Review Article
Rootstock Breeding in Fruit Crops

ABSTRACT

India is the second largest producer of fruits in the world with different fruit growing zones *viz.*, temperate, arid and semi-arid, subtropical, and tropical zones. In this present era of climate change, fruit growers are facing environment-related problems such as sudden changes in temperature, irregular and heavy rainfall, and soil-related problems like compaction, salinity, alkalinity, and acidity. In addition to this, pest and disease incidence also play a major role in limiting fruit production. The purpose of rootstock breeding varies with crops and geographical locations. Developing rootstocks resistant or tolerant to biotic stresses in apple (fire blight and woolly apple aphid), citrus (root rot, nematodes and viral diseases), grape (*Phylloxerasp*. and nematode) and mango (mango fruit fly and stone weevil) for specific tree characters (dwarfing, canopy management) and horticultural traits (yield and quality) are the important aspects in rootstock breeding. The use of rootstocks which are tolerant or adaptable to adverse climatic situations and biotic stress can be an alternative option for scientists and fruit growers to face the challenges encountered by the fruit industry. Objective and result

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Keywords: *Rootstock breeding, Scion Breeding, developing rootstocks, phenolic content*

1. INTRODUCTION

In the world context, India is the leading from the second-largest producer of fruits. There are different fruit-growing zones in India *viz.,* temperate, arid and semi-arid, subtropical, and tropical zones(reference). In this present era of climate change, fruit growers are facing environment-related problems such as sudden changes in temperature, irregular and heavy rainfall, and soil-related problems like compaction, salinity, alkalinity, and acidity. In addition to this, pest and disease incidence also play a major role in limiting fruit production[1].

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Rootstock is the working part of the plant which interacts with the soil to nourish the growth of new plants. This provides a root system that anchors the tree and acts as an absorbing organ of water and mineral nutrients from the soil. It plays a vital component in grafted trees because it determines the success or failure of commercial orchards. Rootstock influences the tree size, precocity in bearing, and resistance to biotic and abiotic stresses. In addition, it also reduces juvenility and improves tree vigor which makes fruit orchard uniformity and consistency[2].

The prerequisites for selecting and using rootstock in horticulture, particularly in the context of grafting, can vary depending on the specific goals and conditions of our project. However, here are some general prerequisites and considerations were suggested by Dhoot et al. (2017) when choosing rootstock[3]. The prerequisites of rootstock involve: i) High germination percentage (if seed propagation), ii) Rooting ability (if clonally propagated), iii) Adaptability to edaphic and adverse climatic situations, iv) Free from nursery disease and pest, v) Substantial horizontal root distribution, vi) Strong, persistent, and adequate growth pattern, vii) Compatibility with most of the scion cultivars.

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The main objective of rootstock breeding is to get maximum quality production per unit area at a low cost and free from biotic and abiotic stresses. The objectives of rootstock breeding vary with fruit crops in relation to different locations and requirements. The objectives may also vary with respect to breeding for rootstock and scion (Table 1). Here are some common objectives of rootstock breeding: i) it should be easily propagated, ii) Resistance or tolerance to biotic stress, iii) Adaptability to different soil and environmental conditions, iv) it should have dwarfing in nature, v) Precocity in bearing, vi) High yield and good fruit quality.

In the case of scion breeding, there are some common objectives are: i) Dwarf growth stature, ii) Regular, precocious, and prolific bearer per unit canopy area, iii) High productivity with good quality fruits, iv) Resistant to biotic and abiotic stresses, v) Attractive fruit color with a pleasant aroma, suitable for processing and export, vi) Good keeping and transport quality. Include objectiveThe objective of the present study was to quantify rootstock-mediated differences in scion fire blight susceptibility and to identify transcripts in the scion whose expression levels correlated with this response

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Table 1.Fundamental difference between scion and rootstock breeding

