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STRESS MANAGEMENT IN FRUIT CROPS: A REVIEW OF MITIGATION MEASURES AND CONSERVATION PRACTICES

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ABSTRACT

Stress management is a widely addressed matter in the production of fruit crops. Limitations that detrimentally affect the growth, photosynthetic efficiency and biomass production is called stress. Research on alleviating detrimental effects caused by abiotic and biotic factors is gaining pace due to the changing environmental conditions. Abiotic causes like changes in temperature, flood, pollution and associated effects of drought, salinity, waterlogging, freezing, scorching, and metal ion deposition are further complicating the efforts to mitigate stress. Different mitigation measures can be adopted based on the research such as the use of anti-transpirants, PGRs, or similar substances, etc. Anti-transpirants aid in the conservation of irrigation water, and create an environment that is favorable for plant growth in aridity. Different internal and external factors that plants respond to their surroundings under stress are managed by plant growth regulators. Several conservation practices traditionally followed like mulching and rainwater harvesting can be adopted after extensive research and standardization of new techniques. There are new findings on the effect of mulching and deficit irrigation for effective conservation and mitigation of abiotic stress. This review gives an insight into newly reported chemicals, methods and effects of various concentrations and applications on stress management of fruit crops.
***Keywords* :** Mitigation; organic compounds; abiotic stress; mulching; PGRs.

Introduction

Any internal or external hindrance that lowers a plant's capacity to convert energy from light to biomass and limits its rate of photosynthetic activity is referred to as stress (Umar *et al.*, 2021). Stress in fruit plants is induced by living or nonliving agents. Stress caused by living agents in plants is biotic stress; if it is by nonliving agents, it is called abiotic stress. Management of stress and the challenges incurred by the plants are included in mitigation measures and conservation practices. Mitigation measures are the tactics or methods employed to reduce the effect on plants and thereby yield reduction. A plant can react to stress in a variety of ways. These include varying growth rates and yield due to changes in gene expression and cellular metabolism.

The increasing severity of climate change scenarios has recently been a major worldwide worry. The agricultural sector in India is severely threatened by climate change since half of its land is rainfed. Crop productivity, water availability, soil processes, and insect dynamics are all impacted by climate change (Pathak, 2023). Several independent studies have demonstrated that drought and rising temperatures can lower the yields of crops by up to fifty per cent (Lamaoui *et al.*, 2018).

Abiotic stressors include drought, soil conditions like salinity, alkalinity, ion toxicity, fertilizer toxicity, etc., flood and waterlogging, temperature stress (high-hot, low- cold and chilling), and pollution as increased levels of CO_2, industrial wastes with significant heavy metal deposition represent a danger to the world food security. Agricultural land subjected to any of these stresses experiences changes in the morphological, biochemical, and physiological processes of plants. These changes result in reduced rates of germination, growth, photosynthesis, respiration, disruption of hormone and enzyme reactivity, increased oxidative stress, and ultimately, lower crop productivity. It is expected that as climate change events increase in the future, the frequency of these pressures will gradually increase. To improve crop resilience and productivity while reducing the negative consequences of these issues on the agriculture sector, it is imperative to develop effective measures. A variety of tactics have been used, such as mitigation measures and conservation practices to create cultivars that are resistant to climate change (Oyebamiji *et al.*, 2024).

Stress management is an important aspect to be dealt with current change in the climate scenario. Mitigation is done by the use of anti-transpirants, PGRs, or conservation practices like mulching, rainwater harvesting etc. Chemicals or the organic compounds that are applied to the leaves of the plants will reduce the transpiration. Different chemicals are used commercially in fruit crops for protection from heat and sunburn. These compounds are of different types which impart a cooling effect to the plants by mitigating heat stress (Dash *et al.*, 2020). Plants are negatively impacted in their output by abiotic stressors at crucial growth phases (Laxman and Bhatt, 2017). Organic chemical substances known as plant growth regulators, when applied in small quantities, can significantly change or regulate a variety of physiological processes in a plant. The detrimental effects of abiotic stress on fruit crops can be effectively mitigated by exogenous treatments of plant growth regulators such as ethylene, gibberellins, auxin, jasmonic acid, salicylic acid etc. (Zahid *et al.*, 2023). Mulch has demonstrated beneficial effects on fruit crop development, production, and quality. Additionally, mulch reduces environmental stressors, creating a climate that is ideal for plants (Shah *et al.*, 2022). Organic type materials like leaves, woodchips, and straw are often used conventionally in orchards to cover the soil. Plastic mulch is a surface-level physical barrier applied to the soil near the plant. Plastic is an efficient mulching material made up of environmental friendly biodegradable plastics and non-biodegradable plastics (Zhang *et al.*, 2021; Iqbal *et al.*, 2020; Retamal-Salgado *et al.*, 2022). The goal of the current review is to outline the impacts of stress on the primary physiological processes of plants as well as strategies and conservation methods for reducing these negative effects.

