Global Research journal of Natural Science and Technology (Grjnst)
Volume: 03 - Issue 3 (2025)
p.ISSN: 2790-7643 e.ISSN: 2790-7651

Impact of Climate Change on Mango (*Mangifera indica* L.), Phenology, Yield, and Quality

Mukhtiar Ahmed
Department of Soil Science, Lasbela University of Agriculture water and Marine Sciences
Corresponding Author: mukhtiarqadir95@gmail.com

Bilal Ahmed Awan
Institute of Horticultural Sciences University of Agriculture Faisalabad bilal.awan@uaf.edu.pk

Badi Uz Zaman
Department of Plant Sciences Quaid I Azam University, Islamabad
bzaman@bs.qau.edu.pk

Khuda Bakhsh
Institute Sindh Agriculture university Tandojam
kbbajoi472@gmail.com

Maha Sohail
Institute of Horticultural Sciences, University of Agriculture Faisalabad
mahail5356@gmail.com

Aisha Rafeeque
Institute of Horticultural Science University of Agriculture Faisalabad
Aisharafeeque0@gmail.com

Hira Afzal
Department of Environmental Sciences, University of Veterinary & Animal Sciences - UVAS Lahore
hirasheikh1004@gmail.com

Adalat Ali
Dr. A.Q. Khan Institute of Biotechnology and Genetic
Engineering, University of Karachi, Karachi, Pakistan,
mehraniadalat786110@gmail.com

Abdul Razzaque
Muhammad Nawaz Shareef University of Agriculture, Multan
abdulrazzaque200@gmail.com

Abstract: *Mango (Mangifera indica L.) is a vital tropical and subtropical fruit crop of significant economic and nutritional importance, yet its production faces severe challenges due to climate change. This paper examines the impacts of climate change on mango phenology, yield, and fruit quality, highlighting disruptions caused by rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events such as* *droughts and heavy rainfall. These changes affect critical physiological processes, including flowering, fruit set, and carbohydrate metabolism, leading to irregular bearing, reduced yields, and compromised fruit quality such as, size, color, and sweetness. climate-induced stressors exacerbate pest and disease pressures, further threatening production. Adaptation and mitigation strategies, including improved irrigation systems, canopy management, mulching, and the use of micronutrients like zinc and boron, are discussed as practical solutions to enhance resilience. The paper also explores future perspectives, emphasizing precision horticulture, climate-smart agricultural practices, and supportive policy frameworks to ensure sustainable mango production. By integrating advanced technologies, resilient cultivars, and innovative farming practices, this study underscores the potential to mitigate climate change impacts and secure mango production for global food security and farmer livelihoods.*

Keywords: *Mango, M. indica L., climate change impact, mitigation strategies, zinc*

I. Introduction

Mango (*Mangifera indica* L.), is an important crop of economic and nutritional significance in the tropics and sub tropics. Moreover, it is the sixth most important fruit crop in the world. It is a real contest for taste and various health benefits, as high demand in both internal and external markets (Ahmad *et al*., 2018; Antwi-Boasiako *et al*., 2024). Farmers utilize mango for export which earns great revenue from fruit products. Hence, Mango is a significant crop which provides them with great socioeconomic benefits. (Normand *et al*., 2015). Mango production faces a significant threat from the continuing effects of climate change. Changes in climate affect physiological processes, phenology, and pest susceptibility of fruit crops. The threats posed by changing temperature and precipitation patterns, as well as the increased occurrence of extreme weather events (such as droughts and excessive rainfall), include those to mangoes (Yadav *et al*., 2023). Changing weather patterns like heat and rain can hamper the flowering and fruiting of mango tree which is critical for yield. In subtropical conditions, it has been observed that low temperature is important for flowering in mango. However, other stressors such as water deficiency can severely affect fruit set and retention as given in (Table. 1) (Luo *et al*., 2019). Changes in the climate will cause phenological mismatches which will affect the flowering and fruiting at irregular times and make them susceptible to pests and diseases for longer duration. The occurrence of adverse climatic conditions can result in less uniform fruit quality and stage of maturity at harvest, posing further challenges for deliveries to markets and consumer satisfaction (Boudon *et al*., 2020).

