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ECONOMICS ANALYSIS OF MUSTARD PRODUCTION IN DISTRICT MIRPURKHAS, SIND 2025

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Abstract
This study analyzed the economic aspects of mustard production in District Mirpurkhas, Sindh. The research aimed to assess the current status of mustard area, production, and yield, identify production practices and challenges faced by farmers, and evaluate the cost-benefit ratio of mustard cultivation. Primary data were collected through a structured questionnaire from 120 randomly selected mustard growers using simple random sampling. The results showed that most farmers were young, had small to medium farm sizes, and faced issues such as high input costs, lack of quality seeds, pest attacks, and unfavorable market prices. The cost of mustard production per acre was calculated as Rs. 62,242, while the average revenue was Rs. 92,215, resulting in a net profit of Rs. 22,973 per acre. The input-output ratio was found to be 1.48, indicating a profitable enterprise. Despite profitability, the mustard growers faced significant challenges that need to be addressed through improved access to quality inputs, technical training, better market facilities, and supportive government policies. The study concluded that enhancing mustard production could play a crucial role in reducing Pakistan's dependency on imported edible oils and improving the livelihood of rural farmers.

INTRODUCTION

Mustard (Brassica spp.) is a vital oilseed crop of global economic significance, ranking third in vegetable oil production after soybean and palm oil. It thrives in cooler climates, has a short growing season, and offers high oil (28–32%) and protein (28–36%) content. In Pakistan, mustard is primarily cultivated during the Rabi season and adapts well to diverse agro-climatic conditions. However, its productivity remains low, averaging 812 kg ha^{-1}, significantly below the global average of 1,560 kg ha^{-1}. Key constraints include suboptimal genotypes, environmental stresses, and pest infestations. Moreover, Pakistan heavily depends on edible oil imports, covering nearly 80% of domestic demand, which substantially burdens foreign exchange reserves. Enhancing mustard production is crucial to reducing this dependency and improving self-sufficiency in edible oil (Abro et al., 2019).

Increasing the cultivation of oilseed crops, particularly mustard, can strengthen local edible oil production and lessen reliance on imports (Tahira et al., 2021).

Despite the development of high-oil-content mustard varieties by research institutions in Pakistan, their full potential remains underutilized due to limited comprehensive research. The performance of different genotypes varies across agro-climatic regions, and their yield potential is inconsistent across different environments (Sher et al., 2019). Genotypic performance in new environments is greatly influenced by factors such as temperature, daylight duration, soil fertility, and water availability (Singh et al., 2019). Mustard production faces several challenges, including climatic factors, soil health issues, pest and disease pressures, and broader environmental concerns such as climate change and biodiversity loss. Addressing these challenges is essential for ensuring the resilience and productivity of mustard crops in a changing climate. Mustard is particularly sensitive to temperature fluctuations, which can affect germination, flowering, and seed development. Extreme temperature variations, including heatwaves and cold spells, may disrupt the growth cycle and reduce overall yields (Fahad et al., 2017). Shifting climate patterns, including variations in temperature and precipitation, directly impact mustard cultivation. To mitigate the effects of climate change, adaptation strategies such as developing climate-resilient varieties are essential (FAO, 2020).

Rapeseed and mustard, both members of the Brassicaceae family, are among the most economically significant oilseed crops worldwide, providing essential sources of edible oil, biofuel, and industrial feedstock's. Consequently, breeding programs are increasingly focused on enhancing oil quality to meet evolving consumer, industrial, and regulatory demands. Various breeding strategies, methodologies, challenges, and future prospects for improving oil quality in rapeseed and mustard have been analyzed. By integrating insights from scientific literature, breeding programs, and industry perspectives, research highlights the complexities, opportunities, and future directions for improving oil quality in these economically valuable oilseed crops. These studies provide guidance for research priorities, strategic decision-making, and the development of enhanced rapeseed and mustard varieties with superior oil quality attributes (Sachan et al., 2024).

Edible oils are essential for human nutrition, providing energy, essential fatty acids, and vital nutrients while playing a crucial role in various physiological functions. Pakistan faces a substantial shortfall in domestic oil production, making it heavily reliant on imports, which has significantly increased import expenses. The growing gap between local production and imports is evident, alongside rising per capita consumption. Strategies to enhance domestic oilseed production, including agricultural land optimization, are explored in research, along with the economic impact of oilseeds in Pakistan. Challenges such as market barriers, seed quality, and inadequate farming equipment are assessed. (Hussain et al., 2023).

Rapeseed (Brassica napus), the world's second most important oilseed crop, is a key focus of breeding research due to its complex polyploid genome. While recent genome sequencing has enhanced genetic understanding, selective breeding for low erucic acid and glucosinolate content has reduced genetic diversity, making its expansion crucial for future advancements. Rapeseed plays a vital role in crop rotations in major growing regions such as Australia, Canada, China, and the European Union, contributing to soil fertility, sustainable agriculture, and farmers' incomes. It significantly supports national economies by producing rapeseed oil and meal, which are widely used in food, animal feed, and fuel. With a high oleic acid (60%) and omega-3 linolenic acid (10%) content, rapeseed oil is valuable for human consumption, while its extraction meal serves as an essential animal feed source. Hybrid breeding, primarily using cytoplasmic male sterility (CMS), has gained prominence due to the heterotic effect, which enhances performance. Future breeding strategies will leverage biotechnological and genomic tools to optimize genetic potential, ensuring higher yield stability and greater industrial value (Friedt et al., 2018).

Mustard is a globally important oilseed crop that provides essential edible oil and industrial raw materials, particularly in regions like South Asia, Europe, and Canada, where it plays a critical role in agricultural economies and food industries. Phenotypic and genotypic selection, molecular markers, transgenic, and genomics-assisted breeding play crucial roles in mustard improvement. The promise of emerging technologies like genome editing and systems biology is discussed for mustard genetic enhancement and climate-resilient varietal development. (Prasanth et al., 2025).

