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Use of antitranspirants in ameliorating drought stress in fruit crops

Arjoo, Rajat and Shreya

Abstract

The productivity, survival, and reproductive biology of fruit trees and crops are significantly influenced by environmental conditions. Drought, high heat, shortage of water, a decline in the quality of irrigation water, and soil and water salinity are all difficulties that are becoming more severe. Due to the rapid and unpredictability of the effects of biotic and abiotic stresses, it is becoming increasingly difficult for horticulture experts and farmers to adapt to challenges posed by them. Drought stress is considered to be the greatest threat to food security in the foreseeable and future climates. Mulching, drip watering, Water conservation, the use of growth retardants, adequate fertiliser management, the use of antitranspirants and PGR, and the use of drought-tolerant rootstocks are some strategies for addressing these issues. The use of antitranspirants is one of these undervalued methods that decreases transpiration and increases the water use efficiency (WUE) of fruit crops to alleviate drought stress, and it deserves more consideration.

Keywords: Antitranspirants, drought, transpiration, WUE, abiotic stress

Introduction

Future crop productivity and global food security will be hindered by increasingly severe and frequent droughts and other abiotic stresses (IPCC, 2018) [30], and antitranspirants (ATs) may play a significant role in alleviating drought stress in this context. About 80% of the world's cropland is dependent on rain-fed agriculture and is susceptible to droughts and generate over 60% of the world's food. (Nellemann *et al.*, 2009) [22]. Drought stress produces dehydration of plant cells and tissues, a deficiency in nutrient intake, and a reduction in carbon dioxide assimilation owing to stomatal closure, which leads to starvation (Karimi *et al.*, 2015) [13]. The development of dehydration stress disrupts physiological processes, including all transitions in the plant as a whole; leaf development and gas exchange at the level of organs; and carbon fixation at the level of cell components; to the point where the stress ultimately reduces plant growth and yield (Chaves and Oliveira, 2004) [20].

To counteract looming vulnerability in the production of fruit crops, a variety of alternatives are available, such as enhancing the water consumption efficiency through irrigation, rainwater collection, and agronomic strategies such as the use of antitranspirants (ATs). In addition to drip irrigation and sprinkler irrigation, new research is investigating the use of environmentally friendly chemicals that may increase the soil's capacity to retain water or slow the rate of evaporation (antitranspirants), thereby allowing fruit plants to survive when there is insufficient water. These compounds can be utilized as necessary. The bulk of conventionally grown agricultural plants lack the physiological adaptations required for survival under situations of high water stress. (Guillen *et al.*, 2013) [12]. Less than five percent of the water received by a plant's roots is utilized for growth and development; the other ninety-five percent is lost through transpiration. (Dawson *et al*, 1996; Prakash and Ramachandran, 2000) [6, 26]. In semiarid environments, where transpiration regularly exceeds water absorption, it is possible to mitigate the negative impacts of water deficit and increase crop output by reducing the quantity of water lost to evaporation. (Poljakoff-Mayber and Gale, 2012) [25]. Consequently, the use of ATs is an underutilized agronomic strategy that has the potential to significantly contribute to the relief of drought stress in horticultural crop production.

Antitranspirants: ATs are chemicals applied to plant leaves that decrease transpiration and, as a result, raise the water potential of the plant. (M Del Amor *et al.*, 2010) [9]. Depending on the type of antitranspirant used and the length of time since its application, the degree of transpiration reduction may range from 80% to 0%. Between 24 hours, reduced transpiration is observable, and it progressively recovers within 10 to 20 days.

Despite the fact that AT products already have commercial applications in horticulture, there is little evidence to suggest that AT products are being used to mitigate the impacts of drought (for example, to protect fruits from sunburn, fruit ripening and to protect against pests). There are four known categories of antitranspirants: metabolic antitranspirants, which include compounds that inhibit or restrict stomatal opening; film-forming compounds, which create an external physical barrier over the leaves, thereby retarding water vapour evaporation; reflecting materials; and growth retardants like cycocel.