Mango trees are likely to be affected in their vegetative and reproductive development due to increase in atmospheric Carbon dioxide (CO2), and soil salinity as well as lower and more erratic rainfall, it could decrease production and make fruits less tasty as shown in (Table. 1) (Normand *et al*., 2015; Jan et al., 2025). Improved cultivation practices and nutrient management including, combined soil application of zinc and boron can help overcome the challenges of dry and wet spells. Practices like these can enhance mango tree yield and physiological quality responses to a certain extent. Moreover, they enhance fruit set, retention, and quality (Ahmad *et al*., 2018). Furthermore, developing a crop model for mango through research can facilitate understanding of these alteration effects on mango and solutions to adapt to changing climate scenarios on mango production (Normand *et al*., 2015).

So, mango is an important crop, but the future stability and productivity of mangoes under climate change will depend on a few targeted interventions in their cultivation and our better understanding through research.

II. Impact on Mango Phenology

The flowering time, fruit set, and irregular bearing of mango: *M. indica* L., an important tropical fruit, are affected by climate change. Due to climate change mango production is impacted by rising temperatures, changing precipitation patterns and increasing frequency of extreme weather events (Normand *et al*., 2015). Mango flowering is sensitive to environmental parameters such as temperature and humidity. Changes in climate can interfere with the timing of these signs which causes shifts in flowering. Mango flowering is complicated, depending on many factors, such as temperature and water supply. In subtropical climates, low temperatures have an important role in triggering flowering, while in tropical climates, the age of the last flush of growth plays a vital role (Luo *et al*., 2019; Jan et al., 2025). If temperatures keep increasing across the globe, then low-temperature cues that enable flowering may decline. As a result of flowering could delay or disrupt (Khalifa and Abobatta, 2023; Luo *et al*., 2019).

The changes in climate may affect the availability and balance of resources necessary for fruit set such as, non-structural carbohydrates. Mango's starch and sugar are crucial for its reproduction and directly influenced by its photosynthesis and starch distribution. Changes in climate can alter the amount of carbohydrates available for trees, then affects fruit set and may lead to a reduction in fruit size and quality (Rossouw *et al*., 2024). Increases in temperature can worsen these problems by changing the rates of photosynthesis and the storage and use of carbs.

Mango trees are known for irregular bearing, which makes it worse by climate vagaries, adopting a regional product approach. By increasing temperatures and rainfall variability, the phenological disparities can happen. For example, flowering and fruiting may not coincide, which causes variability in fruit production from year to year as shown in (Table. 1) (Normand *et al*., 2015). Furthermore, stress from extreme climate events like drought and heavy rain peuvent adversely impact the health and productivity of the trees (Khalifa and Abobatta, 2023; Jan et al., 2025).

Adaptive measures such as breeding for climate-resilient varieties and adjustment in cultural practices are important to mitigate them. You may choose the cultivars that are a good fit for climatic stresses and specify agricultural practices to improve water and soil management (Khalifa and Abobatta, 2023). While, the long-term strategies focus on gaining an understanding of the phenological events changed by climate change and further anticipating these events. The short-term and more practical solutions would involve improving on farm management for a buffer against variability (Yadav *et al*., 2023).

III. Impact on Yield

M. indica L., is one of the sensitive fruits to changes in the climate that adversely affects the physiological and developmental process of the mango. In the following ways, increased temperatures, altered rainfall patterns, and drought conditions reduce mango yield. Higher temperatures during flowering fruit-set and fruit-growth can adversely affect mango production. This excessive heat stress can cause flowers and fruit to drop, severely limiting yield. Also, it can alter the quality of the fruit having an effect on its texture, taste and nutritional value as shown in (Figure.1) (Antwi-Boasiako *et al*., 2024; Normand *et al*., 2015; Jan et al., 2025). The mango tree needs a certain amount of water throughout the growing cycle then it suffers from drought and water scarcity. Droughts, which are now common due to climate change, can cause water stress. The lower fruit production is due to less photosynthesis and vegetative growth. An insufficient water supply at the flowering and fruit-setting stages is particularly detrimental as it reduces the overall fruit set and increases the incidence of fruit drop (Normand *et al*., 2015).

It rains in different amounts and at different times. This can prevent mango trees from growing. Heavy rain can cause root zone waterlogging, and oxygen supply to the roots are restricted. The uptake of nutrients is hindered insufficient rainfall means water deficits that can create stress situations that lower fruit quality and yield. Balanced rainfall levels and timely rainfall are critical for mango trees, which is becoming unpredictable with climate change (Antwi-Boasiako *et al*., 2024; Normand *et al*., 2015). Climate variables like, temperature and rainfall influence the processes of photosynthesis and nutrient uptake in mango trees. Heat and water stress may help reduce chlorophyll content and efficiency. This can adversely affect atmospheric photosynthetic efficiency. This causes energy generation to be lower, limiting growth and fruit production, which reduces yield overall (Normand *et al*., 2015; Jan et al., 2025).

