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The Effects of Growing Conditions on Mustard Varietal Development and Yield in The Gwalior District: An Evaluation

[1]Gayatri Sagar and [2]Dr. Vikas Kumar

[1]Research Scholar, Vikrant University, Gwalior, Madhya Pradesh, India
[2]Professor, Vikrant University, Gwalior, Madhya Pradesh, India

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Corresponding Author: Gayatri Sagar

Abstract

Climate change is significantly impacting various aspects of life, particularly in developing countries like India, where it affects livelihoods, food security, health, and economic prospects. A recent study investigated how different heat regimes influence the agricultural yield of specific crops. Researchers measured the total number of seed pods (siliquae) from different plots and calculated averages, while also assessing seed counts from selected siliquae to gauge productivity. After harvesting, crops were threshed and cleaned, with stover yield recorded and converted for analysis. Findings indicated that heat regimes had a notable effect on both the length and quantity of siliquae produced per plant, as well as on stover yield. The results emphasize the vital connection between climate conditions and agricultural productivity, highlighting the pressing need for adaptive farming strategies. Notably, crops sown on October 31 yielded better than those sown later, likely due to reduced exposure to abiotic stressors, which enhanced branching, dry matter production, and overall yield at maturity.

Keywords: Growing, mustard, yield, development and agricultural

Introduction

The actual threats that climate change and unpredictability pose to agricultural production and the safety of food supplies. The irregular patterns of rainfall and the severe weather events are having a significant impact on the agricultural crops. The climate change is one of the most challenging and diverse issues that is influencing the growth of agriculture on a worldwide scale. The effects of climate change are having a severe impact on people's capacity to earn a livelihood, the availability of food, people's health, economic opportunities, and even the very life of humankind, especially in developing countries such as India. It is anticipated that as a consequence of global warming, there will be a significant increase in the frequency of rainless weather that is warm.

The fluctuation and change of the climate are issues that humans are concerned about. As a result of the frequent droughts and floods, the livelihoods of billions of people who are dependent on land for the majority of their requirements are in grave danger. The economy of the whole world is being severely affected on a regular basis as a result of extreme events such as droughts and floods, cold and heat waves, forest fires, landslides, and other similar occurrences. Even though they are not tied to meteorological catastrophes, natural disasters such as earthquakes, tsunamis, and volcanic eruptions have the potential to alter the chemical composition of the atmosphere due to their impact. This, in turn, will result in calamities that are tied to the weather.

Mustard (*Brassica juncea* L.), commonly known as Indian mustard or rai, is one of the most important oilseed crops grown during the Rabi season in India. It holds a significant place in the agricultural economy due to its multifaceted uses. The crop is primarily cultivated for its seeds, which contain 38-42% oil, making it an excellent source of edible oil. Mustard oil is widely consumed in Indian households, particularly in northern and eastern states, for cooking and pickling purposes. In addition to oil, by-products such as oilcake are used as protein-rich cattle feed, while the green plants serve as nutritious fodder for livestock. Beyond its economic value, mustard contributes substantially to crop diversification, sustainability, and food security. Its short duration, adaptability to diverse climatic conditions, and drought tolerance make it an ideal crop for both irrigated and rain fed farming systems. India ranks among the leading producers of mustard in the world. the crop is cultivated on about 6.5-7.0 million hectares, producing 9.5-10.0 million tons, with an average productivity of 1300-1400 kg/ha. Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, and Gujarat are the dominant mustard-growing states.

Rajasthan alone contributes more than 40% of the total national production. Madhya Pradesh, with approximately 8.0 lakh hectares under mustard, records productivity levels ranging from 1200 to 1300 kg/ha. Within Madhya Pradesh, the Gwalior region, located in the Gird agro-climatic zone, is a major mustard belt where the crop is generally grown under conserved soil moisture conditions or with limited irrigation facilities. Among the various factors that determine mustard productivity, sowing time is regarded as one of the most critical non-monetary inputs. The choice of sowing time directly influences crop duration, growth pattern, and exposure to temperature at sensitive growth stages, and ultimately yields and oil quality. Early sowing often results in prolonged vegetative growth, delayed flowering, and higher susceptibility to frost injury during the reproductive stage.

Literature Review

The ecosystems of our planet, human communities, and our general welfare are all in grave danger from the effects of climate change, which is rapidly becoming a worldwide problem. Changing weather patterns and average temperatures over extended periods of time are known as climate change (UN) Climate change is real, and it has been driven mostly by human activity, as 2023 has demonstrated all too plainly. Global warming is the driving force behind climate change, which in turn has caused glaciers to melt, sea levels to rise, weather patterns to become more unpredictable, and temperature trends to climb over the next century. This study article aims to do two primary things: first, assess the effects of climate change on agricultural output throughout India, and second, investigate the many factors that have contributed to this phenomenon. All of the data included in the research came from secondary sources. Verma, R, 2001 [1].

