

Impact of temperature and precipitation variability on the sowing time and pest incidence on late-season gourd in Pakistan

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Abstract: Pakistan is an agricultural country where most people work in the agriculture sector. However, Pakistan's agriculture industry is being severely impacted by climate change. This study examines the effects of temperature, precipitation, and pest incidence on late-season gourd crops, focusing on the districts of Mardan and Charsadda. Time series data were obtained from Khyber Pakhtunkhwa's Meteorological Office, while cross-sectional data were gathered by survey questionnaires in the research area. Statistical analysis was used to evaluate the effects of temperature and precipitation on the variability of sowing dates and its subsequent impact on the frequency and growth of pests. Temperature rose by 0.15°C/year in Mardan and 0.1°C/year in Charsadda, while rainfall dropped by 1.4 mm/year and 0.9 mm/year, increasing pest damage to 79% and 75%, respectively. The findings indicate that farmers postpone sowing the gourd crop from the first to the last week of September to protect their crops from insect attacks and other damage. This is because the climatic factors (temperature and precipitation patterns) are changing. The primary pest causing significant harm to the gourd crop is the white fly, which spreads the virus known as mosaic viral disease. It is advised to offer heat-tolerant types with a brief lifespan.

Keywords: Agriculture industry, Climate change, Crops productivity, Pest damage, Viral disease, Heat-tolerance, Greenhouse gases, Statistical analysis, Pest incidence, Gourd crops.

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1. Introduction

Long-term climatic variations in weather patterns, which are influenced by the release of greenhouse gases such as carbon dioxide, nitrous oxide, and methane, cause variations in temperature and precipitation. These alterations will result from future extreme weather conditions, including heat waves, floods, droughts, and ozone layer depletion (Steve, 2014; Kumar, 2012; Haider *et al.*, 2016; Ali & Khan, 2022). Carbon dioxide, water vapours, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoro carbons all significantly increase with anthropogenic activity. With the use of fuel, development, manufacturing, and deforestation, the amount of carbon dioxide has risen from 280 parts per million to 380 parts per million (Stern, 2006; Mahato, 2014; Haidar *et al.*, 2016). Temperature and precipitation trends are constantly shifting, making Asia wetter and hotter in the temperate parts. This increases the likelihood of floods during the winter months with significant rainfall and makes the dry seasons drier. Climate influences agricultural output, and these effects are becoming more intense due to climate change (Ali & Khan, 2022). These issues include delayed planting and harvesting dates, erratic irrigation schedules, soil erosion, and declining Gross Domestic Product (GDP) (Shakoor *et al.*, 2011; ADB, 2009).

A shift in weather patterns strains the world's crop system and animals, directly affecting agriculture (IPCC, 2007). The IPCC (2007) projects that by 2100, the global temperature will have increased from 1.11 °C to 6.6 1 °C, which will have an impact on the yield of crops. The expansion and growth of plants are impacted by the atmosphere's rising CO₂ content, which also prevents fruit from ripening and interferes with photosynthesis (Rothan *et al.*, 1997; Burke *et al.*, 2001). In 2011, According to Maplecroft's Global Climate Change Vulnerability Index (CCVI), Pakistan is 16th out of 170 countries, indicating a high degree of susceptibility to the consequences of climate change.

A water shortage due to rising temperatures and altered rainfall patterns causes food shortages, lowering the yield of food crops (Menhas *et al.*, 2016). According to Haidar *et al.* (2016) crops are affected by rising temperatures because early fruit ripening lowers nutritional concentrations. Rainfall can speed up the decaying process even though it somewhat increases production. Siddiqui & Shirazi (2023) examined the climatic factors influencing crop yield production in Punjab and found that while both short and long-term climate changes have a positive effect on wheat crops, rising temperatures may have an adverse effect on wheat, rice, sugar, and cotton. Ahmad *et al.* (2014) said that an increase in temperature during seeding might result in a 7.4% drop in yield, while a similar increase in temperature in January and February could result in a 6.2% increase in production. Shakoor *et al.* (2011) claim that wheat production is reduced by Rs. 4180 for every 1 °C increase in temperature. Higher temperatures cause the respiration rate to increase, resulting in smaller, lighter grains with less biomass produced (Adam *et al.*, 1998).