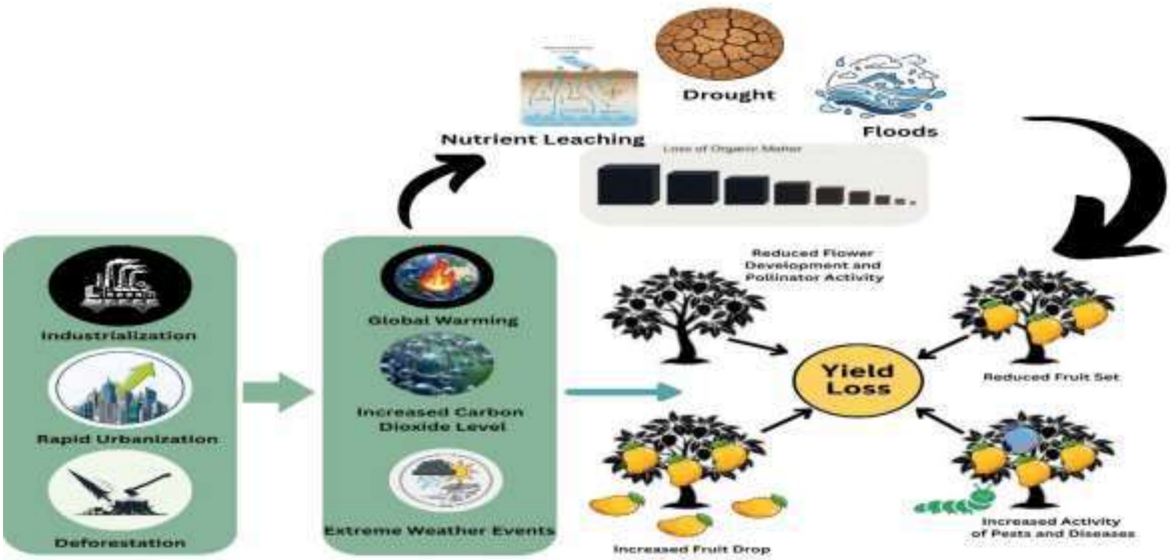

Figure 1. Climate Change Impact on Yield Losses

The pressure of pests and diseases has increased; the change would also affect the pests and disease prevalence and intensity. Further stress to the crops would be given, when temperatures and humidity are high, certain pests and diseases could thrive and worsen the situation affecting mango production as given in (Table. 1) (Antwi-Boasiako *et al*., 2024). The weather challenges the production and quality of mango crops. The concerned authorities are implementing measures to mitigate the negative impact of the weather on mango trees as much as possible. Strategies like, choosing heat and drought resistant mango cultivars, improving irrigation systems, and using integrated pest management (IPM) are key to climate-resilient mango production (Normand *et al*., 2015).

IV. Impact on Fruit Quality

Climate change affects the size, color, sweetness, and postharvest quality of *M. indica* L., due to various factors. These fruit attributes are largely determined by fluctuations in temperature, light and water availability. Mangoes grow to a size that depends considerably on the availability of resources during their growth, especially water and nutrients. The climate is changing, and an increase in temperature, erratic rainfall will lead to water stress. It will impact the size of the fruits as shown in (Table. 1). Additionally, increased temperature may speed up growth processes, then results in reduced fruit size as given in (Figure. 2) (Antwi-Boasiako *et al*., 2024; Léchaudel and Joas, 2007; Jan et al., 2025). Fruit Colour development is sensitive to light and temperature. Changes in these factors because of climate change can result in uneven coloration of the fruits. Higher temperatures, might enhance the activities of the enzymes responsible for synthesizing pigments which might lead to enhanced colour but may also lead to early ripening and other complications (Yadav *et al*., 2023).