Stress and its effect on fruits

Fruit crops are affected by different stress conditions. There are abiotic and biotic stress factors affecting the growth and development of fruits. Common stress conditions for fruit crops are abiotic (drought, high and low temperature, stresses due to high water-flood, waterlogging, soil salinity etc. These stressors cause morphological, physiological, and biochemical alterations that impact fruit quality as well as vegetative and reproductive responses. Different cultivars and crop species will probably exhibit distinct processes and reactions to abiotic stress (Kopecka *et al.*, 2023). Abiotic stress-related reductions in crop production are anticipated to worsen as climate change and other factors create more unfavorable environmental conditions in areas that have historically been used for farming (Godoy *et al.*, 2021). Abiotic stress can lower yields by an average of more than 60% when compared to recorded yields.

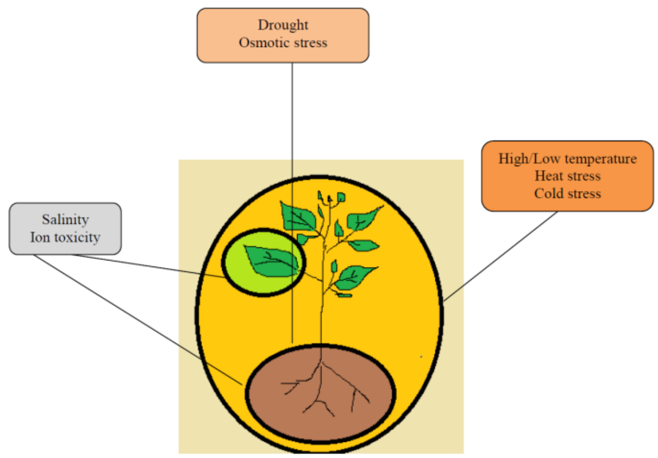

Fig. 1 : Different stress on plants

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Stress management in fruit crops

Mitigation measures

Fruits are an essential part of human diets and offer substantial nutritional benefits. However, abiotic stresses have a detrimental effect on agricultural output, especially during critical growth stages, and climate change is projected to increase the frequency and intensity of these stresses. For tropical fruit crops in India, floods, high temperatures, and salinity are the main abiotic stress factors. The morphology, anatomy, physiology, and biochemistry of these crops are all altered by the abiotic stress in various ways, which ultimately impacts the crops' quality and output. To mitigate the negative impacts of abiotic stressors, techniques including applying anti-transpirants, micro-irrigation, applying growth regulators, applying mulching to the soil, adding soil amendments, and controlling nutrient levels should be used (Haokip *et al.*, 2023). Creating integrated, crop-specific adaptation techniques should be the main focus. The best strategy for preserving fruit crop productivity and output in the face of abiotic stressors is to combine all possible adaptation choices.

Application of anti-transpirants in stress management

Anti-transpirants are chemicals or chemical-based substances that are sprayed on leaves to lessen transpiration and increase the water potential of the plant. This is reportedly used by different researchers and farmers to manage stress in fruit crops. There are two kinds of anti-transpirants.

1. Inhibitors of metabolism
2. Antiperspirants that form a film

Without influencing the intake of carbon dioxide, metabolic inhibitors decrease stomatal opening and boost leaf resistance to water vapour transport. Aspirin, ABA (abscisic acid), and phenyl mercury acetate are a few examples. Film-forming anti-transpirants create a colorless layer on leaf surfaces, allowing gas diffusion but not water vapour. Wax and silicone oil are two examples. These substances help the plants withstand dryness by slowing down shoot growth and speeding up root growth (Ekka *et al.,* 2022). Antiperspirants Increasing temperature leads to severe stress in berries of grapes thereby altering alcohol content.

Mphande *et al.,* 2020 reported different types of anti-transpirant classes like metabolic, reflective and film-forming. He also mentioned that different anti-transpirants like kaolin is used for fruit crops like apples, grapes, pomegranates, nectarines and peaches, pears, strawberries, mango, pistachio, banana, gooseberry, citrus, walnut, kaolin and calcium carbonate for a sweet cherry, banana, pomegranate, citrus calcium carbonate for grapes, ABA for apple, grapes, litchi and citrus, Chitosan for grapes, pomegranate, blueberry, oranges, Di-1-p-menthene for kiwifruit, apples, citrus grapes, sweet cherry, strawberry.