The vitamins, minerals, and other nutrients the average person needs may be found in vegetables (Kumar *et al.*, 2012). The yearly rise in average temperature has an impact on the physiology, metabolic rate, and biochemistry of vegetables, which in turn creates an environment that is conducive to the reproduction of pests and increases the likelihood of disease outbreaks (Lal *et al.*, 2001; Singh *et al.*, 2009; Suhriani *et al.*, 2022). The studies carried out by (Luck *et al.*, 2010) argued that by 2050, a 16% decrease in potato yield is anticipated due to average temperature fluctuations. Temperature can have an impact on vegetable production as well as colouring. Lycopene pigment in tomatoes is destroyed above 27

°C (Kalloo *et al.*, 2001). Flynn *et al.* (2002), Erickson & Markhart (2002), Kurtar (2010), Thumbraj & Singh (2001) concluded in their studies that elevated temperature hinders specific plant processes, including pepper fruit set, chili seed germination, cucumber restriction, melon and okra seed germination, and more. Excessive precipitation during the blooming and fruiting phases of French beans causes ovule abortion above 35 °C and reduces French bean output (Singh, 2010).

Additionally, both the biology and the ecology of pests are significantly impacted by climate change (Jat & Tatarwal, 2012). The dispersion, behaviour, growth and development, survival, reproduction, and overall life cycle of pests are all significantly influenced by temperature, according to scientific studies on precipitation and temperature. An increase in precipitation is thought to eliminate or kill pests from crops, making it an essential management plan for cranberry pests like onion trips and cranberry fruit worms (Reiners & Petzoldt, 2005; Vincent *et al.*, 2003; Bale *et al.*, 2002). Yamamura and Kiritani (1998) reported that insects experience another one to five life cycles per season with temperature increases of 2°C. As the temperature rises, rust disease affects wheat and oats, but other plants are resistant to fungi in high temperatures (Coakley *et al.*, 1999). The ideal growing conditions for fungi that typically cause plant illnesses are temperate temperatures. When temperatures are between 7.2°C and 26.8°C, high moisture levels can lead to a fungal infection known as late blight in potatoes and tomatoes. More severe early blight is caused by the early arrival of warm weather (Wallin & Waggoner, 1950). Vegetable root pests such as apple scab, late blight, and others affect crops that receive more moisture.

Lower levels of humidity result in powdery mildew (Reiners & Petzoldt, 2005). Temperature affects the gender ratio of certain pests, such as thrips, which affects their reproduction (Lewis, 1997). Many insect species are migrating towards higher latitudes due to climate change. *Nezara viridula* is migrating from south to north over Japan Yukawa (2008) and Das *et al.* (2011). Scholars Yamamura and Kiritani (1998) and Awmack *et al.* (1997) in their studies concluded that sucking pests, namely White Flies, Aphids, and Thrips are increasing with rising temperature. This study will provide valuable insights into the changing patterns of pest populations, helping farmers and policymakers implement adaptive measures to protect crop yields and ensure food security. The research will contribute to sustainable agricultural practices in the face of global climate change by analysing the relationship between climate variability and pest prevalence.

2. Materials and methods

2.1. Methodological flowchart

Table-1 presents a methodological flowchart outlining the research process during the study.

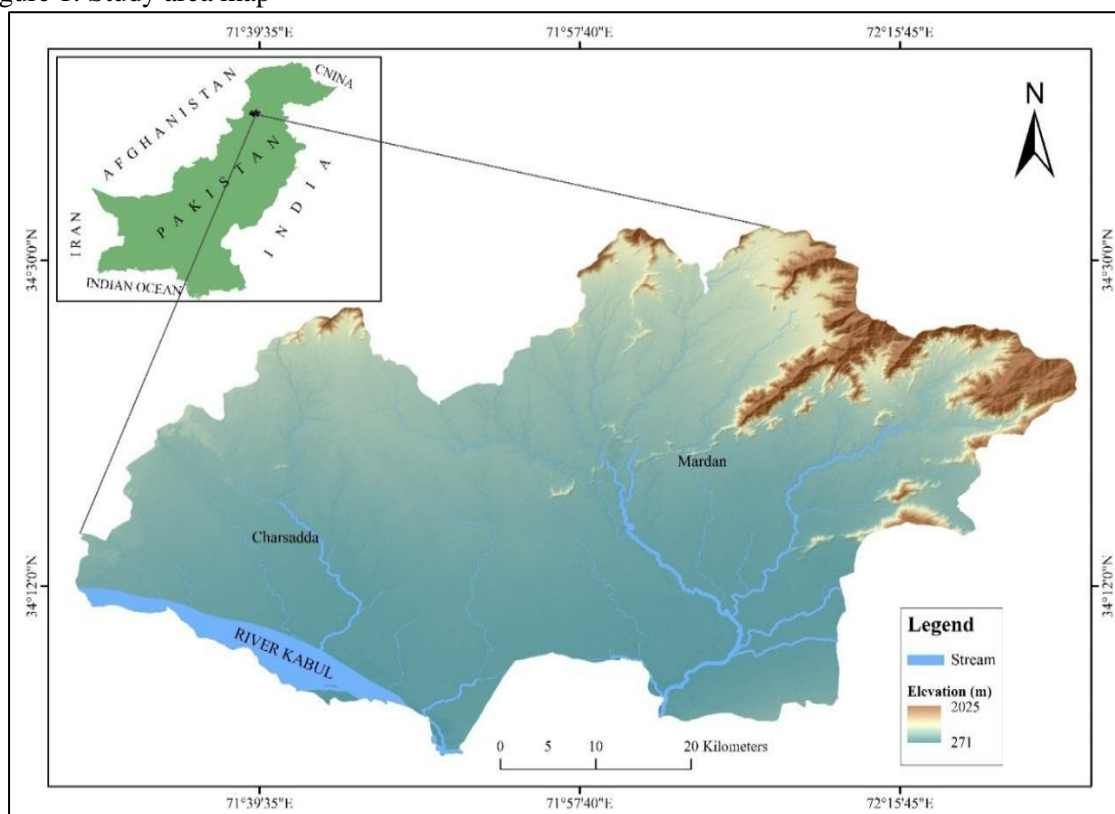
Table-1: Methodological flowchart of a research study

