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CLIMATE CHANGE IMPACTS ON INTERANNUAL (2022 AND 2023) COMPARISON OF WHEAT PRODUCTION UNDER ARID AGROCLIMATIC CONDITION OF PAKISTAN

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Abstract: In this study we assessed the impacts of climate change on the production of wheat in Layyah, Pakistan, for two seasons. The study was carried out with the view of evaluating the effects of temperature and rainfall on biomass production of the wheat crop and consequently on yield and quality of the produce. Weather conditions during the planting, growth, development and maturation period were used for the study. To conduct the experiment, a one-acre field was decided to be divided into four groups comprising two kanals each to avoid any mixing of groups and for proper and effective data collection and assessment. Some of the variables, which were analyzed include grain yield, 1000 grain weight, tiller count, spikelet number and straw yield. The experiment gave the following production; Grain yield of 1960 kg per acre and straw yield of 2840 kg per acre in 2022-2023 production season with improved yield records as compared to the previous year. Also, the yield achieved during the 2022 to 2023 periods was higher in tillers, spikelet's, and a heavier grain content as compared to the 2021 to 2022 periods. According to the study, climate change has quite effect on the production of wheat in Layyah-Pakistan. The 2021-2022 crop growing season experienced La Niña and high temperatures, resulting in lower crop yields. However, during the 2022-2023 growing season, also a La Niña period, crops received sufficient water and optimum temperatures. This led to higher biomass production and increased grain production.
Keywords: Agroclimate; Climate change; Wheat; Food security

1 INTRODUCTION

The impacts of climate change are presently presenting a serious problem for the agricultural industry, especially in developing countries. Crop productivity is significantly impacted by these phenomena. Weather patterns that are unexpected and intense are brought on by climate change, and these weather patterns have a significant impact on agricultural yields, food security, and farmer livelihoods. Wheat, a critical staple crop across the world, is very important to Pakistan's food security. Nearly 200 million hectares of cropland are used to grow wheat, which makes up about 21% of the world's food supply [1]. Triticum aestivum L., also known as wheat, is one of the most widely grown cereal crops in the world, with an estimated annual yield of 420 million tonnes and a cultivation area of around 237 million hectares [2,3,4]. It provides as a minimum one-fifth of the total calories consumed by humans, therefore being a crucial source of dietary calories [5]. The usual height of wheat, an annual grass, is between 1.2 and 1.4 meters. It has a prolonged stalk that ends in a densely packed cluster of spherical kernels encircled by bristly spikes [6]. This specific grain contributes to one-fourth of global cereal output and nearly half of global cereal consumption (McGuire, 2015). Due to causes including development, advancement, and economic expansion, major changes in diets have been noticed throughout Asia, which has resulted in an increase in consumer consumption of wheat products [7]. Considering that wheat accounts for 35% of basic foods and around 17% of the world's agricultural land, enhancing wheat production is crucial to ensuring food security [8]. Recent estimates indicate that wheat yields are only increasing annually by 0.9%, much below the 1.5% annual growth required to reach the anticipated 60% rise in production worldwide by 2050, as predicted by the Research Plan on Wheat in 2016. There is a critical need for creative and sustainable methods to increase wheat production for the purpose to meet this critical requirement.

Wheat farming suffers a number of difficulties across the world, both biotic and abiotic in nature. Heat stress is one of the most crucial factors in South Asia, however, which restricts wheat production. Almost half of wheat is produced in temperate zones of the world, where this problem is also frequently experienced. Based on the duration and extent of the temperature exposure, being exposed to temperatures beyond the ideal range can harm wheat crops irreversibly and result in various levels of yield loss. According to scientific research, sustaining climate-controlled situations at temperatures over the recommended range can result in a 3-5% reduction in crop output for increase in every 1°C mean temperature above 15°C [9]. The average temperature of the Earth is expected to increase by 1.7 to 4.8 C by the end of this century, according to scientists, despite the fact that many wheat-producing regions throughout the world currently experience supraoptimal temperatures [10]. Canopy temperature (CT) is one of several plant properties that are significantly impacted by heat stress [11]. The development of more efficient breeding methods and technology for accelerating genetic gain rates in heat-stressed situations is required to achieve the vital global aim of improving grain production in the face of heat stress. Climate change carried on by climatic variability in countries that are developing may include abiotic pressures that result in significant physiological, biochemical, morphological, and molecular alterations that have a detrimental effect on crop growth, quality, and production [12]. High temperatures negatively affect yield and grain quality and this is one of the worst abiotic stresses affecting wheat worldwide [13]. Wheat plants have heat sensitivity in light of different abiotic influences, including temperature, radiation and humidity in the environment as well as the genotype and development phase of the plant [14]. This stress adversely affects various metabolism and physical growth processes of wheat plants including suppression of growth, yellowing of leaves, low photosynthesis, and low yield of grains [15]. High temperature stress is one of the most important abiotic stress factors that terribly impact wheat plant growth and production. To mitigate the damaging effect of heat stress, different adaptive responses are initiated in wheat plants such as protective compounds accumulation, heat-responsive proteins such as heat-shock proteins, and changed plant hormone signals. Therefore, it is important to understand these molecular processes that determine the wheat plants' heat stress response so as to be in a position to improve their heat tolerance. In the global climatic change scenario, this becomes important and could safe guard the world's produce.