Mustard breeders face substantial challenges in meeting increasing demands for yield and quality traits. In response, genomic approaches have emerged as powerful tools to expedite mustard breeding programs by unraveling the genetic basis of key agronomic traits. Advancements in genomics, including next-generation sequencing technologies, marker-assisted selection (MAS), and genome editing techniques, have significantly contributed to mustard crop improvement. Identifying yield-related genes, quantitative trait loci (QTLs), and markers for efficient trait selection is crucial. Case studies demonstrating the successful integration of genomics into breeding programs are highlighted, along with discussions on regulatory concerns and technical hurdles. Future directions emphasize the potential of genomic approaches to revolutionize mustard breeding, paving the way for sustainable crop improvement (Sunagar & Pandey, 2024) Mustard (*Brassica* spp.) is a vital oilseed crop of global economic significance, ranking third in vegetable oil production after soybean and palm oil. It thrives in cooler climates, has a short growing season, and offers high oil (28–32%) and protein (28–36%) content. In Pakistan, mustard is primarily cultivated during the Rabi season and adapts well to diverse agro-climatic conditions. However, its productivity remains low, averaging 812 kg ha^{-1}, significantly below the global average of 1,560 kg ha^{-1}. Key constraints include suboptimal genotypes, environmental stresses, and pest infestations. Moreover, Pakistan heavily depends on edible oil imports, covering nearly 80% of domestic demand, posing a substantial burden on foreign exchange reserves. Enhancing mustard production is crucial to reducing this dependency and improving self-sufficiency in edible oil. (Abro et al., 2019). Increasing the cultivation of oilseed crops, especially mustard, can strengthen local edible oil production and lessen reliance on imports (Tahira et al., 2021). Despite the development of high-oil-content mustard varieties by research institutions in Pakistan, their full potential remains underutilized due to limited comprehensive research. The performance of different genotypes varies across agro-climatic regions, and their yield potential is not consistent in all environments (Sher et al., 2019) Genotypic performance in new environments is greatly influenced by factors such as temperature, daylight duration, soil fertility, and water availability (Singh et al., 2019). Mustard production faces several challenges, including climatic factors, soil health issues, pest and disease pressures, and broader environmental concerns such as climate change and biodiversity loss. Addressing these challenges is essential for ensuring the resilience and productivity of mustard crops in a changing climate. Mustard is particularly sensitive to temperature fluctuations, which can affect germination, flowering, and seed development. Extreme temperature variations, including heatwaves and cold spells, may disrupt the growth cycle and reduce overall yields (Fahad et al., 2017). Shifting climate patterns, including variations in temperature and precipitation, directly impact mustard cultivation. To mitigate the effects of climate change, adaptation strategies such as developing climate-resilient varieties are essential (FAO, 2020).

Rapeseed and mustard, both members of the Brassicaceae family, are among the most economically significant oilseed crops worldwide, providing essential sources of edible oil, biofuel, and industrial feedstock. Their adaptability to diverse agro-climatic conditions and high oil yield per unit area contribute significantly to global agriculture and food security. The quality of oil derived from these crops is a key factor determining its market value and suitability for various applications, with traits such as fatty acid composition, erucic acid content, glucosinolate content, and tocopherol levels influencing its nutritional properties, flavor, and industrial uses. Consequently, breeding programs are increasingly focused on enhancing oil quality to meet evolving consumer, industrial, and regulatory demands. This review comprehensively analyzes breeding strategies, methodologies, challenges, and future prospects for improving oil quality in rapeseed and mustard, exploring the genetic basis of oil quality traits, the influence of environmental factors and agronomic practices, and the role of molecular breeding and biotechnological interventions in accelerating crop improvement. Additionally, market dynamics, consumer preferences, and regulatory frameworks shaping oil quality breeding initiatives are discussed. By integrating insights from scientific literature, breeding programs, and industry perspectives, this review highlights the complexities, opportunities, and future directions for improving oil quality in these economically valuable oilseed crops, guiding research priorities, informing strategic decision-making, and supporting the development of enhanced rapeseed and mustard varieties with superior oil quality attributes. (Sachan et al., 2024)

Rapeseed (*Brassica napus*), the world's second most important oilseed crop, is a key focus of breeding research due to its complex polyploid genome. While recent genome sequencing has enhanced genetic understanding, selective breeding for low erucic acid and glucosinolate content has reduced genetic diversity, making its expansion crucial for future advancements. Rapeseed plays a vital role in crop rotations in major growing regions such as Australia, Canada, China, and the EU, contributing to soil fertility, sustainable agriculture, and farmers' incomes. It significantly supports national economies through the production of rapeseed oil and meal, which are widely used in food, animal feed, and fuel. With a high oleic acid (60%) and omega-3 linolenic acid (10%) content, rapeseed oil is valuable for human consumption, while its extraction meal serves as an essential animal feed source. Modern breeding efforts focus on improving yield, disease and pest resistance, and quality traits, with genetic resistance becoming increasingly important due to environmental concerns and pesticide bans. Hybrid breeding, primarily using cytoplasmic male sterility (CMS), has gained prominence due to the heterotic effect, which enhances performance. Future breeding strategies will leverage biotechnological and genomic tools to optimize genetic potential, ensuring higher yield stability and greater industrial value (Friedt et al., 2018)

Rapeseed and mustard are important oilseed crops cultivated worldwide for their high oil content and versatile applications in food, feed, and industrial sectors. Various genetic, environmental, and agronomic factors influence the quality of oil derived from these crops. Breeding efforts aimed at improving oil quality traits in rapeseed and mustard have garnered significant attention in recent years due to their impact on market value, nutritional attributes, and industrial utility. In this review, we provide a comprehensive overview of breeding strategies and methodologies employed to enhance oil quality traits in rapeseed and mustard. We explore the genetic basis of oil quality traits, including fatty acid composition, erucic acid content, glucosinolate content, and tocopherol content, and discuss the importance of these traits for different end-uses. Furthermore, we highlight the role of molecular markers, genomics-assisted breeding, and biotechnological approaches in accelerating the breeding process and achieving targeted improvements in oil quality. The review also addresses the challenges and constraints associated with breeding for oil quality in rapeseed and mustard, including genotype-environment interactions, trait stability, and regulatory considerations. Additionally, we discuss emerging trends and future prospects in oil quality breeding, such as genome editing, metabolic engineering, and precision breeding, which offer novel avenues for achieving desired oil quality profiles while addressing sustainability and consumer preferences. Overall, this review underscores the significance of breeding for oil quality in rapeseed and mustard and provides insights into the latest advancements, challenges, and opportunities in this field. By integrating multidisciplinary approaches and harnessing the power of modern breeding tools and technologies, rapeseed and mustard breeders can continue to drive innovation and deliver oilseed crops with enhanced nutritional value, functional properties, and market competitiveness. (Sachan et al., 2024)