Activity	1 st Quarter	2 nd Quarter	3 rd Quarter	4 th Quarter
Perception Survey/ Questionnaire Survey				
Field Observations				
Secondary Data Collection				
Data Analysis				

2.2. Perception survey

A perception survey was conducted in the districts of Mardan and Charsadda (Figure 1) to learn more about the opinions of the local farmers regarding the advantages and disadvantages of climate change on their crops, as well as the methods they currently employ or plan to employ in the future to safeguard their crops, increase crop productivity, and prevent pest infestations. A brief survey with questions was created to collect pertinent information from the farmers. The questions were posed in an easy-to-understand manner to enable farmers to respond appropriately.

Figure 1: Study area map



2.3. Questionnaire survey

In order to gather sufficient information about gourds, their planting dates, and pest attacks, a questionnaire was created. For the survey, only farmers who grow gourd crops were chosen. All possible information about gourds, including their types, forms, and variations, was gathered.

2.4. Personal observation of study area

Primary data, questionnaire surveys, interviews, and meetings were insufficient to obtain a real and meaningful image. Therefore, in order to gather data, in-person visits were conducted to examine how different planting dates affected insect attacks. Secondary data was gathered from the Charsadda and Mardan Agricultural Extension Department, the Statistic Department, and the Nuclear Institute for Food and Agriculture (NIFA).

2.5. Supplementary data

From 2000 to 2016, additional information on temperature and precipitation was gathered from the National Solar Radiation Data Base (NSRDB) and the Meteorological Department Peshawar (MET). The department provided annual data, which was then taken out of each year's sowing months (September) for the gourd in order to collect the necessary data. Plotting sets of four and five years were chosen based on the needs of obtaining a meaningful graph that clearly displayed the results. Software was then used to plot the data in order to provide a graphical representation of the statistical data. The availability and requirements of the data were taken into account when tabulating.

2.6. Data analysis

Divided into layers, random sampling was employed to obtain the perception of the farmer's community. In order to determine the differences that were seen as a result of changes in the variables such as temperature, precipitation, different sowing dates, insect attacks, and crop productivity and to evaluate the statistical links between them, regression analysis and correlational research methods were employed. SPSS were used to set the graphs.

3. Results and discussion

3.1. Impression of the local community

As seen in Figures 2, 3 for Mardan and 4, 5 for Charsadda, 80% and 85% of farmers were aware of the changing climate, and 90% and 60% saw unfavourable effects on their farming techniques. Variations in temperature and precipitation significantly impact the production of their crops. Longer summers cause farmers to postpone planting until an appropriate temperature, such as 25°C to 33°C, to protect crops from pest attacks. However, this also strengthens pest immunity, making it more difficult to control pests with insecticides, and increases the likelihood that pests will attack crops, causing damage to both the field and nearby crops. Rainfall hurts crops because of the dampness that causes the leaves to decay. Additionally, high humidity raises the possibility of fungal attacks that are uncontrollable by fungicides and harm crops.

