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Recent Advances to Combat Drought in Fruit Crops

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Introduction

The most important abiotic stress that affect agricultural crops throughout the world was drought and salinity. Plants experience water stress either when the water supply is limiting to their roots or when the transpiration exceeds absorption rate. In India, most of drought-prone area (35% of total) lies in the arid (19.6%), semiarid (37%) and subhumid (21%) regions of the country. Drought occurs frequently in arid and semi-arid climates with uneven precipitation. It disrupts horticultural crop growth, development and finally results in low productivity of arid and semi-arid region. Arid regions are distinguished by low and unpredictable rainfall (100-420 mm/year), frequent droughts, high summer temperatures (45-50 °C), high wind velocity (30-40 km/h), and high evapo-transpiration (1500- 2000 mm/year). The sandy soils have poor fertility and low water retention (Bhansali *et al.*, 2003). In climate change, rising temperature, increased erratic rainfall, long dry spells, more frequent and extreme weather events. Therefore, in the coming decades, these arid and semi- arid regions are going to suffer from increasing moisture stress and become more vulnerable due to the direct impacts of climate change. Therefore, drought management is important to sustain agriculture and national food production

Major Effect of Drought in Fruit Crops (Arid and Semi-arid)

- In young tree size is reduced and delayed precocity of bearing
- In old tree growth and vigour during a season influence the yield of successive crop, so there by yield and productivity go down
- Reduction in assimilation by reducing photosynthesis (size of leaf is reduced which reduced LAI) and increase respiration and reduced absorption of nutrients.
- Root growth is adversely affected beyond the point of repair
- High root/shoot ratio reduced crop yield as compared to adequate moisture

Strategies to Combat Drought

1. Resistance/tolerant genotype

The germplasm selected should have drought tolerance mechanism like deep root system (bael, ber, date palm), leaf shedding (ber, gonda), presence of thorns (ker, karonda), stomata at lower side (custard apple), wax coating (ber), sparse foliage and leaf orientation (aonla), water binding mechanism (fig), hairyness and sunken stomata (fig, phalsa, ber and lasoda). Intense solar radiation is important feature of arid region and crop like kinnow mandarin can be selected which has tolerance against drought and bear fruits inside well-formed canopy.

2. Use of stress tolerant rootstocks

Fruit Crops	Rootstock
Sapota	Khirni (*Manilkara hexandra*)
Fig	Gular (*Ficus glumerata*)
Ber	*Ziziphus rotundifolia* and *Zizyphus nummularia*
Guava	*Psidium cujavillis*
Grape	Dogridge and 110R,
Citrus	Cleoptera mandarin, Rangpur Lime, Alemow and Swingle
Almond	*Prunus xerophila*, *P. amygdaliformis* and *P. elaeagrifolia*
Apple	MM 111
Pear	*Pyrus betulaefolia* and *Pyrus calleryan*

2. Agronomic measures

Mulching and water harvesting recycling etc. also required to be practiced for effective soil and moisture conservation in arid and semi-arid regions:

- **Wind Breaks:** planting, tall growing trees along the farm boundary. Windbreaks help in reducing the velocity of wind and reduce transpiration and evaporation losses along with development of suitable microclimate. *Sizium cumini*, *Prosopis cineraria* and *Ziziphus numuleria* can used as windbreak in arid region.
- **Soil Organic Matter:** Incorporation of crop residues and farm yard manure to soil improves the organic matter status and improves soil water holding capacity. Soil organic matter content is improved by adopting crop rotation, green manuring and involving agro forestry crops.
- **Foliar Nutrition**: The K and Ca spraying induce drought tolerance in fruits and vegetable crops. Spraying of micronutrients and secondary nutrients improves crop yields and quality.
- **Drip irrigation:** It has been found that up to 81% water saving was observed in lemon compared to flood irrigation with the over 35% increase in yield. Similarly, banana, grapes and pomegranate recorded 45% saving in water using drip irrigation

3. Use of beneficial microbes

Use of Rhizobacteria and Arbuscular mycorrhizal fungus which help to Improved nutrient uptake, better root system architecture, water uptake via extraradical hyphae, greater osmotic adjustment, enhancement of antioxidant defense. Arbuscular mycorrhizal fungus was observed in the citrus rhizosphere and provided drought tolerance in citrus crop (Singh et al., 2011). Arbuscular mycorrhizal fungus inoculation with Glomus mosseae significantly increased absorption areas of root systems in the Trifoliate orange seedlings grown at varying soil water contents as against without arbuscular mycorrhizal inoculation (Wu and Xia, 2006).