In addition to climate change trends, extreme fluctuations in temperature such as El Niño and La Niña phenomena influence weather patterns, affecting wheat production [16]. El Niño is a climate occurrence coupled with the increase in sea surface temperatures in the central and the eastern Pacific Ocean; it is invoked with changes in precipitation and temperature in different parts of the world including SOUTH ASIA [17]. These changes induce heat stress and in timing and intensity of rainfall thus affecting wheat production. By the same token, conditions associated with La Niña, for instance, cool temperatures in the same regions in the course of cooler than average sea surface temperatures can bring rains which could in turn help wheat production though they come with factors that include floods and diseases [18]. Hence, identifying the roles of these phenomena on local brevity of weather perceptive is important to devise effective remedial measures for combating the effects of these phenomena that hampers wheat yield in arid agroclimatic region of Pakistan.

The specific aim of the present investigation is to assess the impacts of temperature and precipitation on the above-ground biomass and grain yield and quality of wheat crop during the growing season. For this two-year experiment, Fakhra Bakhar wheat variety shall be grown on one-acre land of an experimental plot in Layyah Chak no 114 Shahpur Daurata. The data collection process will primarily focus on parameters such as tiller and spikelet counts, grain weight per thousand, yield, and straw output. In order to gather data, a total of 50 plants will be randomly selected and observed. The 1-acre field will be divided into four equal sections, each spanning an area of 2 kanals. Statistical analyses will be employed to assess the impact of different weather conditions on wheat output.

2 METHODOLOGY

2.1 Experimental Site

This study was carried out at Layyah Chak No. 114 Shahpur Daurata, which is situated at latitude 30.9693° N and longitude 70.9428° E, over a duration of two years between 2022 and 2023. The crop used for this investigation was wheat, and the experiment was conducted on a 1acre area employing Randomized complete block design RCBD with factorial design. Fakhra Bakhar was the cultivar employed in the experiment. The technique was the same for both years.

2.2 Soil Analysis

To determine the initial nutrient level of the soil, a soil analysis was done before to the experiment's start. An independently provided soil specimen was used for the study at the Soil and Water Testing Laboratory in Layyah. The soil analysis yielded significant findings. The soil's electric conductivity (EC) was measured at 1.5 (dSm^{-1}). The pH level of the soil registered at 7.8, indicating a slightly alkaline nature. Regarding soil composition, the soil comprised 42.71% sand, 36.29% silt, and 20.99% clay. These percentages denote the relative proportions of these soil particles. The analysis also revealed that 0.78% of the soil consisted of organic matter, which plays a crucial role in soil fertility and nutrient cycling.

2.3 Preparation of Seedbed and Sowing

In order to prepare the seedbed, two rounds of ploughing, followed by two rounds of cultivation and planking, were carried out. The sowing method employed was broadcasting, and the sowing date was fixed as November 3rd for both years. The seed rate used was 50 kilograms per acre.

2.4 Fertilization and Irrigation

A total of 1.5 bags of urea, 1 bag of Diammonium Phosphate (DAP), and half a bag of sulphate of potash (SOP) were utilized as fertilizer. The application of DAP was divided into two portions, with half being applied during sowing and the remaining half during the first irrigation. Throughout the cultivation process, a total of six irrigations were implemented. Prior to planting, an initial watering, known as rouni, was carried out. Subsequently, five additional irrigations were performed at specific stages of the crop's growth. The second irrigation was administered 23 days after seeding, followed by the third irrigation at the tillering stage, which occurred 43 days after sowing. The fourth irrigation was applied 95 days after sowing, while the fifth irrigation took place at the booting stage, 70 days after sowing. Finally, at the milking stage of grain development, which was 125 days after sowing, the sixth and last irrigation was conducted. To control the growth of weeds and grasses, pre-emergence herbicides such as Stomp or Treflan were used at a rate of 1.3-2 L per acre.