Figure 2: Showing Mardan perception survey

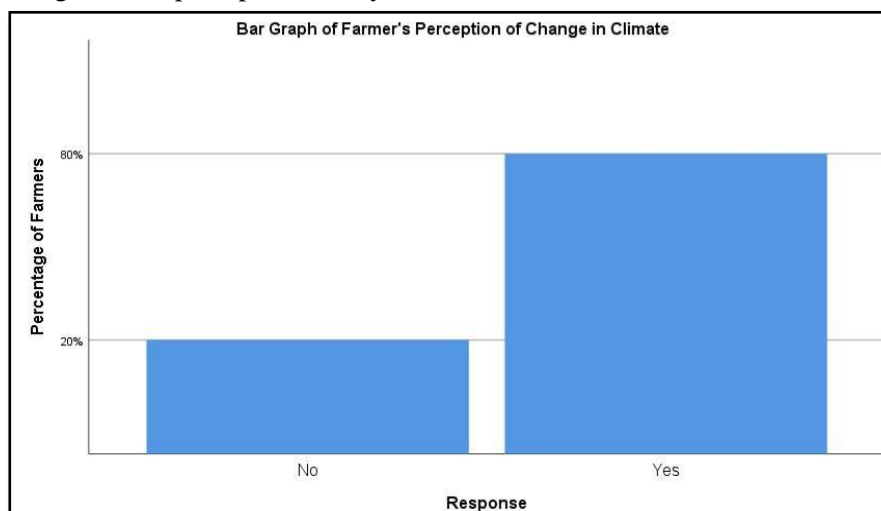


Figure 3: Showing Mardan perception survey

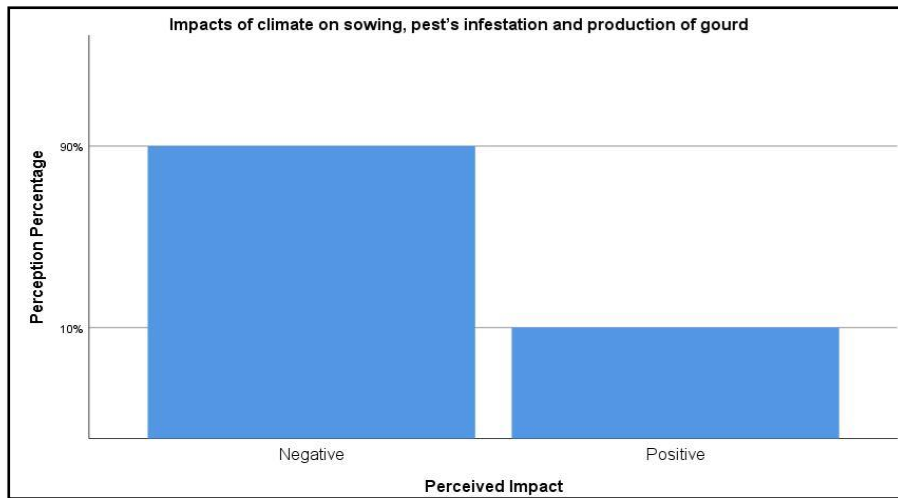


Figure 4: Showing Charsadda perception survey

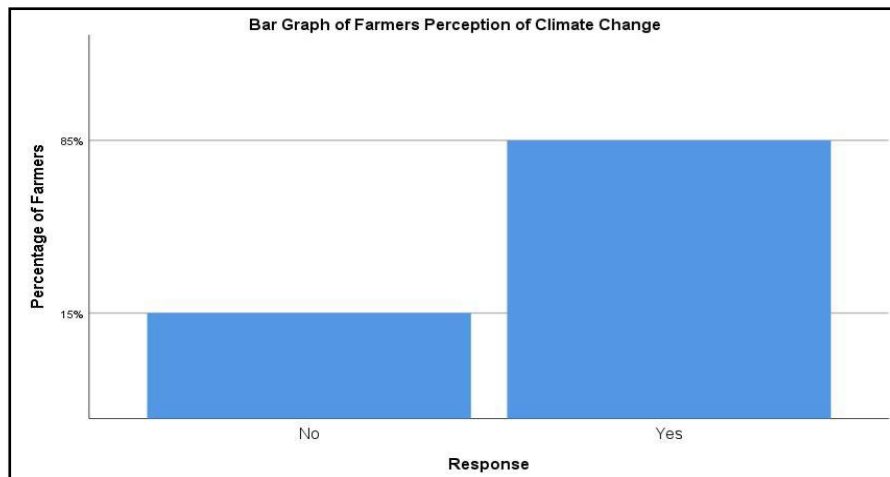
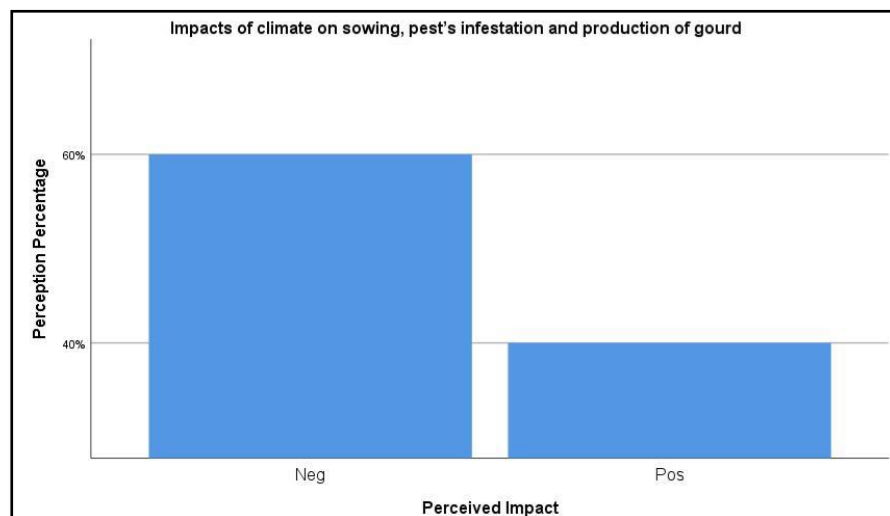