The effects of climate change on agricultural output are severe, threatening not just the stability of economies throughout the world but also the very survival of those living in rural areas. In this chapter, we look at the interplay between climate change and farming, specifically at how changes in temperature regimes, changes in precipitation patterns, and more frequent severe weather events have struck. The quality of crops is negatively affected, and agricultural yields are decreased, as a result of these climate changes. The spread of pests, illnesses, and alien species is already a major problem in agriculture, and climate change is making it worse. These problems are made worse by indirect consequences such soil erosion, less water available, and changed nutrient cycles; thus, it is necessary to know all the weak spots in agricultural systems. Due to their low adaptation capability, resource-poor communities and small-land holding farmers are especially at risk from the climate change consequences, which vary greatly between areas and agricultural systems. Yadav R, 2019 [2].

A number of industries, including farming, are facing serious threats from the worldwide phenomena known as climate change. Agricultural systems and food production are deeply affected by the extraordinary changes in Earth's climate caused by human activity. Climate change is altering precipitation patterns, increasing the frequency of severe weather events, and warming the planet, all of which threaten food security throughout the world. Here, we'll examine how shifting weather patterns are influencing farming, specifically how it's influencing crop yields, food security, and farmers' ability to make a living. To guarantee sustainable food production in the face of a changing climate, we will investigate the unique difficulties brought about by climate change, the susceptibilities of agricultural systems, and the steps that must be taken to strengthen resilience. A better understanding of the complexities of climate change and its effects on farming can help raise awareness, influence policy shifts, and spread best practices that strengthen agricultural systems for the future. We can overcome the obstacles caused by climate change and ensure that agriculture continues to prosper in the face of these changes if we work together and think creatively. Sjoberg, G, 1960 [3].

By surveying 10 randomly chosen villages in the Panna district of the Bundelkhand area, we aimed to gauge farmers' views on climate change and its effects on farming and related industries. Results showed that Panna district farmers are aware of the far-reaching effects of climate change on farming and other industries, and they have a good grasp of how these effects will play out in the future. Farmers everywhere have felt the effects of the altered weather patterns, onset and withdrawal monsoon rain, wind, and dust storms, as well as the rise in unusually severe weather events. Poll takers in Panna noticed changes in crop phenology, such as variations in blooming time and intensity, fruit-bearing pattern, and grain form, size, and quality. There was concern that livestock production may be negatively impacted by climate change. Finally, it seems that the farmers in the Panna area of Bundelkhand have a very clear idea of how climate change would affect their farming. They are mentally prepared to adapt to climate change. Trenberth, KE, 2011 [4].

In light of the anticipated effects of climate change, this research looked at how soybean farmers see the phenomenon and how they plan to adapt to it. In the districts of Diwas, Indore, and Dhar in Madhya Pradesh's Malwa plateau and Nimar valley, 280 rural farmers were chosen using a multi-stage selection procedure. Over time, crop variety is lost and soybean monoculture became widespread in the research region, according to the data. It was discovered that the area's cropping intensity was significantly enhanced once the soybean was introduced. The majority of farmers reported experiencing abiotic weather-related pressures such as a delayed monsoon, unpredictable rainfall, fewer wet days, higher temperatures, more sunny hours, and lower humidity. The yearly rainfall was seen by most farmers as decreasing. As time went on, they also saw an uptick in biotic stressors, such as weeds, insects, and illnesses. Low yields were caused by all of these causes. Research also showed that automation rose sharply, and shorter-lived soybean cultivars mostly supplanted their longer-lived counterparts. Patel, N, 2017 [5].

Research Methodology
Yield attributes
Number of siliquae per plant

When the harvest was complete, the total number of siliquae of the sample plants from each plot was tallied, and the average was determined. It was determined that the number of siliquae on the main, secondary, and tertiary branches were each tallied independently. It was possible to determine the total number of siliquae on each plant by adding up the number of siliquae on the various types of branches at the plant.

Length of siliquae (cm)

Within each plot of the experimental field, ten siliquae were chosen at random for the selection process. Following the measurement of the length from the base to the beak, an average was calculated.

Number of seeds per siliqua

During the harvest, the quantity of seeds produced by each siliqua was counted by counting the number of seeds produced by ten siliqua that were chosen at random from three sample plants in each plot.