Scion Breeding	Rootstock Breeding
~~Objectives-~~ High colour, high yield, seedlessness, better pulp, soft seeds *etc.*	~~Objectives-~~ Ability to impart dwarfness, utilize nutrients, graft compatibility, resistance or tolerance to biotic and abiotic stress *etc*.
Evaluation and selection is easy	Evaluation and selection is difficult
Comparatively less time	Need more time

Rootstock improvement can be done by conventional methods *viz.,* introduction, selection, and hybridization. Apart from these, non-conventional approaches such as somaclonal variation, somatic hybridization, and transgenic breeding are also in practice. According to Shukla et al. (2020), the steps involved in rootstock breeding are elaborated in Figure 1, which include utilization of natural and created variability[4]. Introduction, domestication, and germplasm collection through exploration of wide genetic traits can lead to variability. Attempts have been made to create variability by mutation, somaclonal variation, polyploidy, and hybridization methods.

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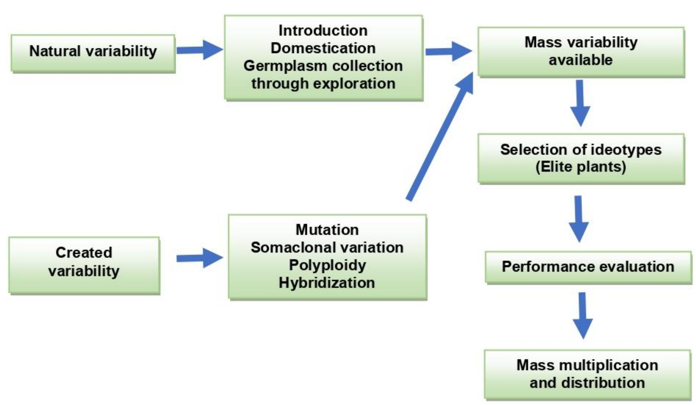

Fig. 1.Steps involved in rootstock breeding

2. SCION AND ROOTSTOCK BREEDING

Dinesh (2016) reported that rootstock breeding is time-consuming when compared to a scion breeding program[2]. The species used in rootstock breeding usually have a reproductive cycle that is more complex. Selecting a candidate rootstock from the population is more difficult than selecting candidate fruiting cultivars because the testing cycle for rootstock is longer than fruiting cultivars. Several factors need to be taken into consideration while taking up rootstock breeding. The physiological environment of the rootstock system is very different from that of the fruiting portion of the tree. The Biotic environment in which the rootstock abides is quite different from that of the scion, the temperature regimes, gas exchange system, and moisture variables are also different. The physiology of the root is different in many ways from that of the leafy portion of the tree. There are substantial variations in environmental conditions within the rhizosphere than above ground.

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Keeping the above factors in mind, the source for a particular trait needs to be looked into rootstock breeding. In the case of breeding for resistance, especially with regard to soil-borne diseases, rootstocks play a very important role. Plant offers three types of resistance mechanisms *i.e.,* morphological, physiological, and biochemical. Morphological resistance offer depends on root structure, length, width, and root hairs; physiologically by synthesis of toxins, tannins, phenolic acids, and biochemically by creating an osmotic environment thereby escaping from stress**.**

3. HISTORY OF ROOTSTOCK BREEDING

Rootstock breeding started during 400 BC; Alexander the Great found dwarf and productive rootstock which is known as the “Paradise” rootstock of apple. Later on, work started for dwarfing, imparting particular architectural and production properties to scion and resistance or tolerance to biotic stress as well as wide geographical adaptability (Table 2)[5]. Phytophthora disease is a major problem in citrus cultivation. To overcome this problem, in 1975 a scientist Chapot introduced citrus rootstock against the Phytophthora disease[6]. In 1986, Iyer and Subramanyam started mango rootstock breeding by using the rootstocks *viz.,*Nileshwar Dwarf, Janardhan Pasand, Manjeera, Amrapali, and Creeping rootstock for imparting the dwarfness in mango plants[7]. The rootstock 13-1 was observed to have less salt retention capacity than re-translocation into the soil; therefore it is regarded as a calcareous soil-tolerant rootstock in mango [8]. Schmid et al. (2003) evaluated various rootstock populations' resistance to *Phylloxera sp*. In grapes which revealed that the hypersensitive reactions on leaves and roots are linked[9]. If plants showed resistance on their leaves, the roots also showed resistance. In the case of guava, rootstock breeding started for imparting dwarfing effect and they have developed extremely dwarf rootstock Pusa Srijan rootstock at IARI, New Delhi followed by rootstock for guava wilt resistance [10]**.**