Figure 5: Showing Charsadda perception survey



Farmers' economies are impacted since they have to spend a lot of money on insecticides, fungicides, bactericides, and other pesticide sprays to keep pests away from the crops they

grow. In Mardan, over 60–70% of farmers grow gourd, while in Charsadda, about 25–30% do. When asked what crop they would grow in place of gourd, farmers responded that gourd was the only crop that could be grown in Mardan and Charsadda, given the September weather.

3.2. Seeding time, incidence of pests, and gourd crop yield

Farmers in Mardan claim that they began planting gourd locally known as “Maru” in 1995 and that no pest attacks occurred while they were using the hybrid diversity. However, farmers in Charsadda started planting in 1998 and used native varieties rather than hybrid ones. The planting dates for the years 1995–2005 were September 5–15.

Due to climatic change, the dates for the years 2006–2016 were changed to September 22–30 in the districts of Mardan and Charsadda. There were two causes for the late seeding. First of all, gourds are grown in warm climates between 25°C to 33°C.

However, because of the long summers, farmers have postponed sowing from the second to the third week of September, when the temperature is more favourable for gourd germination.

Second, as the weather warms up in September, insect attacks particularly the more troublesome white fly infestation disappear. However, white fly continues to harm the gourd crop until the end of September. The white fly infestation caused more significant crop damage between 2004 and 2016, resulting in dotted leaves and fruits that were susceptible to mosaic virus illness.

Occasionally, it results in dwarf plant development. In a similar vein, delaying the sowing dates shortens the gourd’s germination period, lowering yield. Between 1995 and 2005, a total of 90 to 110 gourd shoppers were sent to the market every three to four days; however, between 2006 and 2016, only 50 to 70 shoppers were created.

Farmers have protected their crops for the past ten years with methane dopas and mincoziband sprays, which target viral infections and fungal attacks, respectively. Today, they utilise Aceta and Emeda sprays to fight pests.

Temperature variation makes the circumstances favourable for aphid development and survival. They stay and finish their life cycle beneath the leaves. Rainfall causes fungal infections in crops and the humidity that result in crop rotting leads to Downy Mildew disease. Because of variations in temperature and precipitation, there is a greater correlation between the quantity of pests and crop damage.

3.3. Temperature and precipitation data

Figures 6 and 7 illustrate how temperatures and precipitation changed in September from 2001 to 2014. The green curve represents the temperature variation expressed as a percentage, with September 2001 as the basis month.

This was carried out because, in the same graph, the very variable precipitation data makes it impossible to notice the actual temperature variation, which is so little. The graph’s blue and red curves represent the variations in September’s rainfall for Charsadda and Mardan, respectively, represented in millimetres.

Figure 6: Annual variation in two districts' September temperatures from 2001 to 2014