Yield
Grain yield (q/ha)

It was determined that the net plot area of each individual plot was harvested, and the product was then sun dried. On the basis of the net plot, the crop was threshed and cleaned individually after it had been dried thoroughly. Following the recording of the final weight in kilograms per net plot, the weight was ultimately converted into q/ha.

Stover yield (q/ha)

To get the overall yield, the seed yield was subtracted from the total amount of product that was harvested from the net plot. The yield of stover was measured in kilograms per net plot area and then translated into quarts per hectare.

Biological yield (q/ha)

Following maturity, the sections of the plant that were above the ground were taken from each plot. These parts were then weighted to indicate the biological yield, which was then represented in q/ha.

Harvest index (%)

In order to determine the harvest index, the following formula was utilized: the harvest index is the ratio of the grain yield to the biological yield:

$$\text{Harvest indest } (\%) = (\text{Grain yield}) / (\text{Biological yield}) \times 100$$

Data Analysis
Length of siliqua (cm)

The length of siliqua, measured in centimetres, is shown in Table 1, which includes information on the relationship between environmental conditions and variety. In light of the data that was collected, it was discovered that the heat regimes had a significant influence on the length of the siliquae or plant. When the crop was planted on October 31st, the maximum length of siliqua was measured to be 8.0. This was a significant improvement over the growth circumstances that were present on November 10th and November 20th by a significant margin. The crop was sowed at the temperature regime on November 20th, and the amount of siliqua that was reported was the shortest possible length. These findings are consistent with those found by Singh *et al*. (2014) [6].

There were considerable differences across the variants in terms of the length of the siliqua. According to Singh *et al*. (2008) [7], the Varuna variation has the longest siliqua length (8.07), followed by the NDR-8501 variety (7.7) and the Bio-902 diversity (6.9).

Table 1: Statistical Analysis of Varieties and Sowing Dates at the Plant Level

Treatments	No. of siliquae/plant	Length of siliqua (cm)	No. of seeds/siliqua	Test weight (g)
Thermal regimes (3)				
31st Oct (D)/(23.5 °C)	281.5	8.0	16.8	4.5
10th Nov (D)/(23 °C)	270.5	7.7	14.9	4.3
20th Nov (D)/(21 °C)	242.4	6.9	13.8	4.2
S.Em ±	4.49	0.13	0.28	0.07
CD at 5% Varieties (3)	13.10	0.38	0.82	NS
Bio-902 (V_1)	232.9	6.8	14.1	3.7
NDR-8501 (V_2)	268.0	7.7	15.4	4.4
Varuna (V_3)	293.6	8.0	16.0	4.8
S.Em ±	4.49	0.13	0.28	0.07
CD at 5%	13.10	0.38	0.82	0.22

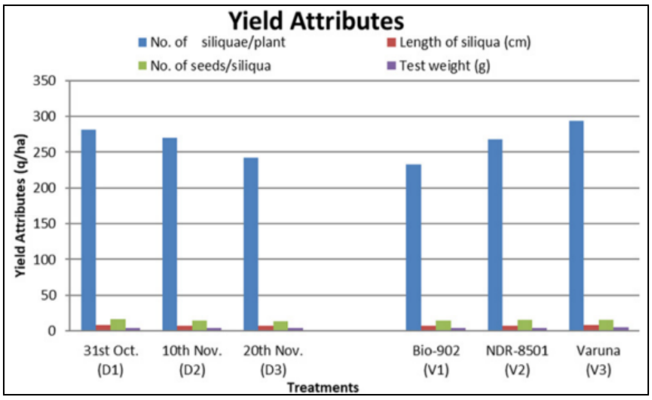

Fig 1: Yield characteristics of mustard influenced by temperature conditions and varieties

The timing of planting and the type of mustard had a major impact on the yield characteristics of the crop. Sowing the seeds earlier (on October 31) resulted in a greater number of siliquae per plant, seeds per siliqua, siliqua length, and test weight (Table 2), which is indicative of improved reproductive efficiency. When these plant-level characteristics were converted into field yield, the predicted yields decreased from 1,540 kg/ha in early sowing to 1,260 kg/ha in late sowing, indicating an 18.2% decrease as a result of delayed planting. Stress from heat during blooming and decreased reproductive efficiency due to late seeding were also factors that contributed to this loss of yield.

Yield Performance of Bio-902 Mustard Variety Pusa Jai Kisan: The given research assesses the yielding of the mustard species Bio-902 (Pusa Jai Kisan) in the altered climatic conditions in Gwalior District. Bio-902 is a high-yielding type of mustard that was developed between 1990 and 1993 with the use of somaclonal variation tissue culture technique wherein Varuna (Type-59) was the starting variety. Genetic enhancement by this approach has led to high yield potential and adaptability of the variety in semi-arid agro climatic conditions.