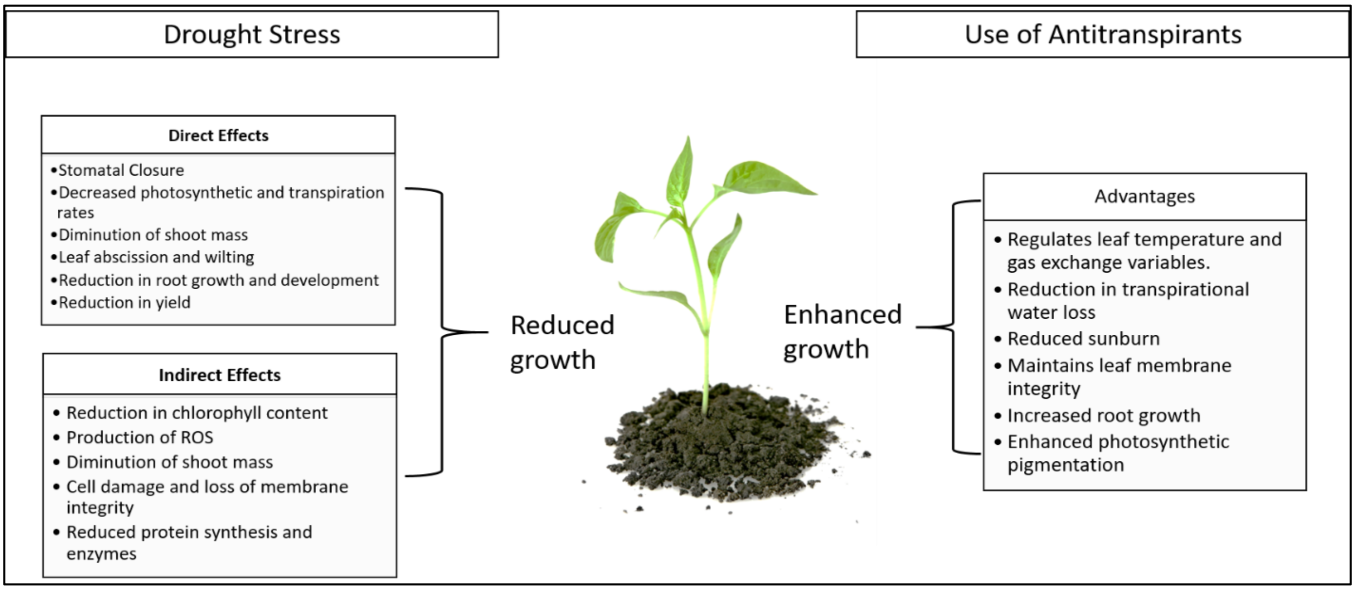

Fig 1: Effect of drought on plants ant its mitigation by ATs

Types of Antitranspirants used in fruit crops

Reflective Antitranspirants: As its name suggests, reflecting ATs rely on reflection to reduce leaf temperature, resulting in a decrease in transpiration rate. The application of reflective ATs modifies the foliar characteristics that absorb, reflect, and emit light, which in turn modifies the factors that regulate leaf temperature and gas exchange. In order for transpiration to occur, there must be a differential between the vapour pressure of the leaf and the surrounding air. (Medina and Gilbert, 2015; Bloomfield *et al.*, 2019) [17, 3]. When the thermal energy balance of a leaf decreases, the vapour pressure differential between the leaf and the surrounding air also decreases. This decreases the rate of transpiration.