Mustard is globally an oilseed crop that provides essential edible oil and industrial raw materials, particularly in regions like South Asia, Europe, and Canada, where it plays a critical role in agricultural economies and food industries. However, worldwide biotic and abiotic stresses pose major challenges to mustard production. Advances in conventional breeding techniques, genetics, and biotechnological tools hold immense potential for developing improved mustard varieties. This review elucidates the evolution of mustard breeding, moving from conventional approaches to advanced molecular tools that allow for precise genetic modifications, enhancing mustard resilience and yield. It highlights the roles of phenotypic and genotypic selection, molecular markers, transgenics, and genomicsassisted breeding in augmenting mustard improvement endeavours. The promise of emerging technologies like genome editing and systems biology is discussed for mustard genetic enhancement and climate-resilient varietal development. The review emphasizes the need of collaboration among research institutions, public-private partnerships, and international networks to accelerate sustainable mustard improvement efforts. (Prasanth et al., 2025) Mustard, a vital oilseed crop, plays a significant role in global agriculture due to its versatile applications in food, feed, and biofuel industries. However, meeting the increasing demands for yield and quality traits poses a substantial challenge to mustard breeders. In response, genomic approaches have emerged as powerful tools to expedite mustard breeding programs by unraveling the genetic basis of key agronomic traits. This review provides a comprehensive overview of genomic strategies aimed at enhancing yield and quality traits in mustard. Beginning with an exploration of traditional breeding methods and their limitations, we delve into the advancements in genomics, including next-generation sequencing technologies, marker-assisted selection (MAS), and genome editing techniques. We discuss how these tools are leveraged to identify yield-related genes, quantitative trait loci (QTLs), and markers for efficient trait selection. Furthermore, we examine genomic approaches for improving oil content, nutritional profiles, and phytochemical composition, crucial for enhancing mustard quality. Case studies demonstrating the successful integration of genomics into breeding programs are highlighted, along with discussions on challenges such as regulatory concerns and technical hurdles. Finally, we outline future directions and the potential of genomic approaches to revolutionize mustard breeding, paving the way for sustainable crop improvement. This study offers valuable insights into the application of genomics in mustard breeding and underscores its importance in addressing the evolving needs of agriculture in the 21st century. (Sunagar & Pandey, 2024) Oilseed crops, which account for a sizeable fraction of the total output, are strongly reliant on the production of edible oil (Msanne et al., 2020). Mostly due to their economic importance, oilseed crops are a lucrative and widely grown commodity worldwide. These crops are primarily grown for their preparation of edible oils, and many oilseeds' meals can be used as a high-protein ingredient in animal, poultry, and fish feed. Due to the rising demand for vegetable oils, animal and poultry feed, drugs, biofuels, and oleochemicals, oilseeds have grown in popularity recently (Adeleke and Babalola, 2020). In Pakistan, cottonseed, rapeseed, mustard, canola, sunflower, and soybean are the main sources of cooking oil. Oilseeds play a vital role in domestic human nutrition, ranking only after grains and sugar crops, and providing 2.5 times the energy of proteins and carbohydrates. Edible oils are a crucial component of the human diet, containing essential fatty acids necessary for healthy growth and development. It is recommended that onethird of daily calories come from fats and oils for a healthy lifestyle. Vegetable oils are derived from plants, with seeds being the primary source of these oils. Oilseed crops are a significant source of animal and human nutrition and industrial products and biodiesel production has been increasing day by day (Ahmed et al., 2021).

Objectives

1. To find out the status of mustard production area and yield in Sindh, Pakistan.
2. To identify the production practices and its problems in the study area.
3. To analyze cost benefit ratio of mustard production in the study area.

REVIEW OF LITERATURE

The district of Mirpurkhas is known for producing some of Pakistan's most renowned mango varieties. Sindhri, a variety native to the region, holds the distinction of being the first variety to ripen during the mango season and commands a premium price in local and international markets (Hassan et al., 2020). Other popular varieties such as Chaunsa and Anwar Ratol are also cultivated in the region, contributing to Mirpurkhas' status as a leading mango producer (Khan et al., 2021). While these varieties are in high demand, the majority of mango growers in the district operate small-scale farms averaging 4.5 hectares (Jatoi et al., 2020). Smallholder growers often face challenges in terms of modern farming techniques and pest control, limiting their overall productivity and income.

(Khan et al.,2023) Research on oilseed crop production in Pakistan highlights the country's heavy dependence on edible oil imports, ranking as the third-largest importer globally after petroleum and machinery. With only 14% of the domestic demand for edible oil being met through local production, a study conducted in Sindh province involving 300 farmers examined the cultivation and marketing challenges of oilseed crops, primarily mustard and sunflower, with mustard being the more dominant crop. The findings revealed that the average cultivated land for oilseeds was 41.82 acres, exceeding the average farm size of 46.76 acres, indicating a high cropping intensity. However, despite the significant cultivated area, the average yields of oilseed crops were lower than those of other major crops, raising concerns among farmers, particularly regarding market price instability. To enhance the profitability of oilseed crops, several recommendations were proposed, including the provision of affordable hybrid seeds, advancements in production technologies, and an increase in crop output. Additionally, the introduction of support pricing for oilseed crops and improved water management practices were suggested as crucial measures for enhancing productivity and profitability. Further suggestions included targeting coastal farmers for the cultivation of non-traditional oilseed crops, ensuring input supply for growing oilseeds on uncultivated lands, and establishing specific cropping zones for oilseed production. These measures aim to address the challenges associated with oilseed farming, improve farmers' economic returns, and reduce Pakistan's reliance on imported edible oils.