Moroni *et al.,* 2020 evaluated the effectiveness of naturally occurring terpene polymer on the water-use efficiency of red raspberry (*Rubus idaeus* L.) cv. Tulameen leaves in a controlled temperature range of 25–40 °C. When applied to the lower leaf surface, the film was most effective in reducing transpiration (E). Following the application of di-1-p-menthene, there was a reduction in both leaf net assimilation (A) and stomatal conductance (g). Consequently, there was no improvement in intrinsic transpiration efficiency (A/g) or instantaneous transpiration efficiency (A/E, or the ratio of net carbon fixation to water loss). Because of stomatal closure, there was very little gas exchange in both treated and untreated leaves at 40 °C. Only in the early phases of the fruit's development the anti-transpirant effectively reduced the water loss from berries when transpiration rates were naturally elevated.

Sharafi *et al.,* 2020 studied the effects of antiperspirants and shade nets on the physiological traits of Malas Saveh cultivar pomegranate fruits and found that talc and TSZK (talc, silica, zinc oxide, and kaolin) enhanced fruit diameter by 10% and 5%, respectively. Sunburn of the fruit was completely avoided by using the shade net and vitamin C increased by five to eight percent when silica, talc, and shading net were utilized. Fruit TSS was raised by two to three percent using shading net, talc, kaolin, and TSZ (talc, silica, zinc oxide). By lowering the fruit's temperature by five to seven degrees Celsius, the anti-transpiration ingredients, nevertheless, enhanced some of the fruit's qualitative traits and skin color, reducing the quantity of burnt fruits.

Abd El-Naby *et al.,* 2020 experimented on Valencia orange trees cultivated in Egypt using magnesium carbonate, kaolin, and calcium carbonate, silicate, and hydroxide and found that the calcium silicate treatment had effectively mitigated heat stress by increasing macro elements like nitrogen (2.54 g/100g) and Mg (0.510 g/100g). Additionally, it was evident that all calcium materials increased the calcium content and peel protein, which reduced the proportion of fruits with sunburns.

Table 1 : Different anti-transpirants on mitigation of stress

Serial No.	Anti-transpirants	Fruit crop	Effect	References
1.	Kaolin at 6%	Apple cultivars of Golab and Shafi-Abadi	33.3% increase in apple fruit weight in deficit (100% ETc) irrigation	Faghih *et al.,* 2021
2.	Kaolin	Touriga-Franca (TF) and Touriga-Nacional (TN) grapevine varieties	Enhanced water use efficiency (23 % in Douro region and 13 % in Alentejo region), carbon assimilation rates (PN; 72 % in Douro region and 25 % in Alentejo region) in high heat stress	Bernardo *et al.,* 2021
3.	Kaolin at 6%	Keitt mango	Enhanced the leaf surface area and tree canopy volume, the number of sunburned fruits was significantly reduced	Hamdy *et al.,* (2022)
4.	Calcium nitrate at 4% and 6% and kaolin at 6%	Pomegranate cv. Wonderful	Percentages of fruit cracking and sunburn were lessened	Al-Saif *et al.,* 2022

5.	Kaolin at 3%	Washington Navel Orange	High water use efficiency, fruit yield and yield efficiency	Ennab, 2023
6.	Calcium carbonate and anti-UV treatments	Citrus	Reduced leaf temperature to 35℃ and 32℃ respectively than control (39 ℃)	Bernardi *et al.*, 2023
7.	Mepiquat chloride at 300 ppm combined with Green Miracle at 4 cm/l	Flame seedless grapes	Better growth and yield under heat stress conditions	Fahmy, 2023

Application of PGRs in stress management

Chemicals called plant growth regulators are used to change a plant's development in a variety of ways, including by promoting branching, decreasing shoot growth, increasing return bloom, removing extra fruit, or changing the ripeness of the fruit. PGR performance is influenced by a wide range of factors, such as the degree to which the chemical is absorbed by the plant, the age and vigor of the tree, the dosage, the timing, the cultivar, and the weather before, during, and after application. substances linked to auxins, gibberellins and inhibitors of gibberellin production, cytokinins, abscisic acid, and substances altering the ethylene status are the five classes into which plant growth regulators fall.