Currently, kaolin, which is an aluminosilicate $Al_4Si_4O_{10}$ (OH_8), is the most popular form of reflecting AT. When applied to the leaf's surface, it forms a white layer that modifies the optical characteristics of the targeted leaf. According to scientific studies, kaolin reduces leaf temperature by more than 3 degrees Celsius. By 5.6 degrees Celsius in walnut (Gharaghani *et al.*, 2018) [10] and between 3 and 4 degrees Celsius in Valencia orange, corresponding to a 22–28% reduction in transpiration. Moreover, kaolin was able to reduce the detrimental effects of drought stress, such as a significant reduction in sunburn on fruit and foliage and an increase in the chlorophyll content of Persian walnut. (Mahmoudian *et al.*, 2021) [16].

The use of kaolin boosted the antioxidant capacity of berries, and this augmentation was shown to be consistent with the raised secondary metabolite content reported during the summer stress. (Dinis *et al*., 2016) [7]. If the treated plant is not experiencing the impacts of drought, kaolin may have the reverse effect on leaf temperature. Brillante *et al*., (2016) [4] reported a 1.47 °C rise in leaf temperature under well-watered circumstances and a 1.30 °C drop under water-stressed conditions in grape plants sprayed with kaolin. The rise in leaf temperature in well-watered conditions is due to kaolin's ability to close stomata, hence reducing the cooling effect of transpiration. This shows that crop physiology must be exposed to drought stress in order to counteract the negative impacts of high temperature. The most prevalent use of kaolin in fruit growing is to protect the fruit from sun damage. Additionally, kaolin is employed in the eradication of insect pests, and research has demonstrated that it is effective against a number of insect species that have been studied.

Two calcium-based reflecting ATs, $CaCO_3$ and CaO, have a similar method of action to kaolin. Few research have been conducted on these ATs, and even fewer have been conducted on horticultural species (such as bananas (El-Khawaga, 2013) [8] and grapes. In grapes and coffee, CaO was revealed to have longer-lasting physiological effects than $CaCO_3$. Following treatment for 28 days, the reflectance of $CaCO_3$ reduced by 31%, whereas that of CaO decreased by 17%. CaO maintained lower leaf temperature, gas exchange variables, chlorophyll content, and reflectance, in addition to a greater chlorophyll content (da Silva *et al.*, 2019) [5]. Magnesium carbonate ($MgCO_3$) (Al-Desouki *et al.*, 2009) [2] and magnesium silicate are examples of reflective ATs that have garnered far less attention than calcium compounds (MgO_3Si) (Schrader, 2011) [27].

Film-forming Antitranspirants: By producing a transparent layer on the leaf's surface, film-forming antitranspirants limits transpiration. These antitranspirants, however, have no effect on the gas exchange mechanisms. In contrast to metabolic antitranspirants, film-forming antitranspirants produce an impenetrable layer on leaf surfaces. The bulk of known film-forming ATs are water-emulsifiable organic polymers that form films during spray drying. The coatings reduce transpirational water loss by serving as a physical barrier across stomata. Di-1-p-menthene (pinolene) is a distillate obtained from pine resin and is the most widely used film-forming AT. Waxy paraffinic hydrocarbons, such as Folicote, Mobileaf, and Transfilm, are also included in this class. Vegetable oils and acrylic polymers are examples of chemicals for which little investigation has been conducted. The former may become popular and widespread due to the fact that they are not only cheaper but also more accessible than manufactured items (Granger and Trager, 2002) [11].

The fact that film-forming antitranspirants have an effect that lasts for a longer period of time is one of the benefits they provide. Antitranspirants that build a film on the surface can maintain their efficacy for up to 15–20 days. It is 30 days for acrylic polymer, but less than nine days for poly-1-p-menthene (Plaut *et al.*, 2004) [24]. The lack of a perfect material that has selective permeability is the primary challenge that must be addressed when dealing with film-forming antitranspirants (allowing CO_2 to pass through while obstructing the passage of water). Due to the fact that the solubilities and diffusion coefficients of gases in polymer films are often related to the molecular weights of the gases, it seems unlikely that an ideal polymer material for antitranspirant activity would ever be discovered. Even if a material with a high CO_2 permeability were found, it would be difficult to fulfil the requirements for additional features such as low toxicity, constant sticking/spreading properties, sunlight stability, flexibility, and durability.