(Kaushal et al., 2025) Research on oilseed crops highlights their significance as a major source of dietary energy, providing 20%–35% of essential omega-6 (linoleic) and omega-3 (α-linolenic) fatty acids. While traditional breeding methods have improved yields in crops such as soybean, sunflower, canola, peanut, and cottonseed, progress has stagnated in recent decades. Oilseed crops face significant yield losses due to biotic and abiotic stresses, as well as changing agro-climatic conditions, making sustainable production a challenge. Recent advances in genomic, transcriptomic, and metabolomics research have enhanced the understanding of the genetic and physiological factors regulating fatty acid biosynthesis. Many oilseed species possess natural stress-resistance mechanisms, including transcription factor regulation, which can be leveraged for crop improvement. With the advent of genome editing technologies like CRISPR/Cas9, precise genetic modifications can be applied to enhance beneficial traits, including improved oil composition and nutritional profiles. The study underscores the potential of genome editing to develop high-yielding, resilient oilseed crops essential for sustainable food security. It is recommended that future research focus on optimizing CRISPR/Cas9 applications for oilseed enhancement, addressing current challenges, and improving breeding efficiency. Additionally, investment in biotechnology-driven agricultural practices, combined with traditional breeding, can help mitigate yield losses and enhance oil production. These advancements hold promise for developing improved oilseed varieties capable of withstanding environmental stresses while meeting the rising global demand for edible oils (Meghwal et al., 2025) Weed management plays a crucial role in enhancing the productivity and profitability of Indian mustard (Brassica juncea L.), as effective weed control measures significantly influence crop growth, yield attributes, and economic returns. Studies have shown that integrated weed management practices, including the application of herbicides and manual weeding, contribute to improved plant height, dry matter accumulation, siliqua formation, seed weight, and oil content, with treatments like Oxyfluorfen 23.5EC 230 g/ha (PE) combined with hand weeding at 40 days after sowing (DAS) achieving superior growth parameters, seed yield, and stover yield, indicating the importance of combining chemical and manual weed control strategies. Additionally, straw mulching and maintaining a weed-free condition through manual weeding at 30 and 60 DAS have shown positive effects on yield components and oil content, while economic analysis further supports the significance of an integrated approach, as Oxyfluorfen 23.5EC 230 g/ha (PE) + HW (40DAS) has resulted in the highest gross and net returns, making it a viable strategy for maximizing profitability. Based on these findings, the primary objectives should focus on evaluating the impact of different weed management practices on the growth and yield of Indian mustard, assessing the economic viability of various weed control methods, and determining the most efficient combination of herbicide application and manual weeding for enhanced productivity. It is recommended that farmers adopt an integrated weed management approach, incorporating Oxyfluorfen 23.5EC 230 g/ha (PE) followed by hand weeding at 40 DAS, as this method has been observed to optimize yield and profitability, while ensuring a weed-free environment through timely manual weeding at 30 and 60 DAS can further enhance crop performance. Future research should explore the long-term sustainability of these practices, their environmental impact, and the feasibility of alternative eco-friendly weed control strategies to enhance mustard production efficiency.

(Biswas et al.,2024) Mustard plays a vital role as a consumable and income-generating crop, with its productivity influenced by factors such as sowing time and varietal selection, as demonstrated in studies conducted in Bangladesh to assess the yield gap between research-level trials and farmer-managed fields. Research findings indicate that different planting times and mustard varieties significantly affect yield-contributing traits, including pod length, number of pods per plant, number of seeds per pod, and 1000-seed weight, with the highest yield recorded for the S2V2 treatment (10th November planting with BARI Sarisha 11), producing 2195.00 kg/ha in research fields and 1800.00 kg/ha in farmers' fields. The observed yield gap, ranging from 280.00 kg/ha to 698.00 kg/ha, with percentage differences from 4.42% to 38.39%, underscores the need for improved agronomic practices and farmer awareness to bridge this gap.

(Khan et al., 2024) The production trends and growth rates of Pakistan's oilseed crops, including rapeseed-mustard, have been a subject of extensive research due to their significant role in food security and economic sustainability. Studies analyzing acreage, production, and yield patterns from 1971-72 to 2021-22 indicate a shift towards greater reliance on imported edible oilseeds, with indigenous production facing challenges despite the positive growth trends observed in mustard and rapeseed cultivation. Research highlights that while groundnut and sunflower cultivation have expanded considerably, crops such as sesame and safflower show fluctuating trends, and soybean has suffered a decline in cultivation area despite minor yield improvements. The decline in castor seed production and the inconsistent performance of linseed further emphasize the need for strategic interventions. These findings underscore the necessity for policy measures to enhance domestic oilseed production and reduce import dependency, aligning with the economic aspects of mustard farming. In this context, the primary objectives should focus on assessing the trends and economic viability of mustard production in Sindh, identifying key constraints affecting local mustard growers, and evaluating cost-benefit dynamics to enhance profitability. It is recommended that policymakers promote sustainable agricultural practices, incentivize mustard and other oilseed crop cultivation through financial support and technological advancements, and strengthen research-extension linkages to facilitate knowledge transfer. Future research should explore the economic implications of production trends, assess the impact of government policies on mustard cultivation, and identify adaptive strategies to improve yield and profitability in response to changing market dynamics.

(Qaisar et al., 2020) The increasing demand for high-quality vegetable oil in Pakistan, driven by population growth, has intensified the need for sustainable oilseed production, with conventional crops such as mustard, brassica, sesame, and groundnut playing a significant role in edible oil supply. However, despite the contribution of these oilseeds, along with introduced crops like soybean, safflower, and sunflower, domestic production remains insufficient to meet national demand, resulting in heavy reliance on imports. Research highlights that while non-conventional sources such as cotton, maize, and rice bran offer additional potential for oil extraction, their utilization remains limited, necessitating strategic interventions to enhance both oil quality and quantity. This underscores the need for policies that promote the expansion and efficiency of local oilseed cultivation, particularly for mustard, which has shown promising production trends. The primary objectives should focus on assessing the economic viability of mustard production in Sindh, identifying key constraints faced by mustard growers, and evaluating strategies to bridge the gap between production and consumption through improved agricultural practices. It is recommended that policymakers support farmers through financial incentives, research-driven advancements in mustard cultivation, and awareness programs to optimize production techniques. Additionally, investment in processing infrastructure and value chain development can further enhance profitability and sustainability. Future research should explore innovative methods to increase oilseed productivity, assess the impact of market fluctuations on mustard farming, and formulate adaptive strategies to reduce import dependency and strengthen Pakistan's edible oil industry.

