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# Agro-climatic response and recent trends of Rapeseed and Mustard crop in Amritsar district of Punjab, India

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**ABSTRACT**

From 2004-05 to 2018-19, the total amount of oilseed crops grown around the world went up by 51%. This shows that there is a lot of demand. The weather, like how much rain, wind, light, and temperature there is, as well as droughts and floods, all affect farming. This research investigates the cultivation of rapeseed and mustard in Amritsar, Punjab, concentrating on area, production, and productivity. Rapeseed and mustard showed the least amount of yield volatility among Indian oilseed crops from 2004-05 to 2018-19, even though productivity went down. The research examined the influence of agro-climatic conditions on yield variations in the Amritsar district. The minimum temperature was more closely linked to yield than the maximum temperature was. On the other hand, the rain had a bad effect. A linear regression equation was made based on these results. From October to March, Amritsar has stable agro-climatic conditions, which makes rapeseed and mustard good crops because they don't have as much yield instability. Rapeseed and mustard are important crops to study and improve because of the agro-climatic conditions in Amritsar. The research indicates that the acreage and yield of rapeseed and mustard crops have increased in the Amritsar district recently. It is determined that rapeseed and mustard are suitable crops in District Amritsar to promote agricultural diversification.

***Keywords:*** Oilseeds, rapeseed mustard, agro-climate, Amritsar, yield instability

## INTRODUCTION

Mustard and rapeseed are two of the most important oilseed crops in the world's agricultural landscape, and they significantly contribute to food security, nutrition, and the economy. They are the third most important oilseed crop in the world, behind oil palms and soybeans (Bhatt *et al.*, 2024; Singh and Kaur, 2022). Together, these crops occupy about 26.09 million hectares of farmed land and produce 46.84 million tonnes of oilseed globally (Sarada *et al.*, 2021). Their extensive production demonstrates their worth as an edible oil source as well as an essential part of resilient and varied farming systems. Mustard-rapeseed is a vital source of good fats like omega-3 and omega-6 fatty acids and is a significant player in the edible oil supply chain worldwide. While the nutrient-rich oilcake is a great protein supplement for dairy and cattle production, the oil is widely used for industrial applications, food processing, and cooking. When incorporated into crop rotations, these crops also promote ecological sustainability by strengthening organic matter, increasing soil structure, and disrupting pest-disease cycles (Mishra *et al.*, 2015; Bhardwaj *et al.*, 2021). India is the third-largest producer of rapeseed-mustard, behind China and Canada. In the nation, the crop is cultivated on approximately 8.81 million hectares, producing about 12.49 million tonnes yearly (Joseph and Karunakaran, 2022). Mustard is vital for rural livelihoods in addition to being a major source of edible oil, particularly in arid and semi-arid regions where few other oilseed crops are as successful (Thind and Dhillon, 2021). It is a reliable rabi-season

crop that boosts farm earnings and fortifies the nation's edible oil self-reliance due to its short duration, low water requirements, and compatibility for a variety of soil types.

Despite its importance, the industry had a sharp drop in productivity from 2004-05 to 2018-19, which raised questions about whether agricultural growth can be sustained over the long run. This decline in yield emphasises how urgently production limitations such the limited use of high-yielding cultivars, inadequate fertiliser and water management, biotic pressures, and climatic challenges must be addressed (Malik *et al.*, 2022; Devi *et al.*, 2023). Reviving the rapeseed–mustard industry requires advancing climate-resilient technology, implementing better agronomic practices, and bolstering research. Improving the performance of rapeseed and mustard is essential for safeguarding farmer livelihoods, promoting sustainable agriculture, enhancing soil health, supporting livestock nutrition, and increasing the availability of edible oil (Glantz *et al.*, 2009). Therefore, achieving long-term agricultural productivity, environmental sustainability, and national food and nutritional security requires improving rapeseed-mustard production systems.

## MATERIALS AND METHODS

To assess the impact of agro-climatic conditions on the yield performance of rapeseed–mustard in India, a thorough and in-depth analysis of numerous research publications was conducted. This comprehensive literature analysis provided insightful information about the complex interactions that regulate rapeseed-mustard growth in a range of environmental settings, as well as a clearer understanding of the relationship between significant climatic parameters and crop productivity. The review was able to provide a solid interpretation of how temperature variations, fluctuating rainfall patterns, and soil properties all work together to influence the production potential of this significant oilseed crop across various agro-ecological zones by combining the results of several reliable studies.