Metabolic or Stomata-closing Antitranspirants: Metabolic ATs are a class of hormone- or hormone-like substances that drive guard cells to partly shut in response to water stress (AbdAllah *et al.*, 2018) [1]. Exogenous abscisic acid (ABA), either in its naturally-occurring bioactive form (S)-cis-ABA (s-ABA) or as a commercially available mix with the synthetic (R)-cisABA, is one of the most notable members of this class (Li J *et al*., 2017) [15] ABA signalling induces an outflow of ions and water from guard cells via osmosis, resulting in flaccidity of the cells and eventual stomatal closure (Kim *et al.*, 2012; Munemasa *et al.*, 2015) [14, 21]. As an antitranspirant, ABA is perhaps the most popular product in this category.

Chitosan and fulvic acid are also utilized, but they are not only ATs; they are biostimulants that enhance the absorption of both major and trace elements in crops, including those that are constantly watered (Sootahar *et al.*, 2019) [28]. Chitosan is a naturally occurring, biodegradable polysaccharide polymer that is an important component of the exoskeletons of crustaceans and insects. Fulvic acid, on the other hand, is a byproduct of organic matter breakdown that dissolves in both alkaline and acidic solutions. Chitosan given through foliar spray at a dosage of 100 mg/L enhanced leaf membrane integrity and increased antioxidant enzyme levels in Apple under circumstances of water stress (Yang *et al*., 2009) [30]. In addition to altering gas exchange variables, chitosan and fulvic acid confer drought resistance through their biostimulatory characteristics. They stimulate the elimination of reactive oxygen species and enhance the stability of cellular membranes by activating antioxidant activities. (Li *et al.*, 2017) [15].

Among others, there are fungicides such as phenyl mercuric acetate (PMA), herbicides such as 2, 4-D, Phosphon D, and atrazine, and metabolic inhibitors such as hydroxy sulfonates and potassium metabisulphite. In addition, growth hormones such as Ethrel, TIBA, and succinic acid are used. The rapid penetration of phenyl mercuric acetate (PMA) into mesophyll cells, where it affects the leaf's natural metabolism, was demonstrated to be damaging. PMA was a significant focus of metabolic AT research in the past. However, it continued to be used as a fungicide until it was banned in some nation's. India appears to be the only country where PMA may still be used as an A.T.

Growth Retardant Type Antitranspirants: Chemicals classed as growth retardants hinder new shoot development while promoting new root development. As a result, the plants are more resistant to dry circumstances. They are also capable of causing stomatal closure. E.g: ABA, Cycocel etc. The application of Cycocel to plants improves their overall water condition. They delay the leaf senescence processes. At a concentration of 500 ppm, Cycocel may alleviate drought stress and significantly enhance photosynthetic pigmentation (Memari *et al*., 2011) [19].

Inadequacies in current knowledge and limitations with antitranspirants use

1. Because ATs impede both transpiration and photosynthesis, they reduce not only the uptake of minerals from the soil but also the assimilation of carbon.
2. Negative consequences can be reduced by choosing appropriate ATs for a specific drought condition. When a dry phase coincides with the most drought-sensitive crop growth stage, metabolic ATs would be excellent, whereas film-forming ATs would be best for lengthy drought occurrences because to their longer-lasting effects (30–40 days, Plaut *et al.*, 2004) [24].
3. One of the longest-standing challenges in film forming type antitranspirants is discovering a product that allows more CO_2 through than water vapour.
4. However, most, if not all, of the research being done right now is only about ATs. An integrated approach is needed. For example, Meena *et al.*, (2016) [18] showed that pomegranates needed less water when shade nets and kaolin were used together.
5. It is expected that global warming will increase the risk of heat stress. This may lead film-forming ATs to perform a secondary function compared to those that reflect solar radiation and lower the leaf's heat burden by attenuating solar radiation.
6. In AT research, a cost-benefit analysis is essential. To make reasonable decisions, prospective adopters want more detailed, evidence-based information on the economic sustainability of using A.T.s in fruit production, specifically in horticulture.
7. The most major environmental issues related with kaolin use are the elimination of natural enemies along with pest management demonstrated that while
8. Kaolin decreased significantly the incidence of olive pests fruit fly (*Bactrocera oleae*) and black scale (*Saissetia oleae*), it also led to the deaths of their natural enemies (e.g. coccinellids or ladybird beetles) as well. (Pascual *et al.*, 2010) [23]