(Hossain et al., 2024) The complexity of agricultural farming necessitates continuous evaluation of different agronomic practices to enhance productivity, as seen in research conducted in the Jamalpur region, which analyzed the impact of various tillage techniques on mustard cultivation. The study compared three treatments—minimum tillage with a BARI seeder in a single pass, tillage with a BARI seeder followed by manual line sowing, and conventional tillage with broadcasting—using the mustard variety BARI Sarisha-14. Results indicated that minimum tillage using a BARI seeder in a single pass produced the highest yield (1.5 t/ha), demonstrating the potential of reduced tillage practices in improving mustard productivity. This research highlights the importance of adopting cost-effective and efficient cultivation techniques to optimize mustard production, aligning with the economic aspects of mustard farming. The primary objectives should focus on assessing the economic viability of mustard production under different tillage methods, id entifying challenges faced by mustard farmers in Sindh, and evaluating cost-benefit dynamics to enhance profitability. It is recommended that policymakers and extension services promote minimum tillage technology, facilitate farmer training programs on advanced sowing techniques, and provide financial incentives for adopting efficient practices. Future research should explore the long-term economic impact of reduced tillage on mustard farming, assess soil health and input cost variations under different tillage systems, and develop region-specific strategies to maximize productivity while ensuring sustainability in Sindh's mustard farming sector. (Akhatar, Upadhyay, & Kumar, 2025) Rapeseed-mustard, a vital oilseed crop belonging to the Brassicaceae family, plays a crucial role in global agriculture, contributing to edible essential oil production, vegetables, and animal feed. Despite extensive breeding programs, countries like India continue to struggle with low productivity due to various biological and environmental stresses. Research highlights the potential of advanced breeding techniques, such as hybrid breeding and cytoplasmic male sterility (CMS) systems, in overcoming these challenges. Effective agricultural practices, including careful soil selection, climate considerations, seed management, and adherence to agronomic guidelines, are critical for optimizing mustard production. Additionally, integrated weed, nutrient, and irrigation management strategies significantly enhance growth and yield. The reproductive characteristics of mustard flowers, particularly their high nectar and water content, make them ideal for studying pollinator behavior and breeding improvements aimed at increasing resilience and productivity. Pollen viability and stigma receptivity, essential for successful fertilization, are influenced by genetic and environmental factors, with fungal diseases posing a major threat to crop health. Addressing these challenges requires effective disease management strategies, such as cultural practices, chemical and biological controls, and the development of resistant varieties. Furthermore, efficient post-harvest techniques, including manual and mechanical harvesting, threshing, and seed extraction, are essential to maintaining high-quality seed production. Based on these findings, the present study aims to assess the current status of mustard production in Sindh, Pakistan, identify major production practices and the constraints faced by farmers, and evaluate the cost-benefit ratio of mustard farming in the region. To enhance productivity, it is recommended that farmers adopt improved seed varieties, implement integrated pest and disease management practices, and optimize irrigation techniques. Additionally, policies should focus on providing access to quality inputs, technical training, and financial support to mustard growers. Future research should explore climate-resilient breeding methods, the role of pollinators in yield enhancement, and sustainable farming techniques to ensure long-term growth and profitability in mustard production.

(Riaz et al., 2021) Mustard, scientifically classified under the Brassica genus, is a vital oilseed crop extensively cultivated for its high oil content and economic significance. Due to its widespread usage, researchers have focused on improving its genetic composition through advanced genomic techniques. Studies highlight the role of gene sequencing, genome mapping, and molecular breeding in enhancing mustard quality and yield. Key genomic aspects, including phylogeny, karyotyping, and identification of genetic variations, play a crucial role in determining plant potential. Research suggests that improving mustard genetics requires an in-depth understanding of phenology, photosynthesis, transformation abilities, and stress tolerance mechanisms.

(Pramanick et al., 2023). Indian mustard (*Brassica juncea L.*) is a vital oilseed crop that often faces challenges related to imbalanced fertilization, leading to suboptimal yield and quality. Recent research highlights the potential of polyhalite (POLY4), a multi-nutrient fertilizer containing potassium, sulfur, magnesium, calcium, and micronutrients, in addressing these nutritional deficiencies. POLY4 has been found to enhance mustard yield and quality attributes compared to conventional fertilization practices using urea, di-ammonium phosphate, and muriate of potash. Field experiments conducted over multiple seasons demonstrated a significant increase in seed yield with POLY4 application, improving production compared to nitrogen and phosphorus-only treatments and recommended NPK fertilization. Additionally, the application of POLY4 led to higher oil and protein content in mustard seeds, improved omega-3 fatty acid composition, and enhanced macro- and micronutrient uptake, thereby improving overall soil fertility. From an economic perspective, POLY4 application resulted in increased net returns, making it a cost-effective alternative to conventional fertilizers. Given these findings, the present study aims to assess the current mustard production status in Sindh, Pakistan, identify key production practices and constraints faced by farmers, and evaluate the cost-benefit ratio of mustard cultivation in the region. To enhance productivity, it is recommended that farmers adopt multi-nutrient fertilizers such as POLY4 to ensure balanced crop nutrition and sustainable soil health management. Additionally, policymakers should promote the use of innovative fertilization techniques through financial incentives, awareness programs, and research initiatives. Future studies should focus on long-term soil health impacts, optimization of POLY4 application rates, and its role in mitigating environmental concerns associated with fertilizer use.

MATERIALS AND METHODS

3.1 STUDY AREA

Mirpurkhas District, located in the Sindh province of Pakistan, has Mirpurkhas city as its capital. As per the 2017 census, the district's total population was 1,504,440, with 434,081 (28.85%) residing in urban areas. The sex ratio stood at 938 females per 1,000 males, while the overall literacy rate was 42.41%, with male literacy at 52.94% and female literacy at 31.22%. Islam is the dominant religion, followed by

60.75% of the population, whereas 38.74% are Hindus, including members of Scheduled Castes. In rural areas, the population of Muslims and Hindus is nearly equal.