An extensive analysis of cropping patterns, cultivated land area, productivity trends, and total production figures of important crops in Punjab's Amritsar district were also part of the inquiry. The analysis's reliance on reliable datasets and respectable institutional and governmental sources ensured accuracy, consistency, and scientific reliability. This trustworthy data base allowed for a thorough evaluation of the environmental elements affecting rapeseed-mustard cultivation, showing how seasonal weather patterns, soil fertility, and regional climates impact the crop's growth trajectory and final yield outcomes.

Additionally, sophisticated statistical techniques including regression and correlation analyses were used to measure the strength of the relationship between particular agro-climatic factors and crop yields. These analytical methods enabled a clearer interpretation of yield-limiting factors and potential production concerns by identifying critical components that have the greatest impacts on productivity. These analyses' findings offered a solid framework for comprehending how changes in soil-related factors, moisture availability, and maximum and minimum temperatures might either improve or impair rapeseed–mustard performance.

By combining these methodological techniques, the study aimed to generate important suggestions for improving the area's rapeseed and mustard production as well as scientific proof. The findings offer helpful guidance for enhancing crop management practices, optimising resource utilisation, and developing flexible strategies to address climate variability. Ultimately, the research ensures higher productivity and long-term agricultural development in Punjab and other similar agroclimatic regions by strengthening the sustainability and resilience of rapeseed-mustard production. This review provides a comprehensive analysis of crop cultivation area and yield changes between 2022-23 and 2023-24. It highlights trends, top-performing crops, and year-over-year percentage changes to support agricultural planning and performance review.

## RESULTS AND DISCUSSION

### Status of Crops and Productivity Determinants

An analysis of long-term trends in area, production, and productivity of major crops indicates that the paddy-wheat rotation has emerged as the dominant cropping system in the Amritsar district (Singh and Kaur, 2015). Over time, both the cultivated area and total output of paddy and wheat have increased substantially, reflecting farmers' growing preference for this system. The assured minimum support price (MSP), stable market access,

and relatively low production risk associated with these crops have made paddy and wheat highly attractive, encouraging farmers to reallocate land from other crops toward this more remunerative rotation. As a result, the area under diversified crops-such as maize, rapeseed–mustard, sugarcane, pulses, oilseeds, and coarse cereals-has declined considerably. This shift has reduced cropping diversity, which traditionally contributed to improved soil health and greater resilience of farming systems. During 2023–24, wheat occupied the largest cropped area (approximately 188.6 thousand ha), followed closely by Basmati rice (about 139.9 thousand ha), together accounting for the majority of the district's cultivated land. Parmal paddy ranked third (around 41.15 thousand ha), while sugarcane and oilseeds occupied relatively small shares (about 6.6 and 2.5 thousand ha, respectively), highlighting a high concentration of land use among a few crops. Crop-wise area dynamics further reveal a strong positive expansion in Basmati rice (+29.4%), indicating a clear shift toward this high-value crop. In contrast, Parmal paddy and pulses recorded sharp declines in cultivated area (–43.6% and –41.4%, respectively), contributing to overall land reallocation away from these crops. Modest area gains were observed for oilseeds (+10%) and sugarcane (+1.3%). Yield trends showed notable productivity losses in pulses and maize (–31.9% and –27.6%), suggesting significant year-to-year production challenges, whereas wheat and sugarcane registered moderate yield improvements (+5.9% and +6.2%). Despite expansion in area, Basmati rice exhibited a slight decline in yield (–5.2%). Notwithstanding the dominance of the paddy–wheat system, rapeseed–mustard cultivation in the district has demonstrated encouraging progress in recent years. Both area and production of these oilseed crops have increased, supported by the adoption of high-yielding and disease-resistant varieties, improved availability of quality seed, enhanced agronomic practices, and more effective extension services. Additionally, rising domestic demand for edible oils has strengthened farmers' interest in rapeseed–mustard as a viable alternative crop, offering potential for diversification within the prevailing cropping system.