Table 1. Impacts of Climate Change on Mango Phenology, Yield, and Quality

Climate Change Factor	Impact on Phenology	Impact on Yield	Impact on Fruit Quality
Rising Temperatures	Shifts in flowering time, disrupted low-temperature cues	Flower/fruit drop, reduced yield	Smaller fruit size, uneven coloration, altered sweetness
Altered Rainfall Patterns	Phenological mismatches, irregular bearing	Water stress, reduced fruit set	Reduced fruit size, lower sweetness
Extreme Weather (Droughts, Heavy Rain)	Irregular flowering and fruiting	Lower photosynthesis, fruit drop	Physiological disorders, reduced shelf-life

Increased CO2/Salinity	Altered vegetative/reproductive development	Decreased production	Less tasty fruits
Pest/Disease Pressure	Increased susceptibility due to prolonged exposure	Reduced yield due to crop stress	Compromised fruit appearance and quality

The flavor of mangoes mainly depends on the production and storage of sugars as the fruit ripens. Changes in climate, particularly temperature rises influence carbohydrate metabolism and hence the sweetness (Datir and Regan, 2022; Romero *et al*., 2021). Warmer temperatures may increase sugar accumulation to a limit but beyond that, excessive heat may inhibit metabolic processes. The quality of mangoes harvested after ripening might be affected by physiological problems. They are caused due to environmental stress during the season. Storing disorders like chilling injury and uneven ripening can impair fruit appearance, texture and favour when fruit is stored. Climate conditions have been causing stress to mangoes which can possibly enhance their post-harvest losses and reduce their shelf-life requiring the application of advanced postharvest technology (Bambalele *et al*., 2021; Ullah *et al*., 2024).

Figure 2. Climate Change Impact on Fruit Quality

V. Adaptation and Mitigation Strategies

To reduce the effects of climate change on the growth of mangoes, several horticultural practices have been suggested. Some of these practices include, irrigation, canopy management, and mulching. Managing water, because of changing rainfall patterns due to climate change, the irrigation of crops is essential. Drip irrigation and other optimized irrigation systems minimize the wastage of water and ensure that mango trees are adequately supplied with water during dry spells. This practice helps maintain soil moisture levels, which is key to reducing damage to mangoes during extremes situations, these all are mentioned in (Table. 2) (Agathoklous *et al*., 2023). Canopy management practices like, pruning improve the microclimate around mango trees, if manage the density and shape of the tree canopy, water loss due to evapotranspiration will decline, light penetration will increase, photosynthesis will improve, and storm and wind damage will be minimized. Mango trees become more resilient to temperature variations and climate stresses with these practices (Martins *et al*. 2024). We can conserve soil moisture and lower soil temperature fluctuations by applying mulch around our mango trees. It also reduces weed growth. Conventional, inorganic mulching materials can often limit water penetration, but when we use organic mulching materials, they improve soil water retention. Successful application of mulching, and shade netting practices help in sustaining soil health under altering climate, thereby aiding in more resilient mango production systems (Saikanth *et al*. 2023; Swarnam *et al*. 2024).

Table 2. Adaptation and Mitigation Strategies for Mango Production

Strategy	Description	Benefits	Reference
Drip Irrigation	Optimized water delivery to maintain soil moisture	Reduces water stress, improves yield	Agathokleous *et al*., 2023
Canopy Management	Pruning to improve microclimate and reduce water loss	Enhances photosynthesis, reduces storm damage	Martins *et al*., 2024
Mulching	Organic mulch to conserve soil moisture and reduce temperature fluctuations	Improves soil health, enhances resilience	Saikanth *et al*., 2023
Micronutrient	Soil application of zinc and	Improves fruit set,	Ahmad *et al*.,

Application	boron	retention, and quality	2018
Climate-Smart Varieties	Breeding drought- and heat-tolerant cultivars	Increases resilience to climate stressors	Khalifa and Abobatta, 2023

VI. Future Perspectives

Tools such as precision horticulture, climate-smart practices and policy measures may help mitigate the adverse impact of climate change on Mango production. They work together to enhance productivity, resilience and sustainability of mango. Precision horticulture applies remote sensing, data analysis, mobile platforms and more to successfully analysis processes in agriculture. Farms are using smart technology today; these are devices that provide the rapid information that a farmer needs. Mango production could use precision horticulture which include site-specific nutrient management and precise water management and monitoring of plant health through nano-biosensors that can detect biotic and abiotic stresses before they hurt production (Miguel-Rojas and Pérez-De-Luque, 2023). Climate-smart agriculture (CSA) encompasses sustainable farming practices that lead to increased productivity, greater resilience, and lower emission. One practice includes conservation agriculture, crop diversification and the incorporation of agroforestry that ensure stable yields and enhance resilience. According to Bhanuwanti *et al*., (2024); and Safdar *et al*. (2024), strategies for CSA have been developed. For example, using drought-tolerant, disease-resistant mango varieties was created. Also, improving soil fertility and irrigation efficiency is an example. It enhances productivity of the mango crop and also contributes to reducing climate-related risks.