Awan *et al.*, 2017 Abscisic acid, ethylene, and jasmonic acid are examples of plant growth regulators that are crucial to the reaction of plants to abiotic stress. Furthermore, plants use their hormones to sense adverse environmental circumstances. By producing phytohormones through biosynthesis, plants provide themselves with the ability to adjust to their environment. While ethylene aids plants in drought, overwatering, cold, and salinity, abscisic acid helps plants deal with these conditions. Plants can heal from mechanical damage and drought stress with the help of jasmonic acid. Abiotic stressors such as heat, salinity, and water shortage cause plants to create enzymes that, depending on their genetic makeup, produce plant growth regulators, which may eventually assist the plants in demonstrating resilience against stress or mitigation.

Sabagh *et al.*, 2021 have mentioned the auxin-mediated stress management in plants as the interaction with calcium and ROS, cytokinin persuaded stress resistance, gibberellins suppression and up-regulation for stress response, abscicic acid-induced stress tolerance and interaction of ethylene for stress relief.

Sharma *et al.*, 2020 reported the use of different hormones and growth regulators like auxin, gibberellins, cytokinins, γ-Aminobutyric acid, brassinosteroids, jasmonates, nitric oxide, melatonin, polyamines to mitigate heat stress in plants.

Cai *et al.*, 2020 investigated the effect of 10 mg l^{-1} 5-aminolevulinic acid (ALA) on strawberry drought tolerance and its potential mechanisms which is treated with 15% polyethylene glycol 6000 to induce stress. Their results showed that ALA greatly reduced PEG-inhibited plant development and enhanced xylem sap flow and water absorption, suggesting that ALA lessens the negative effects of osmotic stress on strawberry plants. Another investigation in strawberries with spray application of 30 µM selenomethionine (SeMet) and mild drought stress showed that it enhanced certain antioxidant enzymes like ascorbate Peroxidase (2.39 IU/mg protein), superoxide dismutase (35.4 IU/mg protein), peroxidase (3.80 IU/mg protein) and catalase (3.73 IU/mg protein) in the leaves than control which in turn increased fruit quality during drought stress Wang *et al.*, 2022. A foliar spray of 2.5 mL of 200 µM Abscisic acid reportedly mitigated the effect of salt stress in strawberries by increasing the CO2 assimilation rate and transpiration rate after 90 days Crizel *et al.*, 2020.

Table 2 : Different PGRs on mitigation of stress

Serial No.	PGRs	Fruit crop	Effect	References
1.	0.5 mM γ-aminobutyric acid (GABA)	Apple	Most effective at relieving drought. It reduced the relative electrical conductivity and MDA content of leaves induced by drought stress and significantly increased the relative water content of leaves. Increased the photosynthetic rate under drought	Liu *et al.*, 2021
2.	10 mM aqueous AA solution	Apple	Exogenous application of AA under drought conditions alleviated the influence of drought stress on plant growth indicators and the fresh weight of whole plants.	Sun *et al.*, 2022

3.	Gibberellic acid (GA3) at 49 g ha^{-1}	Sweet orange	Reducing osmotic and oxidative stress of citrus greening disease and mitigation of citrus greening disease symptoms	Shahzad *et al.*, (2024)
4.	BaZFP924 protein	Thompson Seedless grapes	Higher plant height (203.00 cm) and better growth during high temperature stress	Wu *et al.*, 2024
5.	GA_3 (0.1%)	Guava	Enhanced guava seed germination and seedling development in the presence of heat and osmotic stress	Hosseini *et al.*, 2020

Stress management in fruit crops- 2.2. Conservation practices

Throughout their lives, plants are subjected to unfavorable environmental conditions that negatively impair their growth and significantly reduce crop output. Fruit trees are perennial crops that are subjected to a variety of challenges for an extended period after planting. It would be difficult for the trees to recover if they were seriously harmed by environmental pressures, which would slow down their growth and decrease the amount of fruit they produce. Water stress can be mitigated by adopting suitable soil moisture conservation measures (Bakshi *et al.*, 2022). Using chemicals and plant bio-regulators in conjunction with cultural practice management can effectively handle a variety of abiotic challenges.

Mulching

Mulching is the process of protecting moisture and enhancing the condition of the soil by covering it with mulches like bark, wood chips, leaves, and other organic materials.

Berrios *et al.*, 2024 studied the effect of geotextile mulch under deficit irrigation on the response of mandarin cv. Clemenvilla found that the effect of minimized irrigation is reduced by the mulch which leads to less water stress for the trees.