2.5 Harvesting

Both years, the time-consuming, manual approach of harvesting wheat was employed. Plants are manually cut and stacked into bundles for this operation, which uses a threshing machine to separate the grain from the straw. In 2022, harvesting began on March 29 and ended on April 1; in 2023, it began on April 11 and ended on April 15.

2.6 Data Collection and Analysis

We conducted a scientific study where we examined various factors to assess their impact on crop growth. The parameters we focused on included the number of tillers, the number of spikelet's, 1000 grain weight, yield, and straw production. For the purpose of conducting the study, I was privileged to choose a 1-acre field, whereby I partitioned the field into four different groups. The groups comprised of two kanals; therefore, they assisted in structuring and regulating the study. To do this data was collected with the help of fifty plants from the particular group, which in fact one group was chosen randomly. Determined the arithmetic means for each plant with respect to number of tillers, number of spikelet's, and weight of a single grain respectively. To obtain accurate and correct data, we used data from climate studies and the Climate Information Tool on the AQUASTAT base created by the Food and Agriculture Organization of the UN. Furthermore, the weather was obtained from WeatherSpark [41] as it had updated and relevant data as the time of the study. There are many trustworthy sites that provides detailed and accurate coverage of the average weather and also provide information in the form of graphs at least for the month, day and hourly basis. To make sure that sources of the collected data are reliable and valid, these data sources are prioritized when making analysis and decisions in the study. As for the evaluation measurements in the current study, several kinds of parameters were involved, simply the yield, spikelet weight, yield per 1000 grains as well as straw. Version 8. Among the statistical tools that were applied to offer a broad statistical analysis of these parameters was SPSS and Excel. Impakt analysis charts were created in Excel which helped in between year comparison of the study. For quantitative research, the type of research design that is often used to give an overall description of data and for statistical inferences and comparisons of means of two or more populations is a factorial complete randomization. When the p value is less than 0. 05, then the result is considered to be statistically significant Otherwise, the result is referred to as insignificant at p > 0. 05. 05 is highly regarded as the consensus acceptable alpha level for testing the statistical significance of intergroup differences.

3 RESULTS

3.1 No. of Tillers

During the 2022 growing season, the experimental groups underwent assessment to determine the quantity of tillers, a crucial agronomic characteristic that reflects the growth and development of wheat crops. The results revealed positive outcomes in terms of tiller numbers for the experimental groups. Group 1 exhibited an average of 3.56 tillers per plant, Group 2 had 3.38 tillers, Group 3 had 3.48 tillers, and Group 4 had 3.64 tillers (Table 1). Subsequently, in the following year, during the 2023 growing season, the number of tillers experienced a significant increase across all experimental groups. Group 1 displayed an average of 3.66 tillers, Group 2 had 3.84 tillers, Group 3 had 3.88 tillers, and Group 4 had the highest average number of tillers at 3.92. These results aligned more closely with the potential of the Fakhra Bakhar cultivar. Both years' findings indicate that the performance of the experimental groups was satisfactory. The Fakhra Bakhar cultivar observed better results in the growing season of 2023, demonstrating the major impact of climate variability on wheat crop growth and development. Low rainfall and high temperatures in 2022 caused a negative impact on the production of wheat harvests. In contrast, the growing season of 2023 had more favorable climate conditions for producing wheat, which led to better results for the Fakhra Bakhar cultivar than the year before (Table 3). In terms of tiller counts, the experimental groups generally showed positive results, suggesting the possibility for a high wheat crop production.

3.2 No. of Spikelet's

The purpose of this study was to find out how climate change impacted the quantity of spikelet's in the Fakhra Bakhar wheat cultivar and its production during the cropping season of 2022-2023. Mean number of spikelets per plant was determined for each of the four groups which were formed according to the level of modulation. In 2022, all groups exhibited an average number of spikelet's ranging from 16.72 to 17.28. Group 1 demonstrated the highest mean value of 17.02, whereas group 4 displayed the lowest mean value of 16.9. However, the outcomes obtained in 2023 surpassed those of the previous year. More specifically, the average number of spikelet's per plant of each group was 19.72, 20.02, 20.28, and 19.9 for groups 2, 1, 3, and 4, respectively (Table 1). The results suggest that climatic variations have a substantial impact on the number of spikelet's in the Fakhra Bakhar wheat cultivar. The 2022 season was characterized by low rainfall and high temperatures, which had a detrimental effect on the wheat crop. Conversely, the favorable climate conditions in 2023 facilitated improved growth and development of the wheat crop, consequently leading to the superior results achieved during that year (Table 3). This underscores the significance of climate conditions in wheat production and bears implications for agricultural practices and crop management.