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Table 2.History of rootstock breeding

Year	Characteristics of rootstocks
400 BC	Alexander the Great identified dwarf and productive rootstock that is known as “Paradise” apple rootstock
15th century	Rootstock used for dwarfing
16th century	Particular architectural and production properties to scion
17th century	Dwarfing and precocious rootstock were discovered
18th century	Malling 9 (M 9) rootstock derived in apple
19th century	M 9 is famous for dwarfing effect in apple characterized at East Malling Research Station, Kent, UK

Early 20^{th} century	Works began to address adaptation to specific biopedoclimatic conditions
Mid 20^{th} century	First breeding efforts started to develop rootstocks resistant to woolly apple aphids
	Malling series of rootstocks used for cold hardiness
Late 20^{th} century	Malling series rootstocks were observed susceptible to fire blight and *Phytophthora* root rot
	Cornell-Geneva breeding program systematically started for dwarfing, precocity as well as overcome to fire blight and *Phytophthora* root rot
	Cornell-Geneva institute reported *Malus* species against resistant to fire blight and *Phytophthora* root rot
After 20^{th} century	Focusing on breeding and development of new apple rootstocks in New Zealand, China and East Malling Research Station, Kent UK

4. GOALS OF ROOTSTOCK BREEDING

4.1. Biotic Stress

The purpose of rootstock breeding varies with crops and geographical locations. Developing rootstocks resistant or tolerant to biotic stresses are presented in Table 3. In the case of apple (fire blight and woolly apple aphid); peach (root rot, bacterial canker and root-knot nematode); plum (bacterial canker, root-knot nematode); citrus (root rot, nematodes and viral diseases); grape (*Phylloxera sp.* And nematodes) and mango (anthracnose, powdery mildew, bacterial canker, mango hopper, fruit fly and stone weevil) have been described by the many scientists.

Table 3.Purpose of rootstock breeding to resistant or tolerant to biotic stresses

Fruit crop	Biotic stresses	References
Apple	Fire blight, Apple woolly aphid	[11]
	Apple stem pitting virus	[12]
	Crown rot	[13]
Peach	Root rot, bacterial canker	[14]
	Root knot nematode	[15]
Plum	Bacterial canker	[16]
	Root knot nematodes	[17]
Citrus	Resistance to root rot diseases Resistance to nematodes Resistance to viral diseases	[2]
Grape	Resistance to *Phylloxera* and nematode	[18]
Mango	Resistance to anthracnose, powdery mildew, bacterial canker Resistance to mango hopper, fruit fly, stone weevil	[2]
Guava	?????????????????	

4.2. Abiotic Stress

Purpose of rootstock breeding varies with environment and different soil conditions. Developing rootstock resistant or tolerant to abiotic stresses are expressed in Table 4. In apple (cold hardiness and problematic soil); peach (cold hardiness, drought and water logging); plum (cold hardiness, drought); citrus (excess salts, drought, cold and water logging); grape (drought, acidity and salinity) and mango (high pH, calcareous soil, salty soil *etc*.) several abiotic stresses have been reported by the several researchers.