The secondary data sources were used to examine the performance of Bio-902 with regard to yield in the year of operation and the mean annual temperature and rainfall. An analysis of climatic trends done previously using non-parametric Mann-Kendall (M-K) statistical rank test showed that there was a statistically significant increasing tendency in the temperature, but not in the rainfall. The climatic trends are the foundation of the interpreting of yield behaviour of Bio-902.

Table 2: Mustard Variety Bio-902 (Pusa Jai Kisan) Performance under Varying Climatic Conditions (2015 to 2024) Yield.

Year	Mean Annual Temperature (°C)	Annual Rainfall (mm)	Mustard Yield (kg/ha)	Yield Deviation (%)
2015	26.8	825	1420	+4.4
2016	27.0	790	1390	+2.2
2017	27.2	860	1445	+6.3
2018	27.4	810	1375	+1.1
2019	27.6	780	1330	−2.2
2020	27.8	740	1290	−5.1
2021	28.0	805	1345	−1.1
2022	28.2	770	1285	−5.5
2023	28.4	750	1260	−7.3
2024	28.6	735	1245	−8.4
Mean (2015–2024)	27.7	786.5	1359	—

***Source*:** Compiled from secondary data published by the Directorate of Economics and Statistics (DES), Government of Madhya Pradesh, and the Indian Meteorological Department (IMD).

Table 3 indicates that there are significant changes in the amount of yield produced by mustard variety Bio-902 over the year even though it has great genetic yield potential. The average temperature and precipitation in the study area in both years were 27.7 ºC and 786.5 mm, respectively. It can be observed that the yield has been gradually decreasing since the year 2019, which is accompanied by rising temperatures and relatively low precipitation. Negative yield deviation was noted in years that had above-average temperatures, thus showing the negative effect of climatic stress at the most important stages of growth like flowering and siliqua development.

Table 3: Impact of Climatic Stress Factors on Yield Reduction of Mustard (Bio-902).

Stress Factor	Yield Reduction (%)	Relative Contribution (%)
Heat Stress	12.1	≈ 66
Moisture Stress	6.1	≈ 34
Total Yield Reduction	18.2	100

The analysis of the contribution of stress shows that the heat stress is the major contributor with almost two-thirds of the total yield decrease in mustard variety Bio-902. In spite of the fact that moisture stress also leads to loss in yield, the impact is relatively less. This is a clear indicator that increase in temperature, which was the most important parameter in the analysis using the non-parametric Mann-Kendall test is more of a limiting factor than variability in rainfall in the study area in order to control the amount of mustard produced.

The joint analysis of the yield performance and stress contribution indicates that as much as it is a genetically enhanced variety which is developed using somaclonal variation, the Bio-902 is becoming more susceptible to climatic stress especially rising temperature. The statistically significant warming effect estimated with the help of the Mann-Kendall analysis is one of the strong empirical pieces of evidence of the prevalence of the heat stress found in simulation outcomes in crop. This is an important discovery, as there are no genetic improvements that might be adequate to neutralize the negative effects of climate change unless there are appropriate climate resilient management practices.

Yield Attributes

Number of siliquae/plants

As a function of the heat regimes and the variety. After doing an analysis of the data, it was discovered that the heat regime had a significant influence on the total number of siliquae produced by each plant. A larger number of siliquae per plant (281.6) was found when the crop was sowed on the 31st of October. This was a significant improvement over the growth circumstances that were seen on the 10th and 20th of November. The number of siliquae and plants that were reported to have been planted on November 20th was the lowest of any time period. According to Singh *et al.* (2014) [6], the findings are consistent with their findings.

The varied kinds had a substantial impact on the total number of siliquae and plants growing. It was found that the Varuna variety had the highest number of siliquae per plant (293.6), followed by the NDR-8501 variety (268.03), and finally Bio-902 showed the highest number (232.9). Based on these data, Singh *et al.* (2008) [7] are in accord with their findings.

Table 4: Attributes of Mustard Yield Based on the Date of Sowing

Sowing Date	Siliquae/plant	Seeds/siliqua	Estimated Yield (kg/ha)
31 Oct	165	16.9	1,540
10 Nov	148	15.2	1,410
20 Nov	129	13.8	1,260

According to the information shown in Table 4, the date of planting had a significant impact on the characteristics of mustard production. The mustard that was planted on October 31 generated the largest number of seeds per siliqua (16.9) and the highest number of siliquae (165) per plant, which led to the highest projected yield amounting to 1,540 kg per hectare. These reproductive characteristics were gradually lowered as a result of delaying planting until the 10th and 20th of November. The number of siliquae per plant decreased to 148 and 129, the number of seeds per siliqua decreased to 15.2 and 13.8, and the estimated yields decreased to 1,410 and 1,260 kg/ha, respectively.