3.3 1000 Grain Weight

Numerous factors influenced the growth of crops, including genetics, soil quality, water availability, and weather conditions. One important measure used to assess crop growth is the 1000-grain weight, which determines both the yield and quality of the crop. This study examined the performance of four groups of wheat crops in terms of their 1000-grain weight over two consecutive years, specifically 2022 and 2023. In 2022, the average 1000-grain weight for the four groups of wheat crops was as follows: 40.72g, 40.68g, 40.74g, and 40.56g for groups 1, 2, 3, and 4, respectively. The insight of 1000-grain weight in different groups was elevated in the year 2023 with the average figures of 44. 66g, 44. 62g, 44. 58g, and 44. 48g for group 1, 48g for group 2, 48g for group 3, and 48g for group 4, respectively as shown in Table 1. This is due to the changes in environ-ment factors that influenced the yield of 1000-grain weight indicated by the current and the previous year. In 2022 year: low precipitations, high temperatures during vegetative phase, early reproduction and reduced their capability to accumulate moisture in seeds: that is why grain size was lower. These unfavorable climate conditions affected the yields and the quality of the crops in a very negative way. On the other hand, in 2023, more satisfactory meteorological conditions positively impacted the 1000-grain weight as have been highlighted in Table 3. That transformation in favor of H77 rice was evidently because of some changes in climate where 1000-grain weight between the two years varied. To sum up, the 1000-grain weight is a key indicator of crop growth, and thus, it supports the idea developed in this analysis about the necessity to take into account the environmental conditions in crop–management strategies in order to obtain a higher quality and yield of crops.

Table 1 Average Growth and Yield Parameters of Each Growing Season of Wheat under Climate Variability

Groups	Year	No. of tillersper plant	No. ofSpikelet's per plant	Grain weight (g)
G1(50 plants)	2022	3.56	17.02	40.72
G2(50 plants)	2022	3.38	16.72	40.68
G3(50 plants)	2022	3.48	17.28	40.74
G4(50 plants)	2022	3.64	16.9	40.56
G1(50 plants)	2023	3.66	20.02	44.66
G2(50 plants)	2023	3.84	19.72	44.62
G3(50 plants)	2023	3.88	20.28	44.58
G4(50 plants)	2023	3.92	19.9	44.46

Table 2 Comparison of Mean Values of Growth and Yield Parameters of Plant Groups/2 Kanals under Climatic Conditions

Groups	No. of tillers per plant	No. of Spikelet'sper plant	Grain weight (g)
G1(50 plants)	3.7800^{a}	18.780^{b}	42.690^{a}
G2(50 plants)	3.6800^{a}	18.520^{d}	42.660^{a}
G3(50 plants)	3.6100^{a}	18.415^{a}	42.650^{a}
G4(50 plants)	3.6100^{a}	18.220^{c}	42.510^{b}

Note: The letters "a, b, c, d" indicate the results of statistical comparisons between groups within each column. Values with the same letter are not significantly different from each other, while values with different letters are significantly different at a specified level of significance.

3.4 Wheat Grain Yield Kg/Acre

The primary objective of the present investigation was to evaluate the manner in which the Fakhar Bakhar variety of Triticum aestivum L. (common wheat) became impacted by climate change in terms of production. The study was carried out in 2022 and 2023, two consecutive years. The results showed a significant difference in wheat crop output between the two years as a result of different meteorological circumstances. With an average production of 1640 kg/acre in 2022, the yield was substantially low (Table 3). This drop in yield may have been caused by the adverse impacts of a heat wave in addition to a truncated winter season that went immediately into July. A smaller yield resulted from these circumstances because they caused a reduction in grain size and weight as well as earlier seed development. The production of the wheat crop, on the other hand, significantly increased in 2023, averaging 1960 kg/acre (Figure 1).

Favorable temperature conditions over the crop's whole life cycle were mostly responsible for the rise in yield. The vegetative stage of the 2023 wheat crop had a temporary spike in comfort but this was quickly followed by a significant drop in temperature and an increase in rainfall. The wheat crop was able to grow to its maximum size and weight due to these favorable conditions, which eventually increased the production to meet its needs. The wheat crop's yield in 2023 was unaffected by the high rains that dropped throughout the growth cycle since it had already finished its life cycle and grown to its maximum size and weight. The context of overall, the results of this study indicated that the Fakhar Bakhar wheat variety is highly susceptible to climatic changes, particularly variations in temperature and rainfall during the vegetative stage. In conclusion, this study indicated that climatic conditions significantly affect the yield of the Fakhar Bakhar wheat variety.