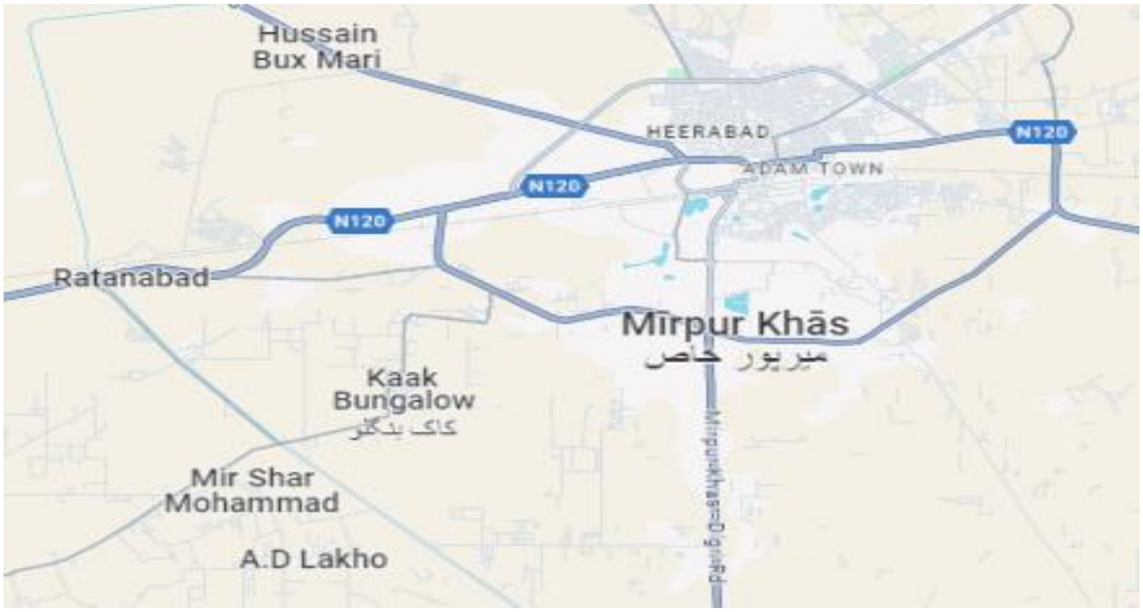

Figure 3.1 Map of district Mirpurkha

3.2 Population and Sample size

The sampling technique used for this study was stratified random sampling. This approach was chosen to ensure that different subgroups of mango growers were adequately represented. The sample consisted of 120 respondents, selected from different areas within the district. The stratification was based on farm size, age, and farming experience, ensuring that both small-scale and large-scale mango growers were included in the sample. This provided a comprehensive view of mango production practices and market interactions across different grower categories.

3.3 Questionnaire

The questionnaire for the study was initially developed with the guidance of the supervisor and subsequently reviewed and approved by the technical committee. Data collection was conducted through face-to-face interviews using a well-designed questionnaire, the questions were carefully designed to align with the research title and objectives, ensuring relevance and focus on mustard cultivation. Interviews were conducted in Sindhi to facilitate clear and effective communication with farmers, while the survey document was prepared in English for consistency and documentation purposes. This approach ensured accurate and reliable data collection from farmers engaged in mustard cultivation.

3.4 Analysis of data

To analyze cost benefit ratio of mustard production in the study area

After the data collection process, the gathered information was systematically organized, tabulated, and analyzed using Microsoft Excel and SPSS (Statistical Package for the Social Sciences). The tabulated data was then summarized, analyzed, and interpreted to align with the objectives of the study. Descriptive statistical tools, including averages, frequencies, and percentages, were primarily employed to present the findings in a clear and comprehensive manner, ensuring a thorough understanding of the results.

3.5. Percentage

The percentage was calculated using the following formula:

P = (F / N) × 100
Where:

- **P** = Percentage
- **F** = Frequency of a specific response
- **N** = Total number of respondents

3.6. Average or Mean

The average (mean) was calculated as the sum of all observations divided by the total number of observations. The formula used is:
Mean (x̄) = (∑xi) / n
Where:

- **x̄** = Sample mean
- **∑xi** = Sum of all observations
- **n** = Number of observations

3.7 Cost-Benefit Ratio

The cost-benefit ratio (CBR) was calculated using the following formula:
Cost-Benefit Ratio = Production Cost Per Unit / Selling Price Per Unit

RESULTS

This chapter presents the results of the study on the market analysis of mango growers in District Mirpurkhas, Sindh, Pakistan. It highlights the key findings derived from the data analysis, focusing on various aspects such as the socio-economic characteristics of mango growers, their production practices, marketing channels, marketing margins, and the factors influencing their marketing decisions. The chapter is organized into sections based on the research objectives, providing a comprehensive understanding of the mango market dynamics in the study area.

4.1 Mustard production in district Mirpurkhas

Table 4.1 Current status of Area, Production, and Yield of Mustard in Sindh Pakistan (2015–2024)

Year	Area (000 Acres)	Production Seed ((000 Tonnes)	Yield Kgs/acre
2014-15	533	210	394
2015-16	539	202	375
2016-17	494	190	384
2017-18	522	206	395
2018-19	643	318	495
2019-20	860	458	533
2020-21	608	338	556
2021-22	692	377	545
2022-23	1,260	785	623
2023-24	850.8	416	489

Source: - Pakistan Economic Survey Pakistan (2024).

Table 4.1 presents the current status of mustard cultivation in Sindh, Pakistan, over a ten-year period from 2014–15 to 2023–24, highlighting trends in area, production, and yield. The data reveals significant fluctuations in all three indicators. The area under mustard cultivation ranged from a minimum of 494,000 acres in 2016–17 to a peak of 1,260,000 acres in 2022–23. Correspondingly, production also varied, with the lowest recorded at 190,000 tonnes in 2016–17 and the highest at 785,000 tonnes in 2022–23. Yield per acre showed a general increasing trend, improving from 394 kg/acre in 2014–15 to a maximum of 623 kg/acre in 2022–23, before declining to 489 kg/acre in 2023–24. These variations suggest both improvements in mustard productivity and shifts in cultivation patterns, possibly influenced by policy changes, market dynamics, and agro-climatic factors.

4.2 Socio-economic characteristics of the growers in the study area

Table 4.2 Socioeconomic Characteristics

Age distribution of mustard growers

Age (Years)	Frequency (n = 120)	Percentage (%)
20 – 30	42	35.0
31 – 40	37	30.8
41 – 50	24	20.0
Above 50	17	14.2

The age distribution of mustard growers in the study reveals that the majority of growers are relatively young, with 35.0% falling in the 20–30 years' age group, followed by 30.8% in the 31–40 years' category. A smaller proportion of growers, 20.0%, are aged between 41–50 years, while 14.2% are above 50 years. This distribution indicates that a significant portion of the mustard growers are in the early to mid-stages of their agricultural careers, potentially suggesting a dynamic and younger demographic involved in mustard cultivation in the study area.

Table 4.3 Educational Background of the Mustard growers

Education Level	Frequency (n = 120)	Percentage (%)
Illiterate	28	23.33
Primary	48	40.00
Secondary	19	15.83
Higher Secondary	15	12.50
Graduate & above	10	8.33

The educational background of the mustard growers in the study reveals that a significant portion of growers have attained at least some level of formal education. The majority (40.0%) have completed primary education, followed by 23.33% who are illiterate. A smaller proportion of growers have secondary (15.83%) or higher secondary (12.50%) education, while only 8.33% have attained a graduate or higher qualification. This distribution indicates a relatively low level of higher education among mustard growers, with primary education being the most common level of attainment.