Conclusion

Plant breeders and crop physiologists are faced with a challenging task when trying to improve drought resistance in fruit crops. This is because drought resistance is a complicated genetic feature that involves numerous complex pathways. Antitranspirants play a very important part in the process of mitigating the effects of drought on fruit crops. They do this by significantly lowering the amount of water that is lost through transpiration and by improving a variety of gas exchange variables, both of which assist fruit plants in maintaining their life in adverse condition.

References

1. AbdAllah AM, Burkey KO, Mashaheet AM. Reduction of plant water consumption through anti-transpirants foliar application in tomato plants (*Solanum lycopersicum* L). Scientia Horticulturae. 2018;235:373-381.
2. Al-Desouki MI, El-Rhman IEA, Sahar AF. Effect of some antitranspirants and supplementery irrigation on growth, yield and fruit quality of sultani fig (*Ficus carica*) grown in the Egyption Western Coastal Zone under rainfed conditions. Research journal of agriculture and biological sciences. 2009;5:899-908.
3. Bloomfield JP, Merchant BP, McKenzie A. Changes in groundwater drought associated with anthropogenic warming. Hydrology and Earth System Sciences. 2019;23:1393-1408.
4. Brillante L, Belfiore N, Gaiotti F, Lovat L, Sansone L, Poni S, *et al*. Comparing kaolin and pinolene to improve sustainable grapevine production during drought. PLoS One. 2016;11:1-19.
5. da Silva PSO, de Oliveira Junior LFG, de Mattos EC, dos Santos Maciel LB, dos Santos MPF, Sena EDOA *et al*. Calcium particle films promote artificial shading and photoprotection in leaves of American grapevines (*Vitis labrusca* L.). Scientia Horticulturae. 2019;252:77-84.
6. Dawson T, Harvey C, Stork A, Traw B, Gregg J, Perkins C, *et al*. Physiological plant ecology: Ecophysiology and stress physiology of functional groups. The Quarterly Review of Biology, 1996;71:416-417
7. Dinis LT, Bernardo S, Conde A, Pimentel D, Ferreira H, Félix L, *et al*. Kaolin exogenous application boosts antioxidant capacity and phenolic content in berries and leaves of grapevine under summer stress. Journal of Plant Physiology. 2016;191:45-53.
8. El-Khawaga AS. Response of grand naine banana plants grown under different soil moisture levels to antitranspirants application. Asian Journal of Crop Science. 2013;5:238-250.
9. FM del Amor, Paula Cuadra-Crespo, David Walker J, José Cámara M, Ramón Madrid. Effect of foliar application of antitranspirant on photosynthesis and water relations of pepper plants under different levels of CO2 and water stress. Journal of Plant Physiology,
10. Gharaghani A, Mohammadi Javarzari A, Vahdati K. Kaolin particle film alleviates adverse effects of light and heat stresses and improves nut and kernel quality in Persian walnut. Scientia Horticulturae. 2018;239:35-40.
11. Granger A, Trager D. Effect of pre-harvest applications of an antitranspirant and vegetable oil on cracking and size of cherry (*Prunus avium* L.) cv. Van fruit. Australian Journal of Experimental Agriculture. 2002;42:93-96.
12. Guillen G, Diaz-Camino C, Loyola-Torres CA, Aparicio-Fabre R, Hernandez-Lopez A, Dıaz-Sanchez M, Sanchez F. Detailed analysis of putative genes encoding small proteins in legume genomes. Frontiers in Plant Science. 2013;4:208.