Table 3 Climate Impact on Wheat Crop Parameters: Comparison of Mean Tillers, Spikelet's, Grain Weight, Straw Yield and Grain Yield Per Acre over Two Consecutive Years

Year	No. of tillers per plant	No. of Spikelet's per plant	Grain weight (g)	Straw kg/acre	Yield kg/acre
2022-2023	3.8250 [a]	19.985 [a]	44.580 [a]	2840 [a]	1960 [a]
2021-2022	3.5150 [b]	16.982 [b]	40.675 [b]	2520 [b]	1640 [b]

Note: The letters "a, b" indicate the results of statistical comparisons between groups within each column. Values with the same letter are not significantly different from each other, while valueswith different letters are significantly different at a specified level of significance.

3.5 Biomass or Straw Production Kg/Acre

In accordance to a research, the 2022 wheat crop produced an average of 2520 kg of straw per acre, which was significantly lower than the 2023 crop's production. As shown in Table 3, the wheat harvest yielded an average of 2840 kg of straw per acre in 2023. The more favorable temperature conditions present at that time can be attributed for the significant increase in biomass production. The difference in temperature conditions between 2022 and 2023, shown in Figure 1, had caused the researchers to notice a considerable difference in biomass production between those two years. Unfavorable temperature conditions adversely affected the wheat crop in 2022, leading to a decline in straw production. Conversely, the crop experienced optimal temperature conditions in 2023, resulting in a significant improvement in straw production. These findings emphasize the susceptibility of wheat crops to climate change, particularly temperature fluctuations, and emphasize the necessity for farmers to adopt climate-resilient practices to mitigate the impact of climate change on agricultural output.

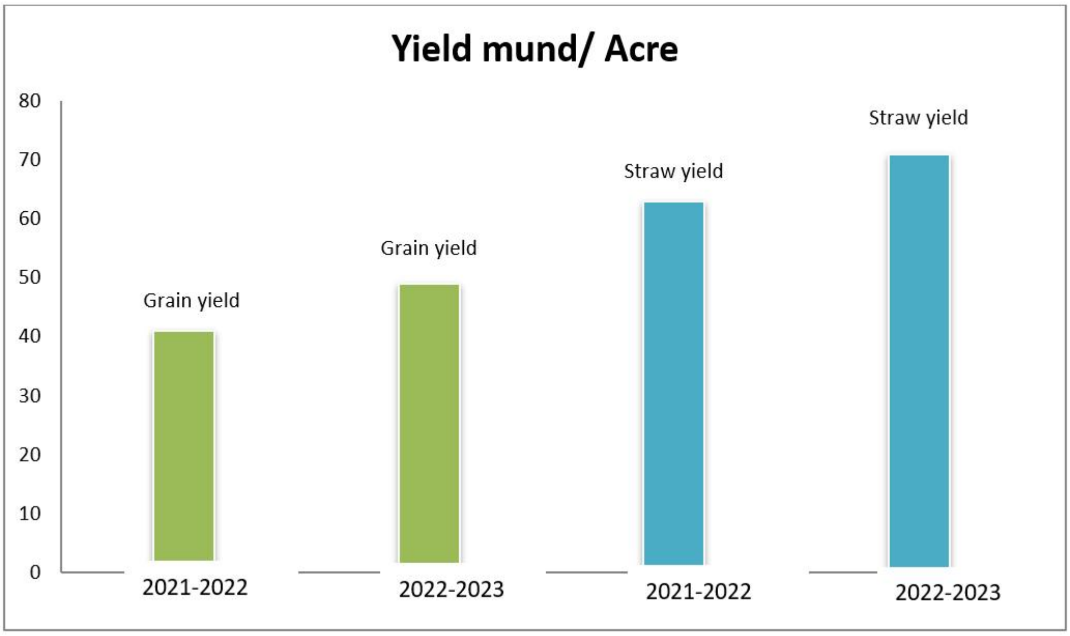

Figure 1 Assessing the impact of climate variability on crop productivity: A case study of straw and yield production in consecutive years

3.6 The Impact of Climate on Wheat

Climate change has emerged as a subject of escalating apprehension due to its effect on agriculture, specifically the cultivation of wheat. This research will evaluate the influence of environmental variables on the wheat growing periods during 2021-2022 and 2022-2023. Parameters to be examined encompass the quantity of tillers, number of spikelet's, grain weight, and overall yield.