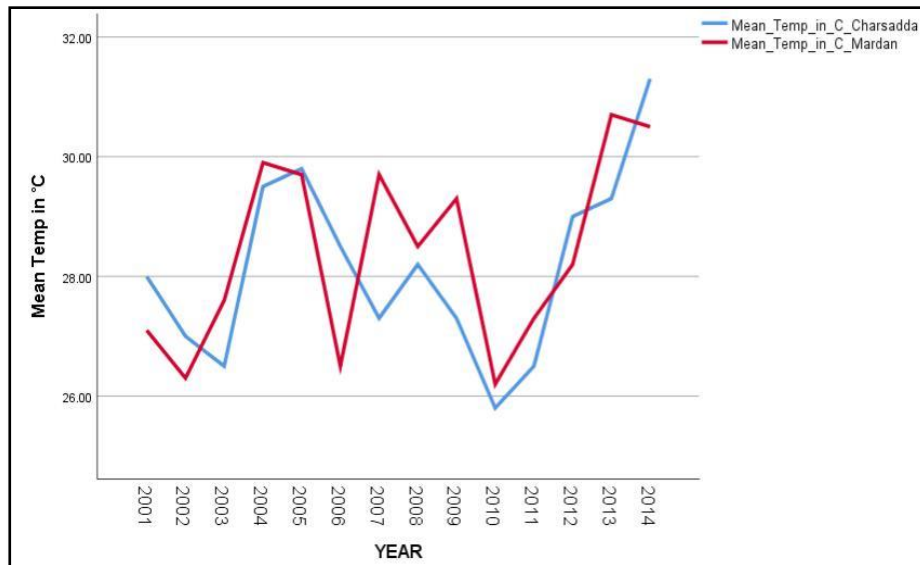
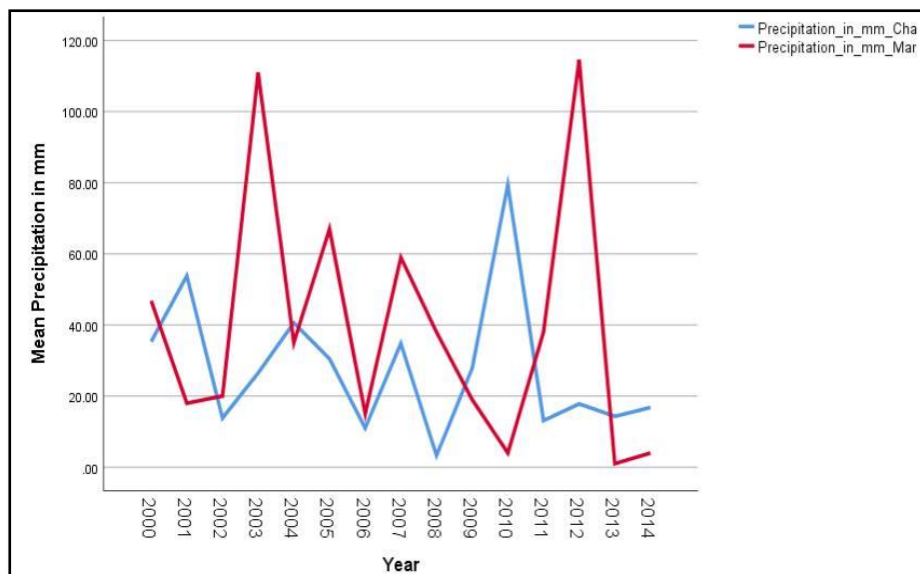


Figure 7: Variations in annual precipitation for September in two districts from 2001 to 2014



Regression was used to determine the pattern for each meteorological variable as follows.

$$X = a + bT$$

Where T is the time span from 2001 to 2014, X is the meteorological variable, a denotes the intercept, and b is the trend coefficient. It was first completed for temperature data and subsequent for precipitation data. Table-2 presents the findings.

The findings of the study indicate that, over the time chosen in Mardan, the temperature has risen by approximately 0.15 degrees per year, and the amount of rainfall has fallen by approximately -1.4 mm per year; in Charsadda, the changes have been 0.1 degrees per year and -0.9 mm of rain. These values will be utilised for contrasting various factors and their interdependencies.

Table-2: Estimated variations in September temperatures and precipitation from 2001 to 2014

	Mardan		Charsadda	
	Mean Temp in °C	Precipitation in mm	Average Temperature in °C	The amount of precipitation in millimetres
Annualised Change Determined	0.1527	-1.454	0.1033	-0.9154
Total Modification over the Course of the Duration	2.1378	-20.536	1.4462	-12.8156

3.4. Impacts of temperature and precipitation on sowing dates

The mean temperature for every week of September from 2001 to 2014 is provided in Tables-3 and 4. The September data for each year is split into four weeks, and the mean temperature for each week is compared to the week before it. The first week and the next two have witnessed much higher temperatures, while the last week is going by very swiftly and the temperature is rising rapidly. The difference in temperature between the first and fourth weeks was higher in the early years of the selected period i.e. 33°C in the first week and 25°C in the fourth.

However, the temperature difference has decreased over the past few years; it was 32°C during the first week and 30°C during the last. This demonstrates that the last two weeks of September in recent years have been getting warmer, and the temperature differential that was ideal for gourd germination in its early stages is becoming less noticeable and, hence, less beneficial. September data, which was taken from the annual data, indicated that, from 2000 to 2005, the temperature between September 5 and September 15 was approximately 29.4°C. However, the same temperature levels were recorded during the third week of the final interval, which corresponds to 2010 to 2014. Farmers postponed sowing the gourd crop until the second or fourth week of September due to the temperature shift and decreased precipitation, as seen in Tables-3 and Table-4 for Mardan and Charsadda, respectively.