4. Use of plant growth regulators (PGRs)

By using the PGRs that regulate several physiological mechanisms like stomatal regulation : PGRs like ABA (abscisic acid) and SA (salicylic acid) are pivotal in controlling stomatal behavior, reducing transpiration rates and conserving water, antioxidant defense: Compounds like melatonin enhance the plant's antioxidant capacity, protecting cellular structures from oxidative damage caused by drought-induced ROS, gene expression modulation: GRs influence the expression of various genes associated with stress responses, enhancing the overall resilience of fruit crops.

In apple trees (*Malus domestica*), ABA application has been shown to improve drought tolerance by enhancing leaf water retention and reducing transpiration rates (Liu et al., 2023)

In grapes (*Vitis vinifera*), JA treatment has been linked to improved water use efficiency and better maintenance of physiological functions during drought stress (Kumar et al., 2024).

In pomegranate (*Punica granatum*), putrescine application has shown positive effects on root growth and drought tolerance (Choudhary et al., 2020)

5. Regulated Deficit Irrigation (RDI) and Partial Root Zone Drying (PRD)

RDI involves applying controlled amounts of water during specific growth stages of fruit trees, allowing for temporary water stress that can enhance certain physiological responses beneficial for fruit development. By imposing water stress at critical growth phases, RDI encourages the plant to adapt by regulating stomatal closure and enhancing root-to-shoot signaling, which can improve water-use efficiency and fruit quality. While PRD involves irrigating only one side of the root zone while allowing the other side to dry out. This method promotes a balanced response from the plant, as it still receives some moisture while experiencing mild stress. The drying side of the root zone induces chemical signals, such as abscisic acid (ABA), which help regulate stomatal behavior and enhance root growth on the wet side.

In citrus tress (Citrus sinensis): Studies have shown that applying RDI during summer months can enhance water-use efficiency by 14 % to 27 %, particularly after critical periods like the "June drop," allowing trees to recover effectively with appropriate irrigation in autumn (Sau et al., 2022)

Jujube Trees (Ziziphus jujuba): PRD has been shown to improve fruit quality and yield by enhancing root activity and optimizing water use during critical growth periods (Galindo et al., 2017)

6. Uses of Anti-transpirants

Anti-transpirants are substances applied to plant surfaces to reduce transpiration, thereby helping plants conserve water during drought conditions. They can be classified into film-forming and metabolic types, each with distinct mechanisms of action.

Film-Forming Anti-transpirants: These create a thin film on the leaf surface, reducing water loss by limiting transpiration.
Example: Vapor Gard is a commonly used film-forming antitranspirant that has been shown to improve water retention in various crops.

Metabolic Anti-transpirants: These substances enhance the plant's physiological responses to drought stress, such as improving stomatal regulation or increasing antioxidant activity.
Example: Salicylic Acid (SA) is a metabolic antitranspirant that helps in closing stomata and enhancing the plant's antioxidant capacity under drought conditions

Some specific antitranspirants commonly used in fruit crops, along with their functions and examples of application

Kaolin

- Function: Creates a protective barrier on leaf surfaces, reducing water loss by reflecting sunlight and lowering leaf temperature.
- Example: In studies on grapes (*Vitis vinifera*), kaolin application has been shown to enhance water retention and improve fruit quality under drought conditions by reducing transpiration rates (Kocięcka *et al*., 2023).

Vapor Gard

- Function: Forms a thin film on leaf surfaces that reduces water loss while allowing gas exchange.
- Example: Applied to citrus trees (Citrus spp.), Vapor Gard has been effective in increasing leaf water potential and improving overall hydration during drought periods, leading to better fruit quality.

Salicylic Acid (SA)

- Function: Stimulates stomatal closure and enhances the plant's antioxidant defenses, helping to mitigate oxidative stress caused by drought.
- Example: Foliar application of SA in kiwifruit (Actinidia chinensis) has shown positive effects on reducing transpiration rates while promoting overall plant resilience under drought conditions (Liu *et al*., 2023).

Paclobutrazol

- Function: Reduces plant height and promotes root growth, which can enhance water uptake efficiency during drought stress.
- Example: In peach trees (Prunus persica), paclobutrazol has been used to improve drought tolerance by enhancing root development and reducing vegetative growth, allowing better resource allocation for fruit production

Conclusion

Drought stress is considered to be a major threat to sustaining food security under current and more so in future climates. There are many approaches like mulching, drip irrigation, water conservation, proper nutrient management, deficient irrigation system, use of growth regulator, antitraspirants, beneficial microbes and drought tolerant rootstocks or genotypes through which we can manage the negative impacts of drought on fruit crops. The use of desirable method under different conditions not only meets the requirement of early and quality fruit production but also provides an alternative approach to mitigate the drought.

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