Table 4.Purpose of rootstock breeding to resistant or tolerant to abiotic stresses

Fruit crop	Abiotic stresses	References
Apple	Cold hardiness	[19]
	Problematic soil	[20]
Peach	Cold hardiness, drought, water logging	[21]
Plum	Cold hardiness, drought	[22]
Citrus	Tolerance to excess salts, drought, cold and water logging	[2]
Grape	Resistance to drought, acidity and salinity	[18]
Mango	Tolerance to adverse soil conditions (high pH, calcareous soil, salty soil *etc*.)	[2]

4.3. Horticultural Traits

The purpose of rootstock breeding in fruits for the influence of horticultural traits is presented in Table 5. Rootstock breeding for the influence of horticultural traits in apple (annual extension growth, tree volume, fruit quality, and yield); peach (scion growth and development, scion physiology); plum (tree size and production, compatibility with scion); citrus (high rate of nucellar embryonic, compatibility with scion, reduction of tree size); grape (influence on scion vigor, compatibility with *V. vinifera* cultivars, influence on yield and fruit quality, influence on vine maturation and cold hardiness) and mango (dwarf stature, polyembryony, good scion-stock compatibility) have been attempted to improvement of the fruit trees by various research workers.

Table 5.Purpose of rootstock breeding for influence of horticultural traits

Fruit crop	Horticultural traits	References
Apple	Influence of tree volume, fruit quality and yield	[23]
Peach	Influence on scion growth and development	[24]
	Compatible with scion physiology	[25]
Plum	Influence of tree size and production	[26]
	Compatibility with the scion cultivar	[27]
Citrus	High rate of nucellar embryony Compatibility with scion Reduction of tree size	[2]
Grape	Influence on scion vigour Compatibility with *V. vinifera* cultivars Influence on yield and fruit quality Influence on vine maturation and cold hardiness	[18]
Mango	Dwarf stature Polyembryony Good scion-stock compatibility	[2]

5. PRESENT STATUS OF ROOTSTOCK BREEDING

5.1. Apple Rootstock Breeding

The present status of rootstock breeding in apples was investigated by different scientists on different parameters such as biotic stress, abiotic stress, and influence of horticultural traits (Table 6). These rootstocks can be used for further improvement of apple cultivation. Jensen et al. (2012) worked on rootstock-regulated gene expression patterns associated with fire

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blight resistance in apples[28]. The objective of the present study was to quantify rootstock-mediated differences in scion fire blight susceptibility and to identify transcripts in the scion whose expression levels correlated with this response. Rootstock influence on scion fire blight resistance was quantified by inoculating three-year-old, orchard-grown apple trees, consisting of Gala scions grafted to a range of rootstocks, with *Erwinia amylovora*. The disease severity was calculated and measured by the extent of shoot-affected necrosis over time. Apple variety Gala scions grafted into G-30 and MM-111 rootstocks showed the lowest severity rates of necrosis, while Gala scions on M-7, Sup.-4, and M-9 showed the intermediate necrosis rates of necrosis. Sandanayaka et al. (2003) studied characteristics associated with woolly apple aphid (*Eriosomalanigerum*), and the resistance of three apple rootstocks[29]. The resistance characteristics of Northern Spy, Robusta-5, and Aotea were compared to the susceptible cultivar Royal Gala by measuring the aphid settlement, development, and survival rates correlated with electronically monitored probing behavior. Mean percentage settlement of woolly apple aphid on Royal Gala, Aotea, Northern Spy, and Robusta 5 for 20 days following inoculation. Robusta-5 and Aotea had a higher level of resistance with significantly shorter periods of phloem-feeding, suggesting that the resistance factors were present in the phloem tissue. Phenological measurements indicated that the aphids showed poor settlement, development, and survival on Robusta-5.

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5.2. Peach Rootstock Breeding