Table-3: Weekly change in temperature

Days/Weeks	Week1 (Mean Temp. in °C)	Week2 (Mean Temp. in °C)	Week3 (Mean Temp. in °C)	Week4 (Mean Temp. in °C)
Sep-00	33.4	32	31	25.8
Sep-01	27.8	28	25.1	27.7
Sep-02	25.4	26.1	27.6	26.2
Sep-03	28.8	27.9	28.8	23.5
Sep-04	32.1	33.3	32.4	28.7
Sep-05	35.2	29.4	28.1	27.4
Sep-06	25.4	28.5	27	26.3
Sep-07	31.4	29.5	31.4	26.4
Sep-08	32	26	29.4	29.3
Sep-09	26.1	28	28.5	30.9
Sep-10	28.6	28.1	26.5	25.2
Sep-11	28.2	28.3	27.6	26.7
Sep-12	29.1	28.2	29.7	27.9
Sep-13	30.7	31.8	30	30.5
Sep-14	32	30.9	29.4	30

Table-4: Weekly temperature

Days/week	Week1 (Mean Temp. in °C)	Week2 (Mean Temp. in °C)	Week3 (Mean Temp. in °C)	Week4 (Mean Temp. in °C)
Sep-01	31	29	28	24
Sep-02	30	27	26	25
Sep-03	31	28	25	22
Sep-04	31	30	30	27
Sep-05	34	32	27	26
Sep-06	32	29	28	25
Sep-07	30	28	27	24
Sep-08	32	28	28	25
Sep-09	31	27	26	25
Sep-10	27	26	26	24
Sep-11	29	26	25	26
Sep-12	33	29	27	27
Sep-13	32	29	28	28
Sep-14	35	31	30	29

3.5. Temperature and humidity affect the rate of insects

An infestation of pests is dependent on meteorological factors. When temperatures are high and rainfall is little, pests prey on crops. Rainfall causes obstacles in the path of pests, as Table-5 for Mardan and Table-6 for Charsadda illustrates.

Table-5: Temperature, precipitation, and pest prevalence for Mardan

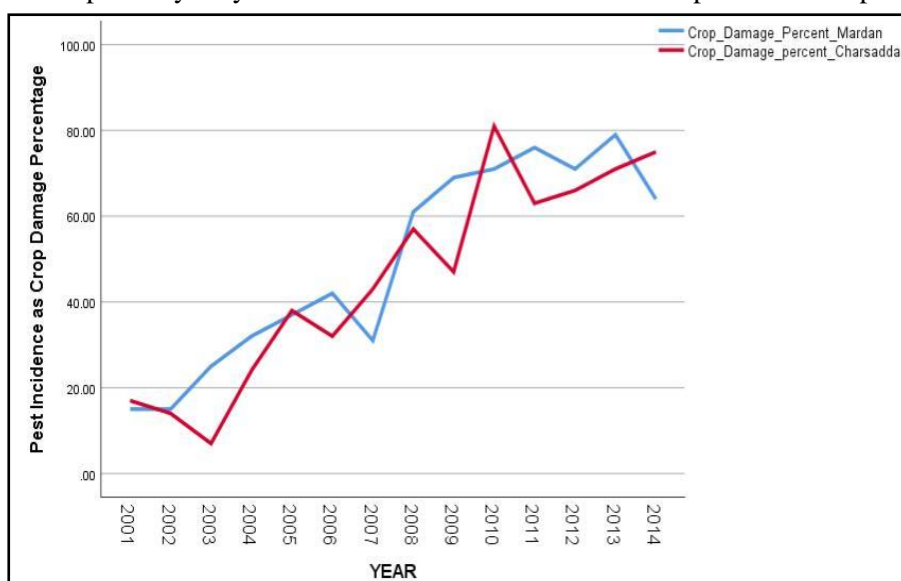
Year	Mean Temperature in °C (Sep-Dec)	Mean value of Rain in mm (Sep-Dec)	Pest Attack (% of crop)
2000	27.6	25.9	11
2001	27.9	14.0	15
2002	26.8	17.0	15
2003	27.5	60.5	25
2004	27.5	30.0	32
2005	28.0	23.0	37
2006	27.2	49.7	42
2007	28.0	26.3	31
2008	28.9	31.0	61
2009	28.4	13.7	69
2010	28.1	2.5	71
2011	27.6	30.7	76
2012	26.9	24.3	71
2013	27.4	22.0	79
2014	27.2	22.3	64

The comparison between the annual rise in crop damage and the mean temperature change over the course of the germination period for Mardan and Charsadda is shown in Figure 8. The crop damage is direct measure of pests attacking the crops. Crop damage is a clear indicator of pest activity against the crops. The larger damage the crop has received implies a higher number of insect attacks. This comparison provides no useful information regarding how temperature affects the frequency of pests.

