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PLANT PHYSIOLOGY

Rootstock breeding for abiotic stress tolerance in fruit crops

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Abstract

In the present era of climate change, drastically increasing or decreasing temperature, irregular or heavy rainfall, increasing level of CO_2, soil degradation *etc*. limiting the crop production in different parts of the world. Due to their rapid and unpredictable effects, it became very difficult for agricultural scientists and farmers to respond to challenges posed by biotic and abiotic stresses. The use of rootstocks tolerant to different abiotic stresses like drought, salinity, temperature abnormality etc. may be an alternative approach to face these challenges. Fruit crops are perennial in nature and mostly propagated through vegetative means to meet the early and quality production requirements. The use of desirable scion and rootstock not only meet the requirement of early and quality production but also provides an alternative approach to face the challenges posed by biotic and abiotic stresses. Keeping in mind challenges of environmental stresses and quality fruit production in stress prone areas, the present need before researchers and growers is to fight with the era of changing climate. So, implication of rootstock breeding in fruit production technology is really instrumental for farmers.

Highlights

- Rootstock breeding, an alternative approach for abiotic stress (Salinity, draught, cold *etc*.) tolerance in perennial fruit trees.
- Use of rootstocks to increase production, productivity and quality in areas where environmental stress pose threat for survival of fruit crops
- To bring the degraded and waste land under cultivation by using desirable tolerant rootstocks.

Key words: Fruit crops, rootstock breeding, salinity, alkalinity, drought, tolerance.

Environmental stresses play crucial roles in the productivity, survival and reproductive biology of plants as well as crops (Redondo-Gómez 2013). Biotic and abiotic stresses, including drought, extreme temperature, scarcity of water, reducing quality of irrigation water and salinity in soil and water are problems which are becoming really acute (Flowers 2004). These stresses can severely affect growth and development of both rootstocks and/or scions, thus reducing both fruit production and fruit quality. To overcome these stresses only few scientific approaches are available, one by making use of certain tolerant varieties/rootstocks or by the use of pesticides etc. But there are very few tolerant varieties is available to overcome abiotic stresses and use of pesticides is harmful for human as well as soil health. So, in this situation, rootstock is only the viable option available before us which were used for propagating fruit trees for more than 2000 years (Webster 1995). Several rootstocks have become integral part of the fruit industry because of their tremendous perspective. However, in tropical and subtropical fruit crops their use is restricted when compared with temperate fruits. In view of increasing population, declining per capita land availability and for efficient utilization of problem soils, there is a need to use efficient rootstocks for enhancing fruit production and productivity in the country. Many of the rootstocks used, affect scion growth, flowering, fruiting, crop production, and adaptability to different biotic and abiotic stresses. In nature, plants are simultaneously exposed to a combination of biotic and abiotic stresses that limit crop yields (Ramegowda and Senthil-Kumar 2015). The use of rootstocks in fruit production includes not only increase resistance against pathogens but also a higher tolerance to abiotic stress conditions such as salinity, heavy metals, nutrient stress, water stress, and alkalinity. Identification of ideal rootstock in fruit crops continues to remain a great challenge. In this review article, we provide overall information of rootstocks in different tropical, subtropical and temperate fruit crops which can be useful for researchers and farmers to combat the abiotic stress with respect to fruit crops. Some of efforts made in fruit crops have been presented hereunder.

Rootstocks use for Abiotic Stress Tolerance in Tropical and Subtropical fruit Crops

Mango

Mango (*Mangifera indica* L.) is one of the most important fruit crops all over the world, especially in tropical and subtropical regions. For increasing productivity of mango, the production from existing area needs to be increased, but at the same time, new areas also need to be brought under cultivation with enhanced fruit production. One of the major limitations for extensive cultivation of mango is abiotic stresses particularly soil salinity, which leads to reduction in plant growth and death afterwards (Maas 1986). Mango being perennial fruit crop, is subjected to several biotic stresses like pests and diseases and abiotic stresses like soil and environmental factors. The variability among the cultivars being very high, there is always scope for locating a source of resistance. The polyembryonic cultivars, for which variability is less and which are generally seen in regions of high rainfall should be screened for these stresses. The focus of rootstock in mango includes development of genotypes that could confer resistant to adverse soil conditions and affect vigour of the scion. The other aspects include polyembryony for uniformity, dwarfing characters for establishing HDP systems, tolerance to calcareous soils, tolerance to soil borne problems and physiological compatibility to commercial scion cultivars (Iyer and Degani 1998). Most of the Indian varieties are monoembryonic but about a dozen varieties from South India are polyembryonic, namely, Kurukan, Chandrakaran, Olour, Bappakai, Muvandan, Mylepelian, Kitchner, Nekkare, Prior, Vellaikolumban, Peach, and Starch which give true to type seedling from nucelllar embryos. 'Rumani' rootstock gave low value for various growth characters with 'Dashehari' scion at CIHS, Lucknow. Vellaicolumban recorded the lowest growth as well as fruit yield of 'Alphanso' scion. Whereas, Olour gave the maximum yield and canopy height, at IIHR, Bengaluru. Salinity tolerance has also been the focus of several researchers. At IARI, New Delhi, Dubey *et al*. (2007) studied the effect of salinization on two polyembryonic mango rootstocks, i.e. Kurukan and Olour. They found that both the genotypes could survive 2.15 dS m-1 salinity level with mild necrosis and scorching on leaves. The use of rootstocks can help in two ways, one is by development of new rootstocks tolerant to problematic soils and another is by way of screening existing polyembryonic cultivars. Screening of mango rootstocks to salinity has shown that the polyembryonic cultivars 'Olour' and 'Bappakkai' could withstand higher level of salinity (Palaniappan 2001). Mango cultivar '13-1' was selected as a polyembryonic (3-6 embryos) rootstock for calcareous soils and/or for irrigation with saline water. Mango trees on '13-1' rootstocks showed excellent performance on soil containing 20% lime, three other cultivars on '13-1' rootstock showed good development on sandy soil with 10-20% lime and irrigation water containing 250 ppm (Gazit and Kadman 1980). Pyramiding and stacking multiple genes controlling different aspects of salt tolerance and identifying QTLs for salt tolerance in *M. indica* L. cv. 13-1 and M. *zeylanica* may provide greater insights into salt tolerance mechanism in mango.