At present status in peaches several rootstocks have been developed by horticultural scientists related to abiotic stresses are tabulated in Table 6. These rootstocks can be used for further improvement of peach. Forcada et al. (2019) evaluated the sugars, organic acids profile, and antioxidant compounds of nectarine fruits influenced by different rootstocks[30]. Thirteen Prunus rootstocks with different genetic backgrounds [five peach-almond hybrids; one *P.persica* x *P.davidiana* hybrid; three hexaploid*P.insititia* plums; three plum x peach-almond hybrids, and a plum-almond hybrid] were budded with the BigTop nectarine. Result of statistical analyses of the experiment showed that rootstocks were affected strongly by fruit phytochemical composition. Compared with peach-based rootstocks, the hexaploidPollizo plums Adesoto-101 and PM-150-AD can increase the sweetness of the low-acid BigTop nectarine, inducing higher contents of sugars and organic acids. Similarly, beneficial antioxidant effects can be enhanced on diploid plum-based hybrids PADAC 04-01, PADAC 99-05, and Rootpac-R, inducing higher contents of sugars and bioactive compounds (total phenols, flavonoids, and vitamin C) and antioxidant capacities. Finally concluded that new plum-based rootstocks seem to induce higher fruit quality based on sugars and organic acids profile, and antioxidants compound into the nectarine cultivar. Jimenez et al. (2013) reported physiological, biochemical, and molecular responses in four Prunus rootstocks submitted to drought stress[31].The physiological, biochemical, and molecular drought responses of four Prunus rootstocks (GF-677, Cadaman, Rootpac-20, and Rootpac-R) budded with the Catherina peach cultivar were studied. Trees were grown in 15-l containers and subjected to progressive water stress for 26 days, monitoring soil moisture content by time domain reflectometry. Root and leaf soluble sugars and proline content were measured. At the end of the experiment, stressed plants soluble sugars and proline concentration changes were observed, in both root and leaf tissues, especially in an advanced state of stress. The accumulation of proline in roots and leaves with drought stress was related to the decrease in osmotic potential and increase in Water Use Efficiency (WUE), whereas the accumulation of sorbitol content in plant leaves, raffinose content in roots and proline content in both the tissues were related only to the increase in the water use efficiency. These results indicate that the accumulation of sorbitol, raffinose, and proline in different tissues can be used as markers of drought tolerance in peach cultivars grafted on Prunus rootstocks.

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5.3. Plum Rootstock Breeding

Present status of rootstock breeding in plums related to biotic, abiotic stresses, and influence of horticultural traits more work has been done by several workers and find different rootstock which is mentioned in Table 6. Citation

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5.4. Guava Rootstock Breeding

Rootstock breeding work in guava has been conducted for the development of resistance and tolerance to biotic, and abiotic stress, and the influence of horticultural traits. These salient findings are listed in Table 6. Bajpai et al. (2007) conducted an experiment with *Psidium* spp. for screening rootstock resistant to wilting in the glass house[10]. Nodal buds excised from severely pruned trees were used for the initiation of sterile cultures and their multiplication. Seasonal response and media constitution in different *Psidium* spp. such as *P. molle*, *P. chinensis, P. cattleianum*, and *P. guinense* were clearly established for explant establishment and bud induction. These cultures were being used under an *In vitro* selection scheme employing culture filtrate of *F. oxysporum* sp. solani. Relatively short-term callus cultures were exposed to the toxin in the culture filtrate. Preliminary results showed extensive callus mortality after 30 minutes of treatment. The study concluded that *P. guinense* showed a higher level of resistance against guava wilt compared to other species. Kamle and Baek (2017) standardized somatic embryogenesis in guava (*Psidium guajava* L.)[32]. Conventional methods of guava improvement encountered restricted achievement in the progress of disease-resistant varieties because of existing high genetic variability in the germplasm. There is a considerable demand for the establishment of successful and efficient regeneration protocols via somatic embryogenesis. Plants regenerated with somatic embryos could be more useful than plants obtained by organogenesis because most somatic embryos are of unicellular origin and have a low incidence of chimeras and a high number of regenerations. The recent status of somatic embryogenesis is the basis for expanding the genetic improvement of guava for quality traits and future perspectives using advanced technologies.

