice-wheat experiment in the Indo-Gangetic Plains of Nepal. Biology and Fertility of Soils. 36, 240–247.

Rosenzweig C., Elliott J., Deryng D., Ruane A.C., Müller C., Arneth A., Boote K.J., Folberth C., Glotter M., Khabarov N., 2014. Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. Proceeding of Natural and Applied Sciences. USA. 111, 3268–3273.

Sofield I., Evans L.T., Cook M.G., 1977. Factors influencing the rate and duration of grain filling in wheat. Australian Journal of Plant Physiology.4, 785–797.

Stone P.J., Nicolas M.E., 1998. Comparison of sudden high temperature stress with gradual exposure to high temperature during grain-filling in two wheat varieties difference in heat tolerance. II. Fractional protein accumulation. Australian Journal of Plant Physiology.25, 1–11.

Tigchelaar M., Battisti D.S., Naylor R.L, Ray D.K.,2018. Future warming increases the probability of globally synchronized maize production shocks. Proceeding of Natural and Applied Sciences. U S A 115(26):6644–6649.

Timsina J., Connor D.J., 2001. Productivity and management of rice–wheat cropping systems, Issues and challenges Field Crop Research, 69, 93-132

Urruty N., Tailliez-Lefebvre D., Huyghe C.,2016. Stability, robustness, vulnerability and resilience of agricultural systems. A review. Agronomy for Sustainable Development. 36(1), 15.

Wahid A., Gelani S., Ashraf M., Foolad M.R., 2007. Heat tolerance in plants: an overview. Environmental and Experimental Botany. 61, 199–223.

Warrington I.J., DunstoneR.L.,Green L.M., 1977. Temperature effects at three developmental stages on the yield of the wheat ear. Australian Journal of Agriculture Research. 28(1), 11–27.

Wheeler T., Von Braun J.,2013. Climate change impacts global food security. Science. 341, 508–513. doi: 10.1126/science.1239402.

Wollenweber B, Porter J.R., Schellberg J., 2003. Lack of interaction between extreme high-temperature events at vegetative and reproductive growth stages in wheat. Journal of Agronomy and Crop Science. 189(3), 142–150.