Citrus

Globally, citrus (citrus spp.) cultivation is plagued by several problems associated with biotic and abiotic stresses, hence there is need for conservation of its rich biodiversity comprising wild and distant species which are source of desired genes. The first use of rootstocks in citriculture was in 1842 to control root rot caused by Phytophthora in Azores

Islands through the use of resistant rootstocks (Chapot 1975). The use of rootstocks allows the shortening of juvenility and the cultivation of citrus in areas normally considered not suitable due to soil characteristics, biotic and abiotic stresses (Castle 2010). The physiology of the whole tree is affected by rootstock, including some of the traits such as tree vigor, fruit yield, fruit size, juice quality, and resistance against biotic and abiotic stresses (Medina *et al*. 2005). A wide variety of citrus rootstocks are available, each having desirable attributes. The success of citrus rootstock is determined by its tolerance to prevailing conditions of soil, climate and disease, while still producing high yields of quality fruits. A rootstock for citrus must be adapted to alkalinity, salinity, and calcareous soils, should be resistant to phytophthora, provides some measure of cold tolerance and produce good yields of high quality fruit. Root stocks like Rough lemon and Rangapur lime are confer high drought resistance due to their spread, well-distributed, and deep root systems that occupy large soil volume and access more efficiently the soil nutrients and water (Syvertsen 1981). Based on the rootstock trials conducted in different regions of India, most promising rootstock among citrus rootstocks is Rough lemon (c. jambheri), which is known by different names in different places. The second important rootstock is Karna Khatta (C. Karna) which is often used in Uttar Pradesh (India). For sweet orange cultivars like Mosambi and Sathgudi with regards to yield and tolerance to disease and salinity in Maharashtra and Andhra Pradesh, a rootstock Rangapur lime has been identified as a promising rootstock. In several breeding programs, existing rootstocks have been screened for abiotic stress conditions, and their current tolerance/resistance levels had been reported that can be used as rootstocks in citrus production. In addition, traditional breeding studies were carried out with these genotypes in order to combine their different tolerance/resistance characteristics in one genotype. By breeding programs several rootstocks have been obtained successfully so far. But traditional breeding takes at least 15 years from the begging of a cross-hybridization program until a new selected rootstock is released to the industry for a commercial use and limited by the complex reproductive biology of citrus. Therefore, rootstock breeders have begun application of biotechnological methods in citrus breeding such as somatic hybridization, genetic transformation, and marker-assisted selection in recent years.