An experiment on rice straw as organic mulch showed that adding more rice straw to the mulching process boosted the orange crop's productivity, quality, and water productivity values. Partial root-drying and adding 100% of the required water also had positive effects. Increased organic mulching of rice straw resulted in less evaporation from the soil surface and more moisture content staying in the root zone for as long as possible. This decreased the amount of time the roots were exposed to water stress and increased the amount of water and nutrients that were added to the soil for fertilization. As the rate of evaporation from the soil drops, so does the amount of accumulated salts. This is why increasing the amount of organic mulching with rice straw also resulted in a decrease in the buildup of soil salts Abdelraouf *et al.*, 2020.

Gholami *et al.*, 2023b claimed that mulching of olive cv. Zard with olive pomace conserved moisture during severe water deficit conditions and resulted in the highest chlorophyll a + b levels (0.49 mg g^{-1} FW) in olive leaves.

Tadayon and Hosseini (2022) investigated the effect of mulching and shade net and concluded that the application of wheat straw organic mulch in a specific manner had a significant impact on the increase and retention of average soil moisture content (79.9%) of forty-five-year-old fig trees. A study by Jat *et al.*, 2021 revealed that deficit irrigation at 50% ETc (DI50) along with silver black improved the quality of guava (VNR Bihi) under water stress. A field experiment with polyethylene mulch found the highest water use efficiency (28.43 kg/hamm) in the strawberries.

Table 3 : Different mulches for mitigation of stress

Serial No.	Mulches	Fruit crop	Effect	References
1.	Straw and polyethylene	Olive	Decreased water stress increased relative water content and chlorophyll content under less irrigation	Gholami and Zahedi (2020a)
2.	Straw mulch	Apple	Controlled soil water content and soil temperature under severe water deficit conditions.	Liao *et al.*, 2021
3.	Silver on black plastic mulch	Strawberry	High water use efficiency (17.5 kg m^{-3}) and yield (60.2 t ha^{-1})	Sarıdas *et al.*, 2021
4.	Sugarcane leaf	Mango	Increased irrigation water use efficiency of 13.6% under severe deficit irrigation.	Liu *et al.*, 2022
5.	Plastic mulch and organic mulch- dried Kans grass	Pomegrana te	Better fruit yield and quality under water stress conditions	Beelagi *et al.*, 2023

	(*Saccharum spontaneum* L.)			
6.	Organic mulch	Mango	Lowest water stress percentage (9%) at 50% deficit irrigation and organic soil mulch in dry environment condition	Alhashimi *et al.*, 2023

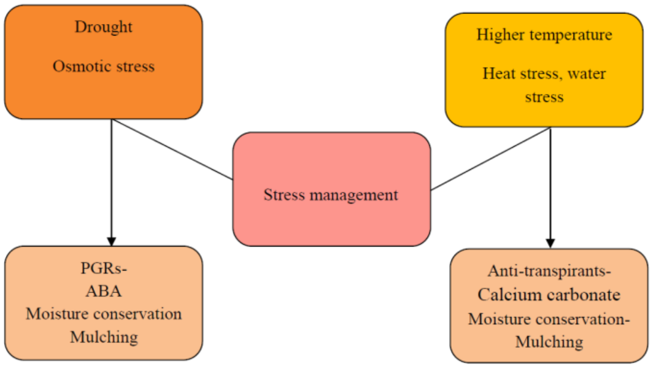

Fig. 2 : Major stress management strategies in fruits.

Conclusion

Different studies revealed the mitigation of stress in fruit plants for resolving the crisis in horticulture and agriculture. Stress management is an interrelated and integrated aspect to deal with the issues of quality and quantity in fruit production. Increased water use efficiency, plant resistance to detrimental effects, improved uptake of nutrients, and proper physiological response to harsh conditions can be achieved using anti-transpirants and PGRs-like substances. Conservation practices like mulching offer a great balance in plant physical conditions. Emerging techniques are efficient in stress management and effective in increasing productivity during unfavorable conditions to plant.

References

Abdelraouf, R. E., El-Shawadfy, M., Fadl, A., & Bakr, B. (2020). Effect of deficit irrigation strategies and organic mulching on yield, water productivity and fruit quality of navel orange under arid regions conditions. *Plant Archives*, ***20***(1), 3505–3518.

Abd El-Naby, S. K. M., Abdelkhalek, A., Baiea, M. H. M., & Amin, O. A. (2020). Impact of spraying some chemical substances on protecting Valencia orange trees from heat stress injuries. *Plant Archives*, ***20***(2), 2265–2270.