To promote climate smart and precision horticulture, effective policy frameworks are needed. Mango producers can get more institutional support through financial motivations, technology access infrastructure such as, roads and institutional frameworks to ensure the CSA practices are implemented. In addition, research and collaboration-promoting policies are crucial to adapting mango production to climate variability, thereby encouraging innovations such as cultivar selection and improvement of cultural practices (Normand *et al*., 2015; Sarma *et al*., 2024). Mango farming can be made sustainable worldwide through the scale-up of CSA practices to secure food production and farmer livelihoods amidst the impacts of climate change (Ghosh, 2019; Singh *et al*., 2024). Using CSA, precision horticulture, and policy changes can help overcome the impacts of climate change on

Mango production. Agricultural technological advances improve productivity, resilience and sustainability in mangoes.

Precision horticulture is an effective management using advanced techniques like remote sensing, data analysis, and mobile apps. Tools like; smart weather stations will be used on farm that will save our natural resources. Mango production can benefit from precision horticulture consisting of site-specific nutrient management, precise water management, and monitoring of plant health through nano-biosensors that can detect biotic and abiotic stresses that can affect production (Miguel-Rojas and Pérez-De-Luque, 2023). CSA combines climate-resilient practices with sustainable operations to improve productivity, resilience, and emissions. Maintaining consistent yields and boosting climate resilience of mango crop can be through CSA practices like conservation agriculture, crop diversification and agroforestry. The use of drought and disease-resistance mango varieties with improved soil fertility and efficient irrigation, CSA strategy that enhances productivity with minimum climate related risks (Bhanuwanti *et al*., 2024; Safdar *et al*., 2024).

Policy interventions play a critical role in facilitating the adoption of climate-smart and precision horticulture practices. Mango producers can receive support from governments and institutions through financial incentives, the development of infrastructure for access to technology, and the creation of institutional arrangements to facilitate CSA implementation. In addition, policies that adoptive research and collaboration must be developed to adapt mango production in response to climate variability. Such policies would encourage innovations such as, cultivar selection and improvement of cultural practices (Normand *et al*., 2015; Sarma *et al*., 2024). We need collaboration between governments, researchers, and farmers to develop tools that help farmers grow and prepare for climate change. By spreading the CSA practices, mango farming will be made climate-resilient to secure food production and livelihoods of farmers, these all given in (Table. 3) (Ghosh, 2019; Singh *et al*., 2024).

Table 3. Future Perspectives for Climate-Resilient Mango Production

Approach	Description	Expected Outcome	Reference

Precision Horticulture	Use of remote sensing, nano-biosensors, and data analytics	Real-time monitoring, optimized resource use	Miguel-Rojas and Pérez-De-Luque, 2023
Climate-Smart Agriculture	Conservation agriculture, crop diversification, agroforestry	Stable yields, reduced emissions	Bhanuwanti *et al*., 2024; Safdar *et al*., 2024
Policy Frameworks	Financial incentives, infrastructure, research support	Widespread adoption of CSA practices	Normand *et al*., 2015; Sarma *et al*., 2024

VII. Conclusion

Climate change can really affect the mango trees. Due to climate change, the environmental stressors faced by mango trees have been exacerbated by increased temperatures, erratic rainfall patterns, drought, and severe weather. Changes in temperature and precipitation can disturb the growth and reproduction cycles of a mango trees. This can impact its phenology, yield, and the quality of the fruit. When temperatures get warmer and heatwaves happen more often, it can hurt how mango trees create food and do other things needed to grow. Due to increase in temperature, there should also be adjustment strategies to have maintained productivity under changed climate condition. Because of climate change, water shortages and salt accumulation in soils are making a bad situation worse. Moreover, socio-economic problems are emerging. Also, the yield and quality of mangoes are being affected.