Grape

Rootstocks are being employed in viticulture to overcome the adverse effects of salinity and drought and also to modify the scion physiology/ morphology in terms of vigour, fruitfulness, bunches and berry characters etc. Rootstocks play a vital role for sustainable grape production in various parts of the world. Problems associated with grape production are salinity build up in soils and water, chlorides in irrigation water and excess levels of sodium and free lime in soils and drought in and around grape cultivated area in India. Under such conditions, the use of rootstock to sustain the productivity of grapes under adverse situation gained popularity. With problematic soils and ever increasing water shortage, grape cultivation is facing dual problem of salinity and drought. Under such conditions, the use of salt and drought tolerant rootstocks provides a viable option for sustainable grape production. In addition to their ability to help scion to cope with biotic stresses, rootstocks can confer also tolerance to a large range of abiotic stresses. Salt tolerance has been mainly associated with the ability of different cultivars, rootstocks or their combinations to accumulate or restrict $Na+$ and Cl^- in leaves or shoot. Cramer *et al*. 2007 confirmed that among different abiotic stresses, drought and salinity serve as a one of the major factors which limits the plant productivity and cause severe yield losses. Therefore, breeding of crop varieties that use water more efficiently is a key strategy for the improvement of agro systems (Marguerit *et al*. 2012). In this relevance, rootstocks may play an important role in limiting crop loss by improving water use efficiency, potential for survival, growth capacity and scion adaptability to stress conditions (Marguerit *et al*. 2012). Abscisic acid (ABA) is one of the most studied water stress responsive hormones in plants which accumulates in leaves, is related to stomatal closure to reduce water loss and eventually limiting cellular growth (Hochberg *et al*. 2013). Grapevine rootstocks that increased the efficiency of stomatal closure by chemical (ABA) and hydraulic (aquaporins) signalling that act as a major tolerance to water stress. *Vitis vinifera* a grape rootstock is moderately sensitive to salinity in soil. Rootstocks obtained from wild Vitis species (*V. rupestris, V. cinerea, V. champini and V. berlandieri*) differ widely in their ability to exclude Cl^{-} and consequently in their capability to tolerate higher salinity. In India 'Thomson seedless' is a commercial cultivar grown for both fresh consumption and raisin making. Dogridge was the only popular rootstock used by the grape growers prior to late 1900s. But this rootstock was known to induce more vigour in scions, resulting in reduced bud fruitfulness and thereby fruit yield. Rootstocks '110R', '1103P' and '99R' were found to enhance water-use efficiency during critical growth stages of fruit bud differentiation and full bloom.

Recently, *Annona glabra* having dwarf characteristics has been identified as rootstock for custard apple for the damp areas; while, seedlings of *A. reticulata* can withstand adverse conditions and grow well in dry and arid regions. In ber there are several species that are used as rootstock, for example, native species boradi (*Z. mauritiana* var. *rotundifolia*) is the most commonly used rootstock in north-west states of India. The *Z. nummularia* (Burm.f.) and *Z. rotundifolia* (Lam.) (Jharber) is suitable for the dry regions. However, these rootstocks are imparting tolerance to stressful environments.

Rootstocks use for Abiotic Stress Tolerance in Temperate fruit Crops

Like most of the tropical and subtropical fruits, the use of rootstocks in temperate fruit production includes not only stronger resistance against pathogens but also a higher tolerance to abiotic stresses such as calcareous soil, salinity, alkalinity, cold hardiness, nutrition and low fertility, waterlogging and drought (Beckman and Lang 2003). There is extensive genetic diversity in temperate fruits which provides several materials to be used as rootstocks against abiotic stress (Cimen and Yesiloglu 2016) is presented in the table below:

Traits	Crop	Rootstocks	References
Tolerance to calcareous soil	Peach	Peach × Almond (GF 677)	Beckman and Lang, 2003
	Almond	Peach and Plum germplasms	Reeves *et al*., 1985; Crossa-Raynaud and Audergon, 1987; Byrne *et al*., 1989; Shi and Byrne, 1995
	Plum	Marianna GF 8-1	Wolfe *et. al*., 2011
Drought tolerance	Peach	Almond, Peach × Almond and Peach × *P.davidiana*hybrids, GF 677	Wang, 1985; Jiménez *et al*., 2013
	Cherry	Mazzard, Mahaleb and M×M series	Beckman and Lang, 2003; Longstroth and Perry, 1996; Wertheim, 1998
Cold hardiness	Apple	G 935, G 11, G 30, G 41, B 9, P 2, M 26, B 9, M 26, MM 106, MM 111 and M 7	Chadha, 2016
	Pear	*Pyrusbetulaefolia* seedling	Roper, 2001
	Cherry	Mahaleb seedling	Roper, 2001
	Plum	Myrobalan seedling	Roper, 2001
Root asphyxia	Plum	Myrobalan	Amador *et al*., 2012
Iron chlorosis	Peach	Adesoto' (*P. insititia* L.), 'Felinem' (*P. dulcis* × *P. persica*)or 'GF 677' (*P. dulcis* × *P. persica*),	Jiménez *et al*. (2008)

Conclusion

Abiotic stresses, especially salinity, drought, temperature and oxidative stress, are the primary causes of plant loss worldwide. Therefore, rootstock breeding aimed at overcoming abiotic stresses need to be quickly and fully implemented, with intensive molecular-assisted traditional breeding and genetic engineering. Identification of ideal rootstock in fruit crops continues to remain a great challenge. Traditionally, indigenous wild species were used as rootstocks being propagated through seeds. The concept of scientific approach to identify efficient rootstocks for desired purpose started with focused efforts at different research centers. The potential to produce new rootstocks by either conventional means or in combination with modern technologies is substantial and demonstrated. It is envisaged to choose right rootstocks so that the potential possibilities of the scion variety and rootstock and environment could gainfully be harnessed in sustainable fruit production.

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