Table 4 Monthly Means of Daily Maximum, Minimum and Mean Temperature, Reference Evapotranspiration, and Rainfall During Two Consecutive Wheat Growing Seasons (2021-2022 and 2022-2023)

Assessing the environmental factors impacting the 2021-2022 1st wheat growing season					
Month	Tmin °C	Tmax °C	Tmean °C	ETO mm/mm	Rainfall mm/m
Nov-21	13.8	26.1	20.1	83	0
Dec-21	8.6	20.2	14.1	57	1
Jan-22	7.4	17.6	12.5	54	25
Feb-22	9.3	22.2	15.8	82	7
Mar-22	16.5	30.7	23.6	146	20
Apr-22	21.3	37.5	29.4	205	3
Understanding the impact of climate change on the 2022-2023 2nd wheat growing season					
Month	Tmin °C	Tmax °C	Tmean °C	ETO mm/m	Rainfall mm/m
Nov-22	9.2	33.4	18.9	79	8
Dec-22	4.8	24.6	14.7	59	1
Jan-23	4.4	25.4	14.9	43	8
Feb-23	9.1	27.4	17.4	60	13
Mar-23	11.3	30.3	20.8	113	24
Apr-23	15.7	34.2	26.4	138	14

The climate data from the 2021-2022 seasons indicates that November and December were warm months, with average high temperatures of 26.1°C and 20.2°C, respectively. The recorded rainfall during this period was relatively low, with no rainfall in November and only 1 mm in December. In January, the temperature was cooler, with an average high of 17.6°C, but there was higher rainfall with 25 mm recorded. February had similar temperatures to December, with an average high of 22.2°C, but lower rainfall and higher evapotranspiration. March and April were characterized by high temperatures, with average highs of 30.7°C and 37.5°C, respectively. March received 20 mm of rainfall, while April received 3 mm (WeatherSpark, 2022). These findings indicate fluctuations in temperature and rainfall patterns throughout the 2021-2022 seasons. Regarding the crop parameters for the 2022 season, all groups showed similar results. The average number of tillers ranged from 3.38 to 3.64, the average number of spikelet's ranged from 16.72 to 17.28 per plant, and the average grain weight ranged from 40.56 to 40.74g.

The temperature and precipitation data for the 2022-2023 seasons reveal certain patterns. In November, the temperature ranged widely, with an average low of 9.2°C and an average high of 33.4°C, while receiving 8 mm of rainfall. December showed a decrease in the temperature range, with an average low of 4.8°C and an average high of 24.6°C, along with only 1 mm of rainfall. Similar temperatures were observed in January; with an average high of 25.4°C and slightly higher rainfall at 8 mm. February had an average high of 27.4°C and experienced 60 mm of evapotranspiration (ETO), along with 13 mm of rainfall. March had the highest ETO at 113 mm and the highest recorded rainfall at 24 mm, with an average high of 30.3°C. Finally, in April, the ETO decreased slightly to 138 mm, the average high temperature dropped to 34.2°C, and there was still 14 mm of rainfall. The crop parameters for the 2023 season exhibited an increase across all groups. The average number of tillers ranged from 3.66 to 3.92 per plant, the average number of spikelet's ranged from 19.72 to 20.28 per plant, and the average grain weight ranged from 44.46 to 44.66g. Examining the yield data, there was an increase in both yield and straw production from 2022 to 2023. Yield was recorded at 1640 kg/acre in 2022, while straw yield was 2520 kg/ acre. But, the yield in 2023 was higher at 1960 kg/acre, with straw production also rising to 2840 kg/acre. Therefore, as evident from the climate change analysis of the 2021-2022 and 2022-2023 wheat growing seasons performance, there existed changes in the temperature, rainfall, and evapotranspiration (ETO) affecting various crop attributes and yield. Such observations explain why further researches on the connection between climate change and agriculture are relevant as well as the need to implement preventive strategies and practices in order to minimize the impact of climate change on produce's output.

4 DISCUSSION

This research was conducted to understand the impact of environmental factors on the development of wheat crops in two different seasons. Especially, we established the research objectives to compare the extent to which temperature and precipitation influenced wheat crop growth. Furthermore, two other sources, namely the AQUASTAT and Weatherspark, were used in gathering other climatic data that include; maximum and minimum temperatures, average temperatures, evapotranspiration rates, and rainfall rates. We divided the 1 acre with land into four groups, with each group holding 2 kanals, to make accurate data collecting and analysis easier. These groups were formed to maintain data on important statistics including the quantity of tillers, spikelet's, and grain weight. Additionally, information on the productivity of grain and straw for an entire acre was collected. The temperature maintained within the typical range during the early growing season of 2021, establishing the perfect conditions for wheat development. The sudden increase in temperature that happened towards the end of the vegetative stage (as indicated in Table 4) produced a negative impact on the growth and yield of the wheat crops. As a result, during the growing season of 2021–2022, the yield decreased. Similar to the previous growing season, the temperature in 2022–2023 started normally but suddenly spiked towards the end of the vegetative stage (Table 4). Fortunately, this temperature changes hardly remained for a few days. Eventually the rainy season started, providing the wheat crops a chance to produce their most yield and biomass. It is important to remember that sudden variations in temperature might have a significant effect on crop growth and yields. As a result, it is crucial to continuously monitor temperature fluctuations and to implement the necessary remedies to avoid adverse effects on the yield of crops.