Efforts to counter climate change impact on mango production have been proposed sustainable solutions. Using micronutrients like, (Zinc and Boron) can enhance the productivity of mango trees. Proper applications of these nutrients through soil improve fruit-set, retention, yield and quality by correcting nutrient deficiencies. In addition, nanoparticles like, (Selenium, Titanium, and Silicon) can improve growth and yield under drought conditions by enhancing different physiological parameters as well as the mineral profile of the leaves. Moreover, adaptive cultivation technology and the development of mango varieties that can withstand drought and heat are important. Changes in cultural practice and the development of a mango crop model could provide essential insights for adaptation planning. In addition, new technology and AI-assisted sustainable farming research projects can address climate change impacts together with the sustainability of mango production.

Acknowledgment

The authors would like to express their sincere gratitude to Lecturer Ameer Jan, Department of Botany, University of Makran, Panjgur, for his valuable guidance, constructive suggestions, and continuous encouragement throughout the preparation of this paper. His support and scholarly input greatly contributed to the quality and completion of this work.

References

Agathokleous, E., Frei, M., Knopf, O. M., Muller, O., Xu, Y., Nguyen, T. H., ... and Feng, Z. 2023. Adapting crop production to climate change and air pollution at different scales. Nature Food, 4(10), 854-865.

Ahmad, I., Bibi, F., Ullah, H., and Munir, T. M. 2018. Mango fruit yield and critical quality parameters respond to foliar and soil applications of zinc and boron. Plants, 7(4), 97.

Almutairi, K. F., Górnik, K., Awad, R. M., Ayoub, A., Abada, H. S., and Mosa, W. F. 2023. Influence of selenium, titanium, and silicon nanoparticles on the growth, yield, and fruit quality of mango under drought conditions. Horticulturae, 9(11), 1231.

Antwi-Boasiako, A., Amponsah, P., Opoku, J. A., Coulibaly, D., and Mintah, P. 2024. Increasing mango production efficiency under the fast-changing climate. In Abiotic Stress in Crop Plants-Ecophysiological Responses and Molecular Approaches. IntechOpen. https://doi.org/10.5772/intechopen.112951.

Bambalele, N. L., Mditshwa, A., Magwaza, L. S., and Tesfay, S. Z. 2021. Recent advances on postharvest technologies of mango fruit: a review. Int. J. Fruit Sci. 21(1), 565-586.

Bhanuwanti, B., Tanwar, H., Saad, A. A., Dar, K. A., Rai, U., Khatoon, A., and Singh, L. 2024. Climate Smart Agriculture: Innovating Sustainable Practices for a Changing Climate. J. Sci. Res. Rep. 30(11), 568-576. https://doi.org/10.9734/jsrr/2024/v30i112585.

Boudon, F., Persello, S., Jestin, A., Briand, A. S., Grechi, I., Fernique, P., ... and Normand, F. 2020. V-Mango: a functional–structural model of mango tree growth, development and fruit production. Annals of Botany, 126(4), 745-763.

Datir, S., and Regan, S. 2022. Advances in physiological, transcriptomic, proteomic, metabolomic, and molecular genetic approaches for enhancing mango fruit quality. J. Agric. Food Chem. 71(1), 20-34.

Ghosh, M. 2019. Climate-smart agriculture, productivity and food security in India. J. Dev. Policy Pract. 4(2), 166-187.

Jan, A., Hussain, Z., Ullah, A., Ahmed, Z., Bakhsh, B. P., Latif, A., ... & Ahmed, M. (2025). Sugarcane Whip Smut: A Comprehensive Review of Pathogen Biology, Epidemiology, and Control Measures. Annual Methodological Archive Research Review, 3(5), 211-232.

Jan, A., Shaikh, G. Y., Ullah, S., Saddam, S., Ali, T., u Rehman, A., ... & Ahmed, M. (2025). In-vitro antifungal activity of medicinal plant extracts against Fusarium oxysporum causing wilt in okra. Indus Journal of Bioscience Research, 3(8), 406-414.

Jan, A., Adil, S., Ali, T., Ahmed, B., Ahmed, Z., & Hussain, Z. (2025). Desert and medicinal plants as novel sources of antimicrobial agents for crop protection. Planta Animalia, 4(3), 197-218.

Jan, A., Ali, T., Chirag, S., Ahmed, S., Ali, M., Wali, S., ... & Ullah, K. (2025). Eco-Friendly Management of Insect Pests and Plant Diseases Using Botanical Extracts. Global Research Journal of Natural Science and Technology.

Jan, A., Razzaq, F., Umair, M., Ullah, I., Shamsullah, S., Uzair, M., Ikram, M., Ayyaz, M., & Ali, T. (2025). Cotton Leaf Curl Disease: Pathogen Diversity, Whitefly Ecology, and Integrated Management Approaches. Planta Animalia, 4(4), 363-371.

