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Abiotic Stress Management in Fruit Crops: A Review

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ABSTRACT

The current changes in fruit production scenario challenged the quality and quantity of fruits required for the vast population. The abiotic and biotic stresses, encountered at critical growth stages and adversely affect productivity of plants. The abiotic stresses like drought, extremes temperature floods and salinity have emerged as major challenges for production of crops. The different abiotic stressescause morphological, anatomical, physiological and biochemical changes and ultimately impacting the productivity and quality of plants. Timely intervention with appropriate adaptation strategies would help in realizing sustainable yields and further enable to overcome adverse effects of abiotic stresses. Successful cultivation of crops and attaining reasonable yields under abiotic stress situations mainly depends on the available adaptation options. Practices like modification in cultural practices, adopting novel irrigation, choice of tolerant rootstocks, choice of tolerant cultivars/crops and biotechnological approaches are to be implemented for alleviating adverse effects. Though, the productivity of fruit crops remains low in areas experiencing abiotic stresses. Therefore, focus is required for developing integrated location-specific and crop- specific adaptation strategies for various abiotic stresses. The integration of all available adaptation options would be the most effective approach in sustaining the production and productivity of fruit crops under abiotic stresses.

Key words: Abiotic stresses, Biotechnological approach, Crop specific strategies, Cultural modifications.

The food and nutritional security warrant the availability of adequate and quality food to meet the dietary and nutritional requirements for a healthy and productive life. The world population is growing at an alarming rate and is anticipated to reach about 9.6 billion by 2050 from the present about 6 billion. For instance, India will be the most populous country by 2050 and its population is predicted to reach 1.6 billion from the present of about 1.3 billion. The predictions are demand for food would increase by 70% and would even double in some low-income countries (FAO, 2009). This of course is related with population rise, but the per capita food consumption coupled with its quality would also improve with growing economies. Therefore, enormous efforts are required to achieve the expected growth rate (44 million tons per annum) to ensure food security especially when agriculture is losing the productive lands due to urbanization and industrialization.

However, horticulture sector, with diverse crops, has been a driving force for nutritive diet and enhanced income in Indian agriculture. Presently, its share in the agriculture GDP is more than 30% (NHB, 2018). The Government of India has recognized horticulture crops as a means of diversification in agriculture in an eco-friendly manner through efficient use of land and natural resources. Fruits due to their nutritional benefits are highly valuable for humanity and along with vegetables, they are part of everyday meals. Thus, fruits and vegetables contribute nearly 90% to the total horticulture production in India. Fruit crops provide not only nutritional security but also provides livelihood security to the farmers.

In order to achieve higher yields, the perfect match between climate of a region and the suitability of a particular fruit species to that region is very essential. The potential yield levels are seldom achieved due to the occurrence of various biotic and abiotic stresses. Worldwide occurrence of environmental stresses is the primary cause of crop losses, with average yield reduction by more than 50% for the major crops (Bates *et al*., 2008).

The majority of fruit crops are peculiar mainly due to perennial nature and deep root system. They undergo vegetative and reproductive phases during different seasons. The abiotic stresses coinciding with these phonological phases play a significant role in determining the duration of phenology and productivity. Further, under climate change and climate variable conditions, fruit crops are likely to face abiotic stresses quiet frequently. Hence, under such circumstances, meeting the increasing demand for fruits becomes challenging. Realizing sustained and enhanced yields under abiotic stress situations primarily depends on implementation of appropriate adaptation strategies like agronomical practices, choice of tolerant root stocks and varieties and/ or through various biotechnological tools.

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Impact and mechanism of abiotic stresses in fruit crops

The specific agro-ecological regions are sustaining the cultivation of fruit crops as niche areas, the variability in climatic conditions during critical stages of crop growth and development causes heavy yield loss and affects fruit quality and quantity. During different growth stages the fruit crops face various abiotic stresses like high temperature, excess and limited moisture and salinity stresses. These stresses occurring, either at intermittent or terminal stages of crop growth agro-ecological zone play a very significant role in determining phenology, growth, development and consequently the productivity of horticultural crops. Global warming is likely to increase the frequency, intensity and duration of excess and limited water and high temperature stresses (Bates *et al*., 2008).