Table 4.4 Distribution of Respondents by Farming Experience

Farming Experience (Years)	Frequency (n = 120)	Percentage (%)
1 – 10	35	29.2
11 – 20	40	33.3
21 – 30	25	20.8
Above 30	20	16.7

Table 4.4 presents the distribution of respondents based on their farming experience. The table categorizes the respondents into four distinct experience ranges. The highest percentage of respondents, 33.3%, have farming experience between 11 and 20 years, followed by 29.2% with 1 to 10 years of experience. A smaller proportion, 20.8%, have 21 to 30 years of farming experience,

while 16.7% of the respondents reported having more than 30 years of experience. This distribution reflects the varied levels of experience among the cotton growers in the study area, with a substantial proportion of respondents possessing intermediate experience in the field.

Table 4.5 Distribution of Respondents by Mustard Growing Experience

Mustard Growing Experience	Frequency (n = 120)	Percentage (%)
Less than 5 years	22	18.33
5 – 10 years	40	33.33
11 – 15 years	34	28.33
Above15 years	24	20.00

Table 4.5 illustrates the distribution of respondents based on their experience in mustard growing. Among the respondents, 33.33% have 5 to 10 years of experience in mustard cultivation, representing the largest group. This is followed by 28.33% of respondents with 11 to 15 years of experience. A significant portion, 20.00%, reported having more than 15 years of experience, while 18.33% of the respondents have less than 5 years of experience in mustard growing. The data highlights a broad range of experience levels among the respondents, with a notable concentration in the intermediate experience brackets.

Table 4.6 Distribution of Respondents by Family Size

Family Size (Members)	Frequency (n = 120)	Percentage (%)
1 – 4	26	21.67
5 – 8	50	41.67
9 – 12	32	26.67
Above 12	12	10.00

Table 4.6 presents the distribution of respondents based on their family size. The largest group of respondents, 41.67%, belongs to families with 5 to 8 members. This is followed by 26.67% of respondents whose families consist of 9 to 12 members. A smaller proportion, 21.67%, reported having families with 1 to 4 members, while 10.00% of the respondents have families with more than 12 members. The data indicates a tendency towards medium-sized families, with the majority of respondents falling within the 5 to 8 members category.

Table 4.7 Distribution of Respondents by Farm Size

Farm Size (Acres)	Frequency (n = 120)	Percentage (%)
Less than 5	30	25.00
5 – 10	44	36.67
11 – 15	26	21.67
Above 15	20	16.67

Table 4.7 provides the distribution of respondents based on their farm size. The majority of respondents, 36.67%, own farms ranging from 5 to 10 acres. This is followed by 25.00% of respondents with farm sizes of less than 5 acres. A smaller proportion, 21.67%, have farms between 11 and 15 acres, while 16.67% of respondents own farms larger than 15 acres. The data reveals a concentration of respondents in the smaller to medium farm size categories, with the largest group of respondents managing farms of 5 to 10 acres.

Table 4.8 Cost Structure of Mustard Production per Acre

Particulars	Quantity	Units	Amount RS
Fixed cost			
Land Tax	Lump sum	Per acre	310
Rent of Land	1	Acre/year	15,740
Sub Total		16,050	
Average labor cost per acre			
Sowing	2	Labor	1,445
Application of fertilizers	2	Labor	1226
Application of pesticides	1	Labor	917
Harvesting	4	Labor	2356
Thresher	1	Hour (Machine)	2,551
Sub Total			8,495
Average marketing costs per acre			
Transportation	1	Trip	1,534
Loading/Unloading	Lump sum	Per crop	1,118
Commission	1	% of sales	710
Sub Total			3,362
Average input costs per acre			
Tractor plough	3	Ploughing	8,625
Seed	4	Kg	3,710
Urea	1.5	Bags(50kg)	9000
DAP	1	Bag(50kg)	13,000
Sub Total			34,335
Grand Total (cost)			62,242

Table 4.8 presents a detailed breakdown of the cost structure for mustard production per acre, totaling Rs. 62,242. The fixed costs amount to Rs. 16,050, which includes land tax and land rent. Labor costs, totaling Rs. 8,495, cover activities such as sowing, applying fertilizers and pesticides, harvesting, and thresher use. Marketing costs add Rs. 3,362, including transportation, loading/unloading, and commission fees. Input costs, which sum to Rs. 34,335, encompass expenses for tractor ploughing, seeds, urea, and DAP. This comprehensive cost analysis highlights the financial investment required for mustard cultivation, covering both fixed and variable expenditures.

Table 4.9 Per Acre Yield and Revenue from Mustard Production

Particulars	Mean Yield (Mounds 40 kg/acre)	Rate per Unit (Rs.)	Total Revenue (Rs.)
Grain Production (Mustard)	16.03	5500	88,165
Stover Yield	13.50	300	4050
Total Revenue	–	–	92,215

Table 4.9 summarizes the per acre yield and revenue from mustard production. The mean yield for grain production is 16.03 mounds, with a unit rate of Rs. 5,500 per mounds, generating a total revenue of Rs. 88,165. Additionally, the Stover yield is 13.50 mounds per acre, priced at Rs. 300 per mound, contributing Rs. 4,050 to

the total revenue. The combined total revenue from both grain and stover amounts to Rs. 92,215 per acre. This table highlights the financial returns from mustard cultivation, considering both the grain and stover yields.

Table 4.10 Per Acre Profitability Analysis of Mustard Growers

Particulars	Formula	Amount (Rs.)
Total Revenue	A = (Grain Revenue + Stover Revenue)	92,215
Total Cost	B = Sum of all production costs	62,242
Net Profit	D = A – B	22,973
Input-Output Ratio	C = A ÷ B	1.48
Cost-Benefit Ratio	E = D ÷ B or (A — B) ÷ B	0.48

Table 4.10 presents the per acre profitability analysis for mustard growers. The total revenue is Rs. 92,215, which is the sum of grain revenue (Rs. 88,165) and stover revenue (Rs. 4,050). The total cost of production is Rs. 62,242. The net profit, calculated as the difference between total revenue and total cost, amounts to Rs. 22,973. The input-output ratio, representing the efficiency of the investment, is 1.48, indicating that for every rupee spent, the grower earns Rs. 1.48. The cost-benefit ratio, which compares the profit to the cost, is 0.48, meaning the grower earns Rs. 0.48 for every rupee spent on production. This analysis highlights the profitability of mustard production, showing a positive return on investment.