Khalifa, S. M., and Abobatta, W. F. 2023. Climate changes and mango production (temperature). Science: Botany; Ecology; Evolutionary Biology., 1(1), 043-046. https://doi.org/10.61927/igmin115.

Léchaudel, M., and Joas, J. 2007. An overview of preharvest factors influencing mango fruit growth, quality and postharvest behavior. Braz. J. Plant Physiol. 19, 287-298.

Luo, C., Fan, Y., Zhang, X. J., Yu, H. X., and He, X. H. 2019. Research advance on the flowering mechanism of mango. Acta Horticulturae, 1244, 17-22. https://doi.org/10.17660/actahortic.2019.1244.2.

Martins, S., Pereira, S., Dinis, L. T., and Brito, C. 2024. Enhancing olive cultivation resilience: sustainable long-term and short-term adaptation strategies to alleviate climate change impacts. Horticulturae, 10(10), 1066. https://doi.org/10.3390/horticulturae10101066.

Miguel-Rojas, C., and Pérez-de-Luque, A. 2023. Nanobiosensors and nanoformulations in agriculture: new advances and challenges for sustainable agriculture. Em. Top. Life Sci, 7(2), 229-238.

Normand, F., Legave, J.-M., and Lauri, P.-E. 2015. CLIMATE CHANGE AND ITS PROBABLE EFFECTS ON MANGO PRODUCTION AND CULTIVATION. Acta Horticulturae, 1075(1075), 21-31. https://doi.org/10.17660/actahortic.2015.1075.1.

Romero, H., Pott, D. M., Vallarino, J. G., and Osorio, S. 2021. Metabolomics-based evaluation of crop quality changes as a consequence of climate change. Metabolites, 11(7), 461.

Rossouw, G. C., Orr, R., Bennett, D., and Bally, I. S. 2024. The roles of non-structural carbohydrates in fruiting: a review focusing on mango (*Mangifera indica*) Funct. Plant Biol, 51(4). https://doi.org/10.1071/fp23195.

Safdar, M., Shahid, M. A., Yang, C., Rasul, F., Tahir, M., Raza, A., and Sabir, R. M. 2024. Climate smart agriculture and resilience. In Emerging Technologies and Marketing Strategies for Sustainable Agriculture (pp. 28-52). IGI Global Scientific Publishing.

Saikanth, D. R. K., Kumar, S., Rani, M., Sharma, A., Srivastava, S., Vyas, D., ... and Kumar, S. 2023. A comprehensive review on climate change adaptation strategies and challenges in agriculture. Int. J. Environ. Clim. Chang. 13(11), 10-19.

Sarma, H. H., Borah, S. K., Dutta, N., Sultana, N., Nath, H., and Das, B. C. 2024. Innovative approaches for climate-resilient farming: strategies against environmental shifts and climate change. Int. J. Environ. Clim. Chang. 14(9), 217-241.

Singh, A., Sarma, A., T, S., Deori, C., Das, J., D, S., Pandey, A. K., and R, G. 2024. A Comprehensive Review on Greenhouse Gas Emissions in Agriculture and Evolving Agricultural Practices for Climate Resilience. Int. J. Environ. Clim. Chang. 14(5), 455-464. https://doi.org/10.9734/ijecc/2024/v14i54206.

Swarnam, T. P., Velmurugan, A., Subramani, T., Ravisankar, N., Subash, N., Pawar, A. S., ... and Dam Roy, S. 2024. Climate smart crop-livestock integrated farming as a sustainable agricultural strategy for humid tropical islands. Int. J. Agric. Sustain. 22(1), 2298189.

Ullah, M. A., Khanal, A., Joyce, P., White, N., Macnish, A., and Joyce, D. 2024. Internal disorders of mango fruit and their management-physiology, biochemistry, and role of mineral nutrients. Plants, 13(18), 2596. https://doi.org/10.3390/plants13182596.

Yadav, S., Korat, J. R., Yadav, S., Mondal, K., Kumar, A., Kumar, S., and Kumar, S. 2023. Impacts of climate change on fruit crops: a comprehensive review of physiological, phenological, and pest-related responses. Int J Environ Clim Chang, 13(11), 363-371. https://doi.org/10.9734/ijecc/2023/v13i113179.