This trend indicates a decrease in yield of 18.2% from early sowing (31 October) to late sowing (20 November), as well as a similar decrease in seed number per siliqua of 18.3%. This suggests that delayed planting has a detrimental impact on both the quantity of reproductive structures and the efficiency with which seeds are set. The decline is most likely the result of heat stress during blooming and pod development, which may lead to a reduction in the effectiveness of pollination, fertilization, and seed filling.

Yield

Grain yield (q/ha)

The results on grain yield (q/ha) as a function of many different heat regimes and varieties are shown in Table 5 and Figure 2, respectively. After doing an analysis of the data, it was discovered that the thermal regimes had a significant impact on the grain yield. The greatest grain yield of 20.7 q/ha was recorded for the crop that was sown on the 31st of October. This was much greater than the growth conditions that were seen on the 10th and 20th of November. The lowest possible grain yield of 16.2 ounces per hectare was achieved by the use of the 20th November Thermal regime for planting. Lalu *et al.* (2010) [8], Kumari *et al.* (2012) [9], and Panda *et al.* (2004) [10] are the relevant references.

Several cultivars have a significant influence on the amount of grain produced per hectare (q/ha). After Varuna, which generated the greatest grain yield (20.6 q/ha), NDR-8501 (19.5 q/ha) and Bio-902 (16.1 q/ha) were the next three top producer of grain. When planting was done too early or too late, all of the growth and yield factors that impacted the grain yield of mustard crop were adversely influenced, which may have resulted in poor growth and photosynthetic translocation from source to sink, resulting in a lower yield. In Singh 2008, *et al.* [7] published findings that were comparable to these.

Table 5: Yield of mustard as affected by thermal regimes and varieties.

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
Thermal regimes (3)				
31st Oct (D1)/(23.5 ºC)	20.7	72.2	93.0	22.3
10th Nov (D2)/(23 ºC)	19.3	67.6	86.9	22.1
20th Nov (D3)/(21 ºC)	16.2	58.7	74.9	21.6
SEm ±	0.35	1.18	1.47	0.37
CD at 5% Varieties (3)	0.97	3.46	4.31	1.1
Bio-902 (V1)	16.1	57.3	73.5	22.3
NDR-8501 (V2)	19.5	68.9	88.5	22.0
Varuna (V3)	20.6	72.3	92.9	21.2
SEm ±	0.36	1.18	1.47	0.4
CD at 5%	0.98	3.46	4.31	1.10

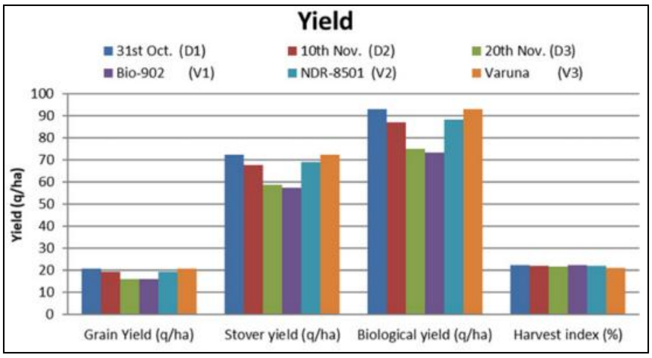

Fig 2: The yield of mustard, as influenced by different cultivars and different thermal

Conclusion

The research conducted in the Gwalior District highlights the significant impact of climate variability on agricultural production, specifically focusing on wheat and mustard crops, which are vital to the local economy. The findings indicate a concerning trend of decreasing wheat yields as projected by the CERES-Wheat model under future climate scenarios. The study emphasizes the importance of planting timing, revealing that seeding on October 31st resulted in higher yields compared to later dates, likely due to reduced exposure to abiotic stressors. This optimal timing facilitated better growth characteristics, including an increased number of branches and enhanced yield-contributing traits. The methodology employed, which included measuring the total number of seed pods and assessing seed counts, provided a comprehensive understanding of crop productivity. Furthermore, the analysis revealed that heat regimes significantly influenced the number of siliquae produced per plant, underscoring the intricate relationship between climate factors and agricultural output. Overall, these findings underscore the need for adaptive agricultural practices and strategies to mitigate the adverse effects of climate change on crop production in the region, ensuring food security and economic stability for the farming community.

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