Alhashimi, A., Al-Huqail, A. A., Hashem, M. H., Bakr, B. M., Fekry, W. M., Abdel-Aziz, H. F., et al. (2023). Using deficit irrigation strategies and organic mulches for improving yield and water productivity of mango under dry environment conditions. *Agriculture*, ***13***(7), 1415.

Al-Saif, A. M., Mosa, W. F., Saleh, A. A., Ali, M. M., Sas-Paszt, L., Abada, H. S., & Abdel-Sattar, M. (2022). Yield and fruit quality response of pomegranate (*Punica granatum*) to foliar spray of potassium, calcium and kaolin. *Horticulturae*, ***8***(10), 946.

Awan, F. K., Khurshid, M. Y., & Mehmood, A. J. (2017). Plant growth regulators and their role in abiotic stress management. *International Journal of Innovative Research in Biosciences*, ***1***, 9–21.

Bai, Y., Zhang, H., Jia, S., Huang, C., Zhao, X., Wei, H., et al. (2022). Plastic film mulching combined with sand tube irrigation improved yield, water use efficiency, and fruit quality of jujube in an arid desert area of Northwest China. *Agricultural Water Management*, ***271***, 107809.

Bakshi, P., & Wali, V. K. (2022). Mitigation strategies of abiotic stress in fruit crops. In B. K. Sinha & Reena (Eds.), *Abiotic & biotic stress management in plants* (pp. 261–288). CRC Press.

Beelagi, R., Singh, V. P., Jat, R., Singh, P. K., Rai, R., Singh, A., & Kumar, P. (2023). Enhancing the fruit yield and quality in pomegranate: Insights into drip irrigation and mulching strategies. *Plants*, ***12***(18), 3241.

Bernardi, L. G., Boaretto, R. M., Blain, G. C., & Mattos-Jr, D. (2023). Particle films improve photosynthesis of citrus trees under excess irradiance by reducing leaf temperature. *Physiologia Plantarum*, ***175***(1), 13844.

Berrios, P., Temnani, A., Zapata-Garcia, S., Sánchez-Navarro, V., Zornoza, R., & Perez-Pastor, A. (2024). Effect of deficit irrigation and mulching on the agronomic and physiological response of mandarin trees as strategies to cope with water scarcity in a semi-arid climate. *Scientia Horticulturae*, ***324***, 112572.

Bernardo, S., Dinis, L., Luzio, A., Machado, N., Gonçalves, A., Vives-Peris, V., et al. (2021). Optimising grapevine summer stress responses and hormonal balance by applying kaolin in two Portuguese Demarcated Regions. *OENO One*, ***55***(1), 207–222.

Cai, C., He, S., An, Y., & Wang, L. (2020). Exogenous 5-aminolevulinic acid improves strawberry tolerance to osmotic stress and its possible mechanisms. *Physiologia Plantarum*, ***168***(4), 948–962.

Crizel, R. L., Perin, E. C., Siebeneichler, T. J., Borowski, J. M., Messias, R. S., Rombaldi, C. V., & Galli, V. (2020). Abscisic acid and stress induced by salt: Effect on the phenylpropanoid, L-ascorbic acid and abscisic acid metabolism of strawberry fruits. *Plant Physiology and Biochemistry*, ***152***, 211–220.

Dash, P. K., Chase, C. A., Agehara, S., & Zotarelli, L. (2020). Heat stress mitigation effects of kaolin and S-abscisic acid during the establishment of strawberry plug transplants. *Scientia Horticulturae*, ***267***, 109276.

Di Vaio, C., Villano, C., Lisanti, M. T., Marallo, N., Cirillo, A., Di Lorenzo, R., & Pisciotta, A. (2020). Application of anti-transpirant to control sugar accumulation in grape berries and alcohol degree in wines obtained from thinned and unthinned vines of cv. Falanghina (*Vitis vinifera* L.). *Agronomy*, ***10***(3), 345.

Ekka, S. K., Bahadur, V., Mishra, S., Kujur, R., Kumar, M. R., & Singh, R. K. (2022). Use of antitranspirants and plant growth regulators in stress management of horticulture crops. *The Pharma Innovation Journal*, ***11***(9), 956–962.

Ennab, H. A. (2023). Effect of irrigation levels, mulching and kaolin on yield and fruit quality of Washington Navel orange trees grown in clay soil. *Annals of Agricultural Science, Moshtohor*, ***61***(1), 177–186.