Climate change, with its influence on water cycles leading to changed precipitation pattern and affect the crop production than increases in temperature. The elevated temperatures would hasten plant transpiration and soil evaporation. These stresses either individually or in combination would significantly influence the production, productivity and quality of fruit crops. Abiotic stresses during different developmental stages can cause morphological, anatomical, physiological and biochemical changes (Ahmad *et al.,* 2011). In order to develop timely and appropriate adaptation measures, a better understanding of the overall effects of abiotic stresses on fruit crops is required. Moreover, the interactions or mechanisms of abiotic factors with physiological processes, phenology, growth and development are extremely important for devising innovative horticultural practices for overcoming the adverse effects of different stresses.

Abiotic stress-management methods

Plants encounter adverse environmental stresses during their life cycle, which have negative impacts on growth and greatly affect crop productivity. As perennial crops, fruit trees are exposed to an array of stresses for a long time once they are planted. If the trees are severely injured by environmental stresses, it would be hard for them to recuperate, leading to retarded growth and reduced fruit production (Laxman and Bhatt, 2017). Successful cultivation of crops and attaining reasonable yields under abiotic stress situations mainly depends on the available adaptation options. The adaptation efforts would enable to channelize concerted efforts for the holistic development of horticulture sector empowering marginal and small farmers. Majority of the fruit crops are perennial, possess deep root system and undergo vegetative and reproductive phases during different seasons in a year. The long-time horizon of perennial horticulture crops itself is a challenge. The quick adaptation strategies, like switching over to tolerant cultivars and changing planting dates or season, followed in annual crops are not likely in perennial fruit crops. Hence, the choice of fruit crops should be guided by the suitability of a crop species and their varieties in a particular location. The planting and rearrangement of fruit orchards with novel irrigation techniques and tolerant rootstocks require long-term consideration ((Sinha and Reena, 2018).

Modifications in cultural practices

The alterations in cultivation practices help in effective management of abiotic stresses in perennial crops. Moisture conservation practices, use of antitranspirants, use of different plant growth regulators, use of hydrophillic polymers and use of bio-stimulants and organic compounds are certain practices used to mitigate different abiotic stresses agronomically.

Adoption of suitable moisture conservation practices in crop production is proving to be an effective means in mitigation water stress induced by climate change. Moisture conservation practices such as maintenance of soil cover and pruning decreases transpiration loss. Summer pruning can also be used in apple to conserve moisture. Severe pruning of peach and pear has been found to reduce transpiration. Similarly, a heavy cropping exhausts metabolites and photosynthates and tends to put less carbohydrate into root growth. Hence, maintenance of crop load is a better way to reduce moisture stress. Green manuring, weeding, rain water harvesting, shady plants and light cultivation also save water during stress conditions or critical growth stages (Mariani and Ferrante, 2017).

Mulching of organic and inorganic materials create favourable conditions for getting maximum production of quality fruits on sustainable basis within the limits of soil, water, temperature and fertility management. Metalized mulch films have the potential to improve early-season fruit development by alleviating, at least in part, heat stress conditions during the establishment period of strawberry. A field trials over two seasons to evaluate black mulch, fully metalized mulch and metalized-striped mulch using two cultivars differing in heat stress tolerance and fruit production patterns in 'Florida Radiance' and 'Florida Beauty'. The effect of plastic mulch type on plant growth and yield was generally consistent across both seasons. Compared with black mulch, metalized-striped mulch reduced afternoon root zone temperature (RZT) by up to 3.1°C and reduced the duration of heat stress conditions (RZT > 30°C) by 119 hours across October and November, but exhibited equivalent soil warming during winter. Yield increases by metalized-striped mulch compared with black mulch ranged from 12% to 26% over the entire season (Deschamps and Agehara, 2019).

Hydrophilic polymers are class of polymers which gets dissolved or swollen by water. It forms three dimensional network of macromolecules of carbon chain and swells by absorbing solution as much 100 times of their weightand deswell to supply water to the plant based on its need. Hydrophilic polymers play a vital role in stress alleviation at appropriate time as needed by the plants. Aquasorb, agrihope, broadleaf p4, hydrogel and hydrosource are the commonly used polymers in agriculture. It improves nutritional and water status of the plant and soil physical properties. It increases soil water holding capacity, yield and water use efficiency of plant and decreases the negative effect of soil salinity on plant (Milani *et al.,* 2017). Barki *et al.* (2019) examined the effect of the hydrogel "stockosorb-660" compared with non treated plants. As compared to non treated plants the hydrogel treatment increased the growth responses, photosynthetic pigments, dry weights and the relative water content of olive cultivars Chemlali and Chetoui under drought stress. Under stress, the chlorophyll fluorescence measurements were about 0.53 and 0.36 for Chemlali and Chetoui cultivars, respectively in hydrogel treatment. Total phenols decreased damages under drought stress and were about 53.94 mg g^{-1} GAE and 57.37 mg g^{-1} GAE for Chemlali and Chetoui cultivars, respectively. Similarly, the relative water content, plant height and leaf dry weight were found to be higher in hydrogel treatments as compared to control. The study confirmed that hydrogel is seems to be suitable for agricultural use because of its capacity to avoid dehydration damages in plants.