Wheat and Basmati dominate area share: Wheat (~188.6 K ha) is the largest, followed by Basmati (~139.9 K ha), together accounting for the vast majority of cropped area. Parmal paddy is a distant third (~41.15K ha); Sugarcane and Oilseeds occupy very small shares (~6.6K and ~2.5 K ha), indicating concentrated area allocation in a few crops (Table 1). Basmati shows the largest positive area growth (+29.4%), while Parmal paddy and Pulses experienced steep declines (-43.6% and -41.4% respectively). Overall area shifts indicate consolidation toward high-value Basmati and modest increases in Oilseeds (+10%) and Sugarcane (+1.3%), suggesting farmer reallocation away from some paddy/pulse area. Pulses and Maize suffered large yield drops (-31.9% and -27.6%), indicating significant productivity issues for these crops year-over-year. Sugarcane and Wheat recorded modest yield gains (+6.2% and +5.9%), while Basmati's yield slightly declined (-5.2%) despite its area expansion.

Table 2 illustrates the seasonal climatic variability during the rabi period (October–March) from 2018–19 to 2023–24. Maximum temperature exhibited an overall increasing trend, rising from 21.42 °C in 2018–19 to a peak of 24.16 °C in 2021–22, followed by slight moderation in the subsequent years. Minimum temperature also showed a steady increase, from 10.81 °C to 11.43 °C, indicating a gradual warming of winter conditions. As a result, mean seasonal temperature increased consistently,

**Table 1.** Crop Area & Yield reported in different crops in Amritsar (2022-23 vs 2023-24)

| Crop | Area 2022-23 (ha) | Yield 2022-23 (q/ha) | Area 2023-24 (ha) | Yield 2023-24 (q/ha) | % Change Area | % Change Yield |
|---|---|---|---|---|---|---|
| Wheat | 189120 | 47.92 | 188570 | 50.75 | -0.29 | 5.91 |
| Parmal paddy | 72948 | 69.84 | 41149 | 70.59 | -43.59 | 1.07 |
| Basmati | 108052 | 51.2 | 139860 | 48.55 | 29.44 | -5.18 |
| Sugarcane | 6537 | 800 | 6623 | 849.94 | 1.32 | 6.24 |
| Maize | 1660 | 45 | 1650 | 32.6 | -0.6 | -27.56 |
| Oilseeds | 2284 | 17.79 | 2512 | 17.44 | 9.98 | -1.97 |
| Pulses | 1000 | 6.2 | 586 | 4.22 | -41.4 | -31.94 |

**Table 2.** Climate Data (Oct–March) from 2018-19 to 2023-24

| Year | Max Temp (°C) | Min Temp (°C) | Mean Temp (°C) | Rainfall (mm) |
|---|---|---|---|---|
| 2018-19 | 21.42 | 10.81 | 16.12 | 128.5 |
| 2019-20 | 22.94 | 10.82 | 16.88 | 39.63 |
| 2020-21 | 23.54 | 11.21 | 17.37 | 131.63 |
| 2021-22 | 24.16 | 11.63 | 17.89 | 42.34 |
| 2022-23 | 23.03 | 11.23 | 17.13 | 75.77 |
| 2023-24 | 23.59 | 11.43 | 17.51 | 79.46 |

reflecting an overall warming trend during the crop-growing season. In contrast, rainfall displayed pronounced inter-annual variability, ranging from a low of 39.63 mm in 2019–20 to more than 130 mm in 2018–19 and 2020–21. Such fluctuations in temperature and precipitation are critical determinants of crop growth, yield stability, and water availability during the rabi season. Against this climatic backdrop, rapeseed–mustard cultivation in Amritsar district has expanded markedly over the last decade. The area under these oilseed crops increased from 217 ha in 2014–15 to 2,512 ha in 2023–24, accompanied by a substantial improvement in productivity from 1,150 to 1,744 kg $ha^{-1}$. This pronounced growth reflects renewed farmer interest in oilseed cultivation and highlights the considerable untapped potential for further expansion of rapeseed–mustard in the district. Importantly, this trend also signals an opportunity to enhance crop diversification, which is essential for sustaining soil fertility, conserving water resources, and improving the long-term resilience of the agricultural production system. To fully capitalize on this emerging opportunity, strengthening research and extension efforts focused on rapeseed–mustard is essential. Priority areas include the development and dissemination of climate-resilient varieties, promotion of efficient water and nutrient management practices, and timely technical support to farmers. Equally important is bridging the existing gaps in the adoption of recommended technologies-such as optimum sowing time, seed treatment, integrated nutrient management, and integrated pest and disease management—to ensure higher and more stable yields. Addressing these constraints will be crucial for reducing Amritsar's heavy dependence on the paddy–wheat cropping system and for promoting sustainable agricultural growth in the region.