Faghih, S., Zamani, Z., Fatahi, R., & Omidi, M. (2021). Influence of kaolin application on most important fruit and leaf characteristics of two apple cultivars under sustained deficit irrigation. *Biological Research,* ***54***, 1–15.

Fahmy, F. E. (2023). Effect of mepiquat chloride and some anti-transpiration agents on growth and productivity of Flame Seedless grapevine under heat stress conditions. *Egyptian Journal of Desert Research*, ***73***(2), 655–677.

Gholami, R., & Zahedi, S. M. (2020a). Effects of deficit irrigation and mulching on morpho-physiological and biochemical characteristics of Konservolia olives. *Gesunde Pflanzen,* ***72***(1), 49–55.

Gholami, R., Hoveizeh, N. F., Zahedi, S. M., & Arji, I. (2023b). Effect of organic and synthetic mulches on some morpho-physiological and yield parameters of 'Zard' olive cultivar subjected to three irrigation levels in field conditions. *South African Journal of Botany*, ***162***, 749–760.

Godoy, F., Olivos-Hernández, K., Stange, C., & Handford, M. (2021). Abiotic stress in crop species: Improving tolerance by applying plant metabolites. *Plants,* ***10***(2), 186.

Haokip, S. W., Sheikh, K. H. A., Gonmei, G., Jamoh, O., & Wangchu, L. (2023). Abiotic stresses in fruit crops and their mitigation strategies. In *Abstracts of the International Conference on Next-Gen Preparedness for Food Security and Environmental Sustainability* (Abstract No. 22, p. 332). Assam Rice Research Institute.

Hamdy, A. E., Abdel-Aziz, H. F., El-Khamissi, H., AlJwaizea, N. I., El-Yazied, A. A., Selim, S., & Elkelish, A. (2022). Kaolin improves photosynthetic pigments, antioxidant content, and decreases sunburn of mangoes: Field study. *Agronomy,* ***12***(7), 1535.

Hosseini, M. S., Zahedi, S. M., Hoveizeh, N. F., Li, L., Rafiee, M., & Farooq, M. (2020). Improving seed germination and seedling growth of guava under heat and osmotic stresses by chemical and hormonal seed treatments. *Bragantia,* ***79***, 512–524.

Iqbal, R., Raza, M. A. S., Valipour, M., Saleem, M. F., Zaheer, M. S., Ahmad, S., & Nazar, M. A. (2020). Potential agricultural and environmental benefits of mulches—A review. *Bulletin of the National Research Centre,* ***44***, 1–16.

Jat, R., Singh, V. P., Rai, R., Singh, O., & Singh, P. K. (2021). Effect of deficit irrigation regimes and mulching on VNR Bihi guava agronomical and fruit quality performance. *Biological Forum,* ***13***, 153–159.

Kopecka, R., Kameniarova, M., Černý, M., Brzobohatý, B., & Novák, J. (2023). Abiotic stress in crop production. *International Journal of Molecular Sciences,* ***24***(7), 6603.

Lamaoui, M., Jemo, M., Datla, R., & Bekkaoui, F. (2018). Heat and drought stresses in crops and approaches for their mitigation. *Frontiers in Chemistry,* ***6***, 26.

Laxman, R. H., & Bhatt, R. M. (2017). Abiotic stress management in fruit crops. In P. Minhas, J. Rane, & R. Pasala (Eds.), *Abiotic stress management for resilient agriculture* (pp. 399–412). Springer.

Liao, Y., Cao, H. X., Xue, W. K., & Liu, X. (2021). Effects of the combination of mulching and deficit irrigation on the soil water and heat, growth and productivity of apples. *Agricultural Water Management,* ***243***, 106482.

Liu, C., Wang, H., Zhang, X., Ma, F., Guo, T., & Li, C. (2021). Activation of the ABA signal pathway mediated by GABA improves the drought resistance of apple seedlings. *International Journal of Molecular Sciences,* ***22***(23), 12676.

Liu, X., Zhang, Y., Leng, X., Yang, Q., Chen, H., Wang, X., & Cui, N. (2022). Exploring the optimisation of mulching and irrigation management practices for mango production in a dry hot environment based on the entropy weight method. *Scientia Horticulturae,* ***291***, 110564.

Mphande, W., Kettlewell, P. S., Grove, I. G., & Farrell, A. D. (2020). The potential of antitranspirants in drought management of arable crops: A review. *Agricultural Water Management,* ***236***, 106143.