Antitranspirants are the materials or the chemicals which decrease the water loss from plant leaves by reducing the size and the number of stomata (Prakash and Ramachandran, 2000). Antitranspirants are non toxicity materials that specifically effects on guard cell and not to other cells and the effect persist for one week. The exogenous kaolin application in grapevine has shown a great potential as summer stress mitigation strategy because it positively impacts fruit quality as a result of many molecular and biochemical changes. Bernardo *et al*. (2017) studied on the effect of kaolin application in grapevine and relived that the stress full condition results over production of proline in control plants as that of kaolin treated plants. The enzymatic activity of superoxide dismutase (SOD) and catalase (CAT) activity and was increased as that of control plants. Sunburn injury in mango is common to take place on fruits due to high solar radiation levels air temperatures, low relative humidity and high elevations. Thus, Baiea *et al.* (2018) studied the influence of of kaolin and screen duo foliar application on fruit sunburn, yield and fruit quality. The obtained results revealed that the response to screen duo was more pronounced the differences between its three concentrations were significant in most cases as compared each other from one hand and the highest one (18 cm^3/L.) was the most effective in most cases from the other hand referring the specific effect of times of spray. Spraying screen duo at 12 and/or 18 cm^3/L twice in summer months (at mid of both June and July) had a positive effect to prevent fruit sunburn damage and improved yield and fruit quality of Keitt mango fruits.

Various phytohormones, biomolecules and chemicals are assigned different roles to manage different kind of stresses. Phytohormones, such as salicylic acid (SA), jasmonic acid (JA), ethylene (ET) and abscisic acid (ABA) are endogenous, low-molecular-weight molecules that primarilyregulate the protective responses of plants against both biotic and abiotic stresses *via* synergistic and antagonistic actions, which are referred to as signaling crosstalk. Zhao *et al.* (2020) examined the effect of a postharvest treatment consisting of a brief (30 s) dip in the natural plant hormone jasmonic acid, prior to storage at 4°C. Jasmonic acid treatment reduced the severity of internal flesh browning and did not inhibit fruit softening over a 35 day storage period, by regulating ethylene and sugar metabolism.

Plant biostimulants, sometimes referred to as agricultural biostimulants, are a diverse classification of substances that can be added to the environment around a plant and have positive effects on plant growth and nutrition, but also on abiotic and biotic stress tolerance,and these aredistinguished into two main categories: microbial and non-microbial biostimulants. The former includes beneficial bacteria (*i.e.,* N-fixing bacteria) and fungi (*i.e.,* arbuscular mycorrhizal fungi). It accumulates compactible solutes to avoid cell dehydration, regulates ion and water uptake by roots, reduce oxidative stress by enhancing the antioxidant capacity and stabilize photosynthesis for sustained growth. Later it defines several complex substances or mixtures of both organic and inorganic origin such as seaweed extracts, plant extracts, protein hydrolysates, amino acids, humic acids and glycine betaine (Van-Oosten *et al.,* 2017). Arbuscular mycorrhizal fungus (AMF) induced drought tolerance in *Citrus* species. Genera such as *Acaulospora*, *Gigaspora* and *Glomus* were dominantly observed in the citrus rhizosphere. AMF inoculation with *Glomus mosseae* significantly increased the active and total absorption areas of root systems in the Trifoliate Orange seedlings grown at varying soil water contents compared to non-AM inoculation (Wu and Xia, 2006). The Rhizospheric and endophytic bacteria (CSR-G-1, CSR-B-2, 3) have been found promising to enhance salinity tolerance in horticultural crops (Van-Oosten *et al.,* 2017).

Adoption of novel irrigation methods

Systematic irrigation scheduling enhances water productivity largely because of improved efficiency and timing of water applications. Drip irrigation method enables judicious use of available irrigation water in fruit orchards. Overall it saves up to 30-70% irrigation water and also helps in realizing higher yields by 25-80% (Sikka and Samra, 2010). Various studies have shown that the adoption of micro-irrigation systems increased yield and productivity of fruit increases by 42.3%. This resulted in improved water use efficiency and an average irrigation cost has been brought down by 31.9%. This has helped the farmers to introduce new crops.