Different crop species respond differently to temperature at various stages of their life cycle. Temperature influences the growth of each species, with specific thresholds. These thresholds include maximum and minimum temperatures, as well as an optimal temperature that allows for the highest rate of plant growth (see Table 2 and 4). However, growth rates start to slow down beyond the optimal temperature, and growth eventually ceases when exposed to the maximum temperature threshold [19]. Recent research conducted by [20, 21] indicates that wheat yields decrease by 3-10% for every 1°C increase in temperature during the wheat-growing season. These results demonstrate the significance of managing temperatures in crop development. To maintain maximum crop yield in an environment of evolving climatic circumstances, it is essential to establish sustainable agricultural methods. Increased temperatures have been shown to have an adverse impact on the duration of the grain-filling phase in small grains like wheat in several studies [22,23,24,25] . The recent 2021-2022 growing season has experienced a similar issue, where a sudden temperature rise during the grain-filling stage has resulted in reduced yield. Shortening of the grain-filling duration has been attributed to factors other than limitations in assimilate, as previous studies have shown [26]. Additionally, rising temperatures negatively impact photosynthesis, further reducing wheat production, especially when combined with water scarcity [27]. Therefore, it is essential to consider how rising temperatures may affect wheat production and to establish strategies to mitigate these adverse effects. According to [28] the ideal temperature range for the photosynthetic rate in wheat is between 20 and 30ºC. Based to research by [29] this temperature range is 10ºC above the ideal temperature of 15ºC for grain production and single grain growth rate. Wheat plants' rubisco activity decreased at high temperatures together with a reduction in photosynthetic rate, according to research by [30]. Wheat plants exposed to temperatures above 25 to 35ºC during grain filling exhibit a shortened grain filling period, resulting in reduced wheat yields. Thus, maintaining temperatures within the optimal range is crucial for maximizing photosynthetic rate and wheat yields. According to [31] if the temperature continues to rise globally, a reduction of 5.4% in wheat yield is expected per 1ºC increase in temperature. [32] found that exposure to temperatures of 36/31ºC for 2 to 3 days before anthesis resulted in the production of small unfertilized kernels with symptoms of parthenocarpy, small shrunken kernels with notching, and chalking of kernels. [33] in a study that focused on temperature effects on grain yield of wheat conducted during the grain filling period, revealed that grain yield reduced along the gradient of increasing mean temperature. These findings reveal the susceptibility of wheat crops to heat increase and, therefore, stress the need to devise workable approaches to buffering the impacts of climate change on farming.

In a study by [34] the subject examined the impact of heat stress on chlorophyll and carotenoids in plants; the researchers noted a decline on both components. Reduced kernel weight was also observed here due to heat stress which in turn reduced the yield and this has been supported by [35] . This is due to grain filling process before and after flowering, which is termed as grain filling and the utilization of vegetative reserves can significantly affect the yield as has been said by [23]. This study further revealed that the use of sulfhydral compounds obtained from outside sources had beneficial effects on other growth and yield factors. Also, there was a decrease in the effective tillers in both genotypes under late sown condition which lead to the decline in yield under stress conditions as reported by [34]. This study shows that changing sowing time to create a better environment also considerably enhances yield in a crop. This may be attributed to the heat stress during grain filling period since this affected that yield response. However, they too have deleterious effects on tiller number and biomass and ultimately yield is affected. As highlighted by [36,23] these findings concord with earlier studies. Stress at the final stage of grain filling is identified as one of the critical factors affecting wheat productivity. Hence, from the outcome of this study [37] held an opinion that Raj 4083 has superior seed yield potential over PBW 373 both in normal temperature and during high temperature stress. Thus, it can be concluded that there was a negative effect of high temperature stress on all the growth, physiological and yield parameters of the crop.

The recorded data in scientific publications, concerning the negative impact of shortage of water and high temperatures on plant yield and biomass production, can no longer be a subject to doubt. High temperatures affect plant reactions and cause the cessation of physiological processes that enable it to produce desirable yields. In addition, the above-mentioned conditions have a negative effect on plant growth of wheat, various plant what and essential plant and grain affairs including tiller count, spikelet development, grain weight as well as grain size. Past studies have underscored the relevance of our research in the farming area. A lot of the conclusions have implications for improving heat-related misfortunes and increasing crop productivity. Therefore, our learnings can be useful to the farmers and at the same time make informative intervention into the field of agriculture.