Moroni, F. J., Gascon-Aldana, P. J., & Rogiers, S. Y. (2020). Characterizing the efficacy of a film-forming antitranspirant on raspberry foliar and fruit transpiration. *Biology,* ***9***(9), 255.

Oyebamiji, Y. O., Adigun, B. A., Shamsudin, N. A. A., Ikmal, A. M., Salisu, M. A., Malike, F. A., & Lateef, A. A. (2024). Recent advancements in mitigating abiotic stresses in crops. *Horticulturae,* ***10***(2), 156.

Pathak, H. (2023). Impact, adaptation, and mitigation of climate change in Indian agriculture. *Environmental Monitoring and Assessment,* ***195***(1), 52.

Retamal-Salgado, J., Loor, B., Hirzel, J., López, M. D., Undurraga, P., Zapata, N., et al. (2022). Chlorophyll fluorescence and fruit quality response of blueberry to different mulches. *Agronomy,* ***12***(7), 1702.

El Sabagh, A., Mbarki, S., Hossain, A., Iqbal, M. A., Islam, M. S., Raza, A., et al. (2021). Potential role of plant growth regulators in administering crucial processes against abiotic stresses. *Frontiers in Agronomy,* ***3***, 648694.

Sarıdaş, M. A., Kapur, B., Çeliktopuz, E., Şahiner, Y., & Kargı, S. P. (2021). Land productivity, irrigation water use efficiency and fruit quality under various plastic mulch colors and irrigation regimes of strawberry in the eastern Mediterranean region of Turkey. *Agricultural Water Management,* ***245***, 106568.

Shah, S. T., Ullah, I., Basit, A., Sajid, M., Arif, M., & Mohamad, H. I. (2022). Mulching is a mechanism to reduce environmental stresses in plants. In *Mulching in agroecosystems: Plants, soil & environment* (pp. 353–376). Springer Nature Singapore.

Shahzad, F., Livingston, T., & Vashisth, T. (2024). Gibberellic acid mitigates Huanglongbing symptoms by reducing osmotic and oxidative stress in sweet orange. *Scientia Horticulturae,* ***329***, 112976.

Sharafi, Y., Emarlou, A., & Tabatabaei, S. J. (2020). Influence of anti-transpirants and shading net on physiological traits of Malas Saveh pomegranate fruit. *Iranian Journal of Horticultural Science and Technology,* ***21***(4), 383–394.

Sharma, L., Priya, M., Kaushal, N., Bhandhari, K., Chaudhary, S., Dhankher, O. P., et al. (2020). Plant growth-regulating molecules as thermoprotectants: Functional relevance and prospects for improving heat tolerance in food crops. *Journal of Experimental Botany,* ***71***(2), 569–594.

Sun, T., Zhang, J., Zhang, Q., Li, X., Li, M., Yang, Y., & Zhou, B. (2022). Exogenous application of acetic acid enhances drought tolerance by influencing the MAPK signaling pathway induced by ABA and JA in apple plants. *Tree Physiology,* ***42***(9), 1827–1840.

Tadayon, M. S., & Hosseini, S. M. (2022). Shade net and mulching measures for improving soil and plant water status of fig trees under rainfed conditions. *Agricultural Water Management*, ***271***, 107796.

Umar, O. B., Ranti, L. A., Abdulbaki, A. S., et al. (2022). Stresses in plants: Biotic and abiotic. In M. Rahman (Ed.), *Current trends in wheat research* (pp. 399–412). IntechOpen.

Wang, B., Yang, W., & Shan, C. (2022). Effects of selenomethionine on the antioxidative enzymes, water physiology and fruit quality of strawberry plants under drought stress. *Horticultural Science*, ***49***(1), 10–18.

Wu, J., Zhong, H., Ma, Y., Bai, S., Yadav, V., Zhang, C., et al. (2024). Effects of different biostimulants on growth and development of grapevine seedlings under high-temperature stress. *Horticulturae*, ***10***(3), 269.

Zahid, G., Iftikhar, S., Shimira, F., Ahmad, H. M., & Kacar, Y. A. (2023). An overview and recent progress of plant growth regulators (PGRs) in the mitigation of abiotic stresses in fruits: A review. *Scientia Horticulturae*, ***309***, 111621.

Zhang, H., Miles, C., Gerdeman, B., LaHue, D. G., & DeVetter, L. (2021). Plastic mulch use in perennial fruit cropping systems—A review. *Scientia Horticulturae*, ***281***, 109975.