In addition to drip irrigation and mulching, novel irrigation methods, regulated deficit irrigation and partial root zone drying are designed to limit vegetative vigour and improve water use efficiency in perennial crop plants such as grapevines and fruit trees.

These two methods of irrigation do, however, differ fundamentally in two key respects. With regulated deficit irrigation water application is manipulated over time whereas, with partial root zone drying irrigation, water is manipulated over space (Laxman and Bhatt, 2017).

Regulated deficit irrigation is the practice of using irrigation to maintain plant water status within prescribed limits of deficit with respect to maximum water potential for a prescribed part or parts of the seasonal cycle of plant development. The aim in doing this is to control reproductive growth and development, vegetative growth and/or improve water use efficiency and save 43% to 65% of water (Permanhani *et al.,* 2016). In partial rootzone drying (PRD) irrigation method, only part of the root zone is wetted while the remainder is allowed to dry. Irrigating part of the root system keeps the leaves hydrated while drying on the other part of the root system promote synthesis and transport of so-called chemical signals from roots to the shoot *via* the xylem to induce a physiological response. Manjunath *et al.* (2017) reported that better soil moisture in the root zone could be maintained under partial root zone drying irrigation by shifting laterals on either side at fortnightly intervals with improved growth parameters as compared to fixed laterals with the same amount of water.

Deep drip irrigation is method to deliver water efficiently to the root zone and results less weed seed germination since surface soil remains dry. A drip size of 14'' is suitable for annual crops, whereas 24'' and 36" for initials years of fruit trees and palms and established trees respectively (Berkalaar, 2020).

The buried diffuser is a new technique for underground irrigation which can be used for trees (fruit trees, forest trees, ornamental trees) and shrubs, vegetables in fields and in green houses and plants in containers, pots or boxes. The tree buried diffuser (15×15 cm or 15×30 cm) can be used for the irrigation of all kind of trees such as banana, mango, papaya, litchi, guava, avocado, pomegranate, date palm, oil palm, apple, apricot, grape, olive, orange, citrus, almond, nut, pear, fig, *etc*. These are installed in holes, 50 to 70 cm below the topographic soil surface. It is possible to install the diffusers in the plantation before the installation of the tree. In this case the diffuser should be 50 to 70 cm far from the axis of the tree. When the diffusers are added after the trees plantation, they should be installed in the extremities of the canopies (Berkalaar, 2020).

Choice of tolerant rootstocks

In situations where there is a strong consumer preference for a select cultivar that is susceptible and if alternative tolerant cultivars are not available, the option of using rootstocks for better performance needs to be explored. Rootstocks with better root system, having capacity for enhanced water and nutrient uptake, could be used for grafting commercial cultivars to mine water from deeper soil layers or survive the plant from adverse conditions. Rootstocks react at the physiological, biochemical and genetic level to tolerate various adverse climatic conditions like drought, flood, salinity, high and low temperatures by the production of various solutes or by morphological or genetically (Laxman and Bhatt, 2017). Pandey *et al.* (2014) conducted a study on the growth and nutrient uptake in polyembryonic rootstocks with four levels of NaCl. The Chloride uptake in leaf tissues was increased minimum in Olour at each salinity level as compared to other rootstocks and that will lead to increases the uptake of Potassium ions and that create tolerant behavior of Olour due to impeding the uptake of Chlorine ion accumulation. Yi-Ling *et al.* (2015) conducted a study to evaluate drought resistance of citrus rootstocks and select drought resistant resources, with four rootstocks and a mandarin cultivar as scion. Physiological parameters such as relative water content (RWC) and the activity of superoxide dismutase (SOD) are observed and the result shows rootstock 'Sanhuhongju' have higher drought resistance than others because of the higher rate of enzyme activity and relative water content.