4.1 Climatic Factors and Their Effects

This clearly shows that the growing season of 2022-2023 in its generality had better performance in wheat growing and yield than the previous one of 2021-2022. It is probable that climatic influences such as fluctuations in temperature played a part in these disparities as well as the reference evapotranspiration (ETO) and variations in rainfall.

4.1.1 Temperature and Rainfall

2021-2022 Season: In this growing season higher mean temperature and less rainfall compared to 2023 climate during certain growth stages in the year, which ranges from November to April (Table 4). This was accompanied by the scarcity of rain with far below the amount compared to the Season 2022/2023. The conditions such as high temperatures and low rainfall could have further raised the physiological stress that lowered the tillers and spikelet's hence grain weight [38].

2022-2023 Season: This season is comparatively optimal rather than the previous year with nearer temperatures and more rainfall. Specifically, March and April 2023 would register better rainfall of 24 mm and 14 respectively than the rainfall that was recorded in 2022 of only 20 mm and 3 mm respectively. The impact of these changes indicated by higher yield was apparently due to aspects such as increased moisture availability and reduced stress conditions [39].

4.1.2 Evapotranspiration (ET)

ET values were higher at most points in the 2021-2022 season this year, which means higher water evaporation rates from soil and plant surfaces due to higher temperatures and reduced humidity. This would have worsened water shortage during the year that the region was facing severe water shortages. On the other hand, it is worth noting that ET-based values were lower during the 2022-2023 growing season implying that there was less water evapo-transpired and water use efficiency was better, which in turn supports the better yield and the growth of the plant Influence of El Niño and La Niña:

4.1.3 El Niño and La Niña Events

2021-2022 Season (Potential El Niño Year): El Nino conditions generally lead to warmer global temperatures but can increase rainfall in some areas. This growing season of 2021-2022 had low rainfall and high temperature and these are some of the factors that cause plant stomata have closing mechanisms that helps in saving water. The above stress reduced the grain size, weight and yield as the crops were not growing as required.

2022-2023 Season (Potential La Niña Year): This leads to cooler and wetter conditions mainly in the tropic regions, and results in higher rainfall this season and increased crop growth and production as in 2022-2023. The recent 2022-2023 many-season has experienced high rainfall and low temperature a factor that promotes improved crop growth and production. The availability of water and the cooler climate enabled full cycles of crop mature with larger size of grain, heaviness and overall production of the grain.

4.1.4 Vapor Pressure Deficit (VPD)

VPD, which measures the difference between the amount of moisture in the air and how much moisture the air can hold when saturated, is a critical factor in plant stress and water use efficiency: VPD, which measures the difference between the amount of moisture in the air and how much moisture the air can hold when saturated, is a critical factor in plant stress and water use efficiency:

High VPD in 2021-2022: Intense heat and reduced humidity reduces the VPD and consequently, the moisture stress on the plants would have been much higher. This state probably narrowed down stomatal conductance thus restricting the photosynthesis and growth rates [40].

Lower VPD in 2022-2023: If there were more rainfall and moderate temperature then the VPD would have been less and thus lower sensitivity of stomata, less stress on plant and better functioning of stomata increasing growth and yield [39].

5 CONCLUSION

In conclusion, the findings of the conducted experiment are meaningful and they show the importance of consideration of the climate variability for growth of the wheat crops because it affects it greatly. The analysis of the results obtained in the course of the given investigation indicated that all groups numbering the tillers, spikelet's, and the weight of 1000 grains augmented in the year 2023 significantly, which pointed to the rather high potential to reach the maximum yield of the wheat crop. These findings call for the right strategy and means to develop suitable measures of agriculture and crop handling which should consider the changing climate patterns in order to achieve the right quality and quantity of crops in the market. The findings of this study are useful for farmers, agronomists and to policy makers through providing crucial information needed to establish efficient and sustainable mechanisms of agriculture crop production in order to reduce impacts of climate change on crop yields.

The study shows that climatic change affects wheat production in numerous ways and at various levels of growth. The more favorable climates during the upcoming seasons to be sowed, namely the 2022-2023 El Niño year should result in higher tiller and spikelet formation as well as higher grain weight than the low yielding and drought affected La Niña year of 2021-2022. Adaptive measures to deal with the climatic effects will be very important for enhancing production of wheat when climate conditions change in future.

COMPETINGINTERESTS

Theauthorshavenorelevantfinancialornon-financialintereststodisclose.

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