13. Karimi S, Yadollahi A, Arzani K, Imani A, Aghaalikhani M. Gas-exchange response of almond genotypes to water stress. Photosynthetica. 2015;53(1):29-34.
14. Kim J, Malladi A, Van Iersel MW. Physiological and molecular responses to drought in Petunia: the importance of stress severity. Journal of Experimental Botany. 2012;63(18):6335-6345.
15. Li J, Wu Y, Xie Q, Gong Z. Abscisic acid. Hormone Metabolism and Signaling in Plants. Academic, New York, 2017, 161-189.
16. Mahmoudian M, Rahemi M, Karimi S, Yazdani N, Tajdini Z, Sarikhani S, *et al*. Role of kaolin on drought tolerance and nut quality of Persian walnut. Journal of the Saudi Society of Agricultural Sciences. 2021;20(10):1016-22.
17. Medina V, Gilbert ME. Physiological trade-offs of stomatal closure under high evaporative gradients in fi eld grown soybean. Functional Plant Biology. 2015;43:40-51.
18. Meena V, Kashyap P, Nangare DD, Singh, J. Effect of coloured shade nets on yield and quality of pomegranate (*Punica granatum*) cv. Mridula in semi-arid region of Punjab. Indian Journal of Agricultural Sciences. 2016;86(4):500-505.
19. Memari H, Tafazoli E, Haghighi A. Effect of drought stress and cycocel on seedling growth of two olive cultivars. Journal of Science Technology Agriculture Natural Resource. 2011;55:1-10
20. Chaves MM, Oliveira MM. Mechanisms underlying plant resilience to water deficits: prospects for water-saving agriculture, Journal of Experimental Botany. 2004;55(407):2365-2384.
21. Munemasa S, Hauser F, Park J, Waadt R, Brandt B, Schroeder JI. Mechanisms of abscisic acid-mediated control of stomatal aperture. Current Opinion in Plant Biology. 2015;28:154-62.
22. Nellemann C, MacDevette M, Manders T, Eickhout B, Svihus B, Prins AG, *et al*. The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal, 2009.
23. Pascual S, Cobos G, Seris E, González-Núñez M. Effects of processed kaolin on pests and non-target arthropods in a Spanish olive grove. Journal of Pest Science. 2010;83:121-133.
24. Plaut Z, Magril Y, Kedem U. A new film forming material, which reduces water vapour conductance more than CO_2 fixation in several horticultural crops. The Journal of Horticultural Science and Biotechnology. 2004;79:528-532.
25. Poljakoff-Mayber A, Gale J. Physiological basis and practical problems of reducing transpiration. In: Kozlowski, T.T. (Ed.), Plant responses and control of water balance. Academic Press, Inc., New York, 2012, 277-306.
26. Prakash M, Ramachandran K. Effects of chemical ameliorants on stomatal frequency and water relations in brinjal (*Solanum melongena* L.) under moisture stress conditions. Journal of Agronomy and Crop Science. 2000;185:237-239.
27. Schrader LE. Scientific basis of a unique formulation for reducing sunburn of fruits. Hort Science. 2011;46:6-11.
28. Sootahar MK, Zeng X, Su S, Wang Y, Bai L. Molecules

the effect of fulvic acids derived from different materials on changing properties of albic black soil in the Northeast Plain of China. Molecules. 2019;24:1-12.

29. Yang, Hu F, Li J, Wu J, Qian X, Yurong. Chitosan enhances leaf membrane stability and antioxidant enzyme activities in apple seedlings under drought stress. Plant Growth Regulation. 2009;58:131-136.
30. Beck S, Mahony M. The IPCC and the new map of science and politics. Wiley Interdisciplinary Reviews: Climate Change. 2018 Nov;9(6):e547.