Choice of tolerant crops/cultivars

In areas where the crops perennially face water and high temperature stresses, the knowledge should be shared with farmers on fruit crops which would be most suitable. In such circumstances, the selection of appropriate fruit species or varieties becomes very important. Many fruit crops are endowed with physiological and morphological adaptations and have capacity to withstand adverse effects of water stress. Leaf hairiness, hypostomatous distribution and sunken stomata are all characteristic features of species that exist in drought-prone regions (Clifford *et al*., 2002). In salt-affected lands where cultivation of annual field crops is limited, adopting relatively tolerant crops like ber, aonla, guava, grape, karonda, jamun and phalsa would help in utilization of such lands for horticulture. These crops could be considered as candidate crops to face the challenges of abiotic stresses under climate change conditions. Varieties for drought conditions should be short in duration. Some of the drought tolerant varieties in fruit crop *viz.* -Ruby (Pomegranate), Arka Sahan (Annona), Deanna and Excel (Fig), Karpuravalli and Kanthali, (banana), har Neelkanth (Mulberry) and Goma Aiswarya (Aonla). The varieties like Rajapuri, Poovan, Tahiti Lime, Fuerte and Duke are cold tolerant whereas, New Castle, Early Shipley in apricot and Tropical Beauty, Michel and Anna are low chilling varieties of apple. The grape cultivars Thomson Seedless, Perlette, Cardinal, Black Rose and strawberry varieties Lassan and Shasta are found to be salt tolerant in nature (Nimbolkar *et al.,* 2016).

Biotechnological approaches

Biotechnological strategies for amelioration of abiotic stress

Biotechnology is the best way by which the productivity of crops can be improved by enhancing their ability to resist or tolerate abiotic stresses. In biotechnology different strategies are involved for the improvement of crop yield and quality. The emergence of the novel "omics" technologies, such as genomics, proteomics and metabolomics, is now allowing researchers to identify the genetic behind plant stress responses. These omics technologies enable a direct and unbiased monitoring of the factors affecting plant growth and development and provide the data that can be directly used to investigate the complex interplay between the plant, its metabolism and also the stress caused by the environment (Perez-Alfocea *et al*., 2011).

Genetic engineering strategies amelioration of abiotic stress

Genetic engineering technique offers myriads of applications in improvement of fruit crops for biotic and abiotic stress tolerance and produce quality enhancement.

Transgenic approach is now a widely used procedure for introducing genes from distant genepools, ranging from prokaryotic organisms such as *E. coli* to halophytes or glycophytes, into many plant species for the development of stress tolerant plants (Borsani *et al.,* 2003). In recent years, a number of genes with diverse function and mechanism were employed for the development of transgenic fruit plants to improve resistance/tolerance to different abiotic stresses. However, in most cases this resistance/tolerance to abiotic stresses was linked to increased antioxidant capacity of the tissues or accumulation of compatible solutes through control of the genes involved in these mechanisms. Dehydration response element binding *(DREB) 1b* is a cold-inducible transcription factor in *Arabidopsis thaliana*. *DREB1b* was genetically introduced into grape *Vitis vinifera* L. cultivar Centennial Seedless through *Agrobacterium*-mediated transformation for improving its cold resistance and exploring new genetic breeding approaches to obtain cold-resistant cultivars. Further characterization of transgenic grapevines confirmed that both electrolyte leakage conductivity and the freezing point of the transgenic plants were lower than those of wild-type plants. After the cold treatment at -4°C for 12 h, 26% of transgenic plants wilted among which 95% plants recovered once being placed under the condition of temperature 22 to 25°C. However, subjected to the same treatment, 98% of non- transgenic plants wilted and only 2% recovered (Jin *et al.,* 2009). Li *et al.* (2010) isolated the transporters (MdNHX1) from a salt tolerant rootstock of apple and introduced it into the widely used rootstock M.26. The M.26 transgenic rootstock had improved salinity stress tolerance, compartmentalizing more Na in the roots and also maintaining a relatively high Na+/K+ ratio in the leaves compared with wild plants.

CONCLUSION

Under both natural and agricultural conditions plants are frequently exposed to stress. Some environmental factors can become stressful in just a few minutes; others may take days or even months to become stressful. Evaluation of crop season in soil moisture variations based on water budgeting for selecting suitable crops and varieties and evolving site-specific land use planning strategies. Adaptation of appropriate soil moisture conservation techniques helpful in overcome the water stress. Management of cultural practices in conjuction with use of plant bio-regulators and chemicals go a long way in management of various abiotic stresses. Recent genomic and proteomic research on stress response in fruit trees is also being used to develop a more comprehensive understanding of environmental stress resistance. Hence, the impacts of abiotic stresses on fruit crops could be overcome by adopting different strategies. An integrated approach with all available options is the most effective for sustaining production, productivity and quality of fruit crops.

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