**Agro-climatic factors and yield instability**

In order to comprehend how different agro-climatic factors contribute to yield loss and yield instability in rapeseed and mustard crops in the Amritsar area; a thorough examination was conducted using regression analysis and correlation coefficients. With the use of these statistical methods, the relationship between crop performance and climatic variables could be thoroughly examined, assisting in the identification of the precise components that have the most effects on productivity. Lower evening temperatures generally encourage plant growth and enhance seed formation in mustard and rapeseed, according to the data, which showed a **positive correlation of 0.5 between lowest temperature and crop yield**. Compared to the negative correlations found for **rainfall (-0.3)** and **maximum temperature (-0.3)**, this positive connection was significantly stronger. These negative connections imply that excessive rainfall and abnormally high daytime temperatures during crucial crop growth phases may be detrimental, resulting in poor pollination, decreased seed set, and heightened disease susceptibility. A best-fit linear regression equation was created as part of the analytical framework to help clarify how these agro-climatic factors affect crop production. The predicted association between temperature, rainfall, and yield behaviour was better understood. Additionally, the model offers a solid foundation for predicting yield results under various climatic conditions, which is crucial for organising agricultural operations and reducing production risks.

Table 3 depicts the relationship between rapeseed–mustard yield and key climatic variables during the rabi season (October–March) from 2017–18 to 2022–23. Considerable inter-annual variability in yield was observed, with values ranging from 1,511 kg $ha^{-1}$ to a maximum of 1,779 kg $ha^{-1}$. Higher yields were generally recorded in seasons characterized by moderate maximum temperatures and relatively higher minimum temperatures, as evident during 2018–19 and 2022–23. In contrast, years experiencing elevated maximum temperatures or low and erratic rainfall, such as 2019–20 and 2021–22, registered comparatively lower yields.

**Table 3.** Yield and Climatic Variables (Rapeseed & Mustard)

| Year | Yield (kg/ha) | Max Temp (°C) | Min Temp (°C) | Rainfall (mm) |
|---|---|---|---|---|
| 2017-18 | 1511 | 22.7 | 9.4 | 127.4 |
| 2018-19 | 1740 | 21.4 | 10.8 | 128.5 |
| 2019-20 | 1661 | 22.9 | 10.8 | 39.6 |
| 2020-21 | 1550 | 23.5 | 11.2 | 131.6 |
| 2021-22 | 1605 | 24.2 | 11.6 | 42.3 |
| 2022-23 | 1779 | 23 | 11.2 | 75.8 |

Rainfall exhibited wide year-to-year fluctuations, underscoring its strong influence on yield variability in rapeseed–mustard. Despite this variability, the temperature and rainfall patterns indicate that the agro-climatic conditions of Amritsar remain largely stable during the rapeseed–mustard growing period. Compared with the more erratic weather conditions of the summer and monsoon seasons, the rabi months are characterized by fewer temperature extremes and a relatively moderate distribution of rainfall. These stable climatic conditions provide a favourable environment for crop establishment, flowering, and grain filling, thereby minimizing environmental stress during critical growth stages. The predictability of weather during the rabi season plays a key role in maintaining yield stability across years, which in turn enhances farmer confidence and supports regional food and economic security. Collectively, the results clearly demonstrate that rapeseed and mustard are well suited to the agro-climatic conditions of the Amritsar district. The combination of congenial minimum temperatures, limited heat stress, and reasonably consistent seasonal rainfall reduces yield variability and enhances the reliability of these oilseed crops. These findings also highlight substantial scope for further expansion of rapeseed–mustard cultivation through targeted research and development interventions. Strengthening extension services, promoting climate-resilient varieties, and refining agronomic practices can significantly improve productivity. By addressing existing technology adoption gaps and ensuring timely farmer training, advisory support, and input availability, rapeseed and mustard can be positioned as priority crops in future agricultural development strategies, contributing meaningfully to long-term sustainability and economic growth in the district.

## CONCLUSIONS

The study confirms that Amritsar's stable rabi-season climate favors rapeseed–mustard cultivation, with yields closely linked to temperature and rainfall patterns. Expanding these oilseeds through climate-resilient varieties, improved agronomic practices, and strong extension support can enhance diversification, reduce paddy–wheat dependence, and promote long-term agricultural sustainability.

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