Table-6: Temperature, precipitation, and pest prevalence for Charsadda

Year	Average temperature in °C (Sep-Dec)	Average rainfall (mm) from (Sep to Dec)	Pest Attack (% of crop)
2001	30.0	53.8	17
2002	29.0	13.8	14
2003	29.0	26.5	7
2004	28.0	40.6	24
2005	31.0	30.5	38
2006	30.0	11.0	32
2007	31.0	34.8	43
2008	32.0	3.3	57
2009	31.0	27.8	47
2010	30.0	79.4	81
2011	30.5	13.1	63
2012	32.0	17.8	66
2013	33.0	14.3	71
2014	34.0	16.8	75

Figure 8: The impact of yearly climate and rainfall variations on the prevalence of pests



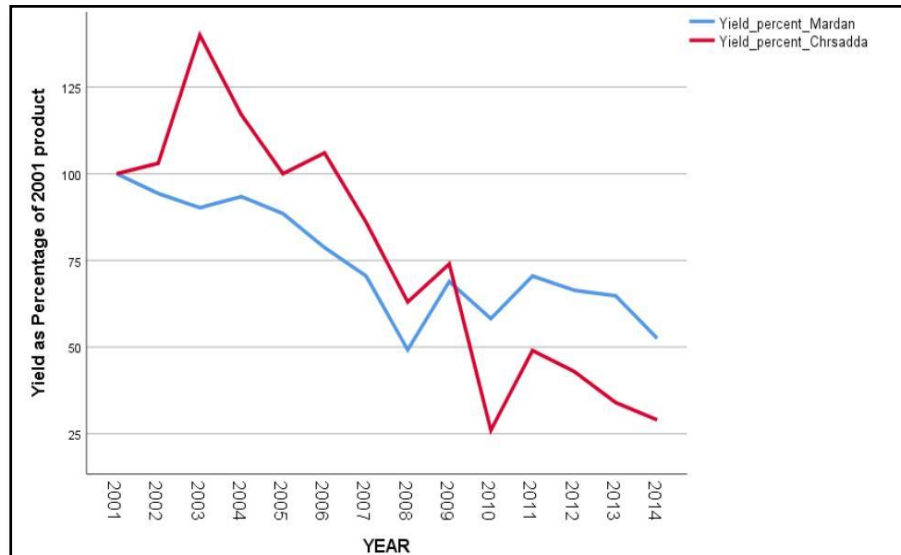
If one pays close attention, the annual changes in the mean temperature, the amount of rainfall during the germination period, and the amount of pest attacks on crops can be used to approximate the increase in pest activity in conjunction with a decrease in rainfall. However, the temperature change is too little to be meaningful. More specifically, the association between pest damage and temperature and between pest damage and rainfall indicates that a large rise in insect attacks coincides with a decline in precipitation.

3.6. Rain and temperature effects on output

Figure 9 illustrates that temperature and precipitation variations shorten the period crops have for germination, which results in decreased crop output. The fluctuations in temperature and

precipitation also encourage the proliferation of pests that prey on crops. Another element that inhibits or halts the development of plants and causes dwarf crops is frost. The contrast provides a general understanding of how yield decreases with temperature. This also makes it abundantly evident that a decrease in rainfall causes a yield to decline.

Figure 9: The effect of yearly climate and rainfall variations on productivity



4. Conclusion

From the study results, it is concluded that the ongoing changes in the climate are impacting the agriculture industry. The farmers in both regions are conscious of how the changing environment is impacting their farming operations. The gourd harvests are not greatly saved by the methods of delaying sowing dates in response to temperature and precipitation patterns. Conversely, white fly is the primary pest causing damage to the gourd crop. White fly resilience to climate change appears to grow since they continue to target crops even after they have been delayed in seeding. This results in viral infections that harm both the surrounding crops and the entire gourd output. Farmers are spending millions of dollars on new hybrid seeds and pesticides to save their crops. According to a past climatic events evaluation, the yield of the gourd crop is significantly impacted by changes in climatic variables. Variations in temperature and precipitation cause pests to have a greater probability of surviving, which damages crops over an extended period of time. This results in a decrease in gourd production. Untimely rainfall causes the soil's humidity to rise, hastening the decaying process and harming the crops. Moreover, integrated pest management programs should be implemented to manage gourd pests.

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