Table 4.11 Major Problems Faced by Mustard Growers in the Study Area

S. No.	Problems Faced	Frequency (n = 120)	Percentage (%)
1	High cost of inputs (seeds, fertilizers, fuel)	61	50.83
2	Lack of quality mustard seed	33	27.50
3	Pest and disease attacks	12	10.00
4	Unfavorable market prices	8	6.67
5	Limited water irrigation availability	6	5.00

Table 4.11 outlines the major problems faced by mustard growers in the study area. The most prevalent issue, reported by 50.83% of respondents, is the high cost of inputs such as seeds, fertilizers, and fuel. A significant portion, 27.50%, expressed concerns about the lack of quality mustard seeds, while 10.00% of respondents highlighted pest and disease attacks as a major problem. Unfavorable market prices were mentioned by 6.67% of the respondents, and 5.00% reported limited water irrigation availability as a challenge. This table illustrates the key difficulties encountered by mustard growers, with input costs and seed quality emerging as the most critical issues.

DISCUSSION

This chapter presents the results of the study on the market analysis of mango growers in district Mirpurkhas, Sindh, Pakistan. It highlights key findings derived from the data analysis, focusing on various aspects such as the socio-economic characteristics of mango growers, their production practices, marketing channels, marketing margins, and the factors influencing their marketing decisions. The findings are compared with previous studies to provide a comprehensive understanding of the mango market dynamics in the study area.

The analysis of mustard production trends from 2014–2024 shows significant fluctuations, with yields peaking at 623 kg/acre in 2022–23 before declining to 489 kg/acre in 2023–24. This variability reflects the broader instability in Pakistan's oilseed sector, as noted by Khan et al. (2024), who attributed such inconsistencies to climatic uncertainties and suboptimal agronomic practices. The yield gap between research trials (2195 kg/ha) and actual farmer fields (1800 kg/ha), as observed in studies like Biswas et al. (2024), underscores the need for better extension services and technology dissemination. Addressing this gap could significantly improve productivity, particularly given the untapped potential demonstrated in experimental conditions.

The socioeconomic profile of mustard growers in Mirpurkhas highlights structural challenges that hinder productivity. A significant proportion of farmers are young (35% aged 20–30) and possess limited formal education (40% with only primary schooling), which aligns with findings by Uddin et al. (2024) in Bangladesh, where farmer demographics influenced the adoption of improved agricultural practices. Additionally, the predominance of smallholder farms (36.67% operating 5–10 acres) mirrors the constraints identified by Khan et al. (2023) in Sindh's oilseed sector, where fragmented landholdings limit economies of scale. These socioeconomic barriers, coupled with high input costs (reported by 50.83% of respondents) and limited access to quality seeds (27.5%), pose significant obstacles to productivity—echoing Dubey & Bose's (2023) observations in Uttar Pradesh. Addressing these constraints requires targeted interventions, such as subsidized inputs and farmer education programs, to enhance adoption rates of best practices.

Economically, mustard cultivation remains viable, with a benefit-cost ratio (BCR) of 1.48 and net returns of Rs. 22,973 per acre. However, profitability is vulnerable to input price volatility, particularly fertilizer costs, which constitute 21% of total expenses—a pattern consistent with Pathak et al.'s (2024) findings in India. Despite this, the current yields (16.03 maunds/acre) remain below the potential demonstrated in research trials (21.95 maunds/acre, Biswas et al., 2024), suggesting room for improvement through optimized agronomic strategies. For instance, integrated weed management (Meghwal et al., 2025) and precision fertilization (Pramanick et al., 2023) could enhance yields by 15–20%, offering a pathway to greater economic resilience for farmers.

The decline in mustard cultivation area (from 1,260 to 850.8 thousand acres post-2022–23) may reflect shifting farmer preferences due to market instability or climatic risks—a trend also observed in Pakistan's sunflower and soybean sectors (Khan et al., 2024). Similar patterns have been noted globally, where oilseed farmers shift to less risky crops amid input inflation (Riaz et al., 2021). However, mustard's relative profitability in Sindh positions it as a strategic crop for reducing Pakistan's heavy reliance on imported edible oils (Hussain et al., 2023). Policy measures such as hybrid seed subsidies (Qaisar et al., 2020) and minimum support pricing (Khan et al., 2023) could stabilize production, while climate-smart practices like minimum tillage (Hossain et al., 2024) may reduce costs and improve sustainability.

While this study offers valuable insights, its focus on a single district and reliance on self-reported data may limit generalizability. Future research should explore regional variations and the long-term impacts of emerging technologies, such as drought-resistant mustard varieties developed through CRISPR/Cas9 (Kaushal et al., 2025). Additionally, gendered labor dynamics in mustard farming warrant further investigation to ensure inclusive policy formulation. Nevertheless, the findings emphasize the need for integrated strategies—combining agronomic innovation, policy support, and market reforms—to strengthen Pakistan's oilseed sector. By addressing the systemic bottlenecks identified in this study, Sindh could serve as a model for sustainable mustard production, reducing import dependency while improving farmer livelihoods.

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The analysis of mustard production in Mirpurkhas, Sindh (2014–2024), reveals significant fluctuations in cultivation area, yield, and profitability. The cultivation area peaked at 1,260,000 acres in 2022–

23, followed by a decline to 850,800 acres in 2023–24. Yield reached its highest at 623 kg/acre in 2022–23 but decreased to 489 kg/acre in 2023–24, indicating instability in production.

Socioeconomic data show that a large proportion of mustard growers are young (35% aged 20–30) and possess limited formal education (40% with only primary schooling). Most farms are small to medium-sized, with 36.67% operating on 5–10 acres. These factors, combined with challenges such as high input costs (reported by 50.83% of respondents) and limited access to quality seeds (27.5%), hinder productivity. Despite these challenges, mustard cultivation remains economically viable, with a benefit-cost ratio of 1.48 and net returns of Rs. 22,973 per acre. However, profitability is sensitive to input price volatility, particularly fertilizer costs, which constitute a significant portion of total expenses.

Recommendations

1. **Enhance Access to Quality Inputs**: Implement subsidies or support programs to make high-quality seeds and fertilizers more affordable and accessible to farmers.
2. **Farmer Education and Training**: Develop targeted training programs focusing on modern agronomic practices, pest and disease management, and efficient resource utilization to improve productivity.
3. **Promote Sustainable Farming Practices**: Encourage the adoption of integrated weed management and precision fertilization techniques to enhance yields and reduce environmental impact.
4. **Market Stabilization Measures**: Establish minimum support prices and improve market infrastructure to protect farmers from price volatility and ensure fair returns.
5. **Research and Development**: Invest in the development of drought-resistant and high-yield mustard varieties through advanced breeding techniques to enhance resilience against climatic challenges.
6. **Policy Support**: Formulate policies that support smallholder farmers, including access to credit, insurance schemes, and land consolidation initiatives to achieve economies of scale.

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