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5.5. Citrus Rootstock Breeding

More studies have been reported on rootstock breeding in citrus by horticultural researchers for the development of resistance and tolerance to biotic stresses, adaptation to abiotic stresses, and influence of horticultural traits. These findings are tabulated in Table 6. Abbate et al. (2019) studied four allotetraploid somatic hybrids of citrus, with the potential for rootstock improvement, and further evaluated hybrids for their response to Citrus tristeza virus (CTV) infection[33]. Somatic combinations of Milam lemon + Sour orange, Calamondin + Keen sour orange, Calamondin + Femminello lemon, and Cleopatra mandarin + Femminello lemon were studied along with sour orange and citrus alemow rootstock as a control. Plants were grafted with CTV-infected Valencia sweet orange bud wood. They have confirmed that decreased level of viral replication in tested somatic hybrids, as compared to the susceptible genotypes sour orange and citrus alemow. Bowman et al. (2016) recorded the yield and yield efficiency of sweet orange trees with huanglongbing (HLB)[34]. The rapid spread and destruction of huanglongbing disease caused by bacteria (*Candidatusliberbacterasiaticus*) in Florida began to seriously threaten the future of Florida's citrus industry and led to major changes in cultivar use and management practices. Four new citrus rootstocks developed by USDA, ARS and released between 2001 and 2010 achieved significant commercial popularity in Florida and were used for propagation. The effect of rootstocks on tree vigor varies widely. When used as a sweet orange rootstock, US-802 usually maintains vigorous vigor and large tree development, US-812 and US-942 produce moderate vigor, and US-897 produces a relatively dwarf tree. Plant other traits and characteristics of the four rootstocks are also discussed, including effects on yield, fruit

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quality, disease and pest resistance, and tolerance to abiotic factors. Importantly, the relative tolerance of these rootstocks to huanglongbing can be inferred from a combination of data from several sources, with US-942 and US-802 typically producing the best yield per tree in many trials.

5.6. Grape Rootstock Breeding

Grape improvement has been done through rootstock breeding reported by different researchers according to the need for improvement such as resistance or tolerance to biotic stresses, adaptability to adverse climatic conditions as well and influence of horticultural traits. These are recorded in Table 6.Satisha et al. (2007) conducted an experiment on the physiological and biochemical characterization of grape rootstocks[35]. Ten grape rootstocks were characterized for their various morphological, physiological, and biochemical parameters. Significant differences were observed for most of the parameters studied. Rootstocks in the group of *Vitis berlandierii* × *Vitis rupestris*, such as 110-R, 1103-P, 99-R, and B2-56, had a significantly higher content of total phenols, flavonols, flavonoids, proline, and total protein. The high phenolic content in rootstocks such as Dogridge, 99-R, 110-R, and 1103-P may help in reducing the incidence of major grape diseases in commercial table varieties if grafted onto these rootstocks. Thus, the physio-biochemical characterization of rootstocks may help to identify particular rootstocks that could influence a desired trait in commercial table/wine grape varieties after grafting.

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5.7. Mango Rootstock Breeding

Present status of rootstock breeding in mango several rootstocks evaluated for resistance and tolerance to various pests and diseases, adaptability to adverse climatic situations and problematic soils, and also the influence of horticultural traits for yield and quality. These rootstocks are presented in Table 6.Nimbolkar et al. (2018) investigated the seed germination and seedling responses of polyembryonic mango (*Mangifera indica* L.) genotypes to salinity stress[36]. In this experiment, the effects of salinity stress (induced by 50 mM NaCl) on seed germination, biomass content, and growth responses of newly emerged seedlings of sixteen polyembryonic mango genotypes namely EC-95862, Vattam, Vellaikolamban, Nekkare, Mylepelian, Turpentine, Sabre, Manipur, Kitchener, Kensington, Olour, Kurukkan, Bappakkai, Chandrakaran, Muvandan and Deorakhio were investigated. Among these genotypes, Turpentine, Bappakkai, and Vattam were showed early and maximum germination after 20 days of sowing while the genotypes, Chandrakaran, Sabre, Kensington, and Vellaikolamban depicted medium germination. With respect to growth behavior, the genotypes Turpentine, Deorakhio, and Olour showed a minimum reduction in biomass under salinity.Kannan et al. (2018) investigated the effect of soil sodicity on salt-tolerant polyembryonic mango rootstocks[37]. This study was conducted to assess the movement of Na^+ and K^+ between leaves, stem, and root segments of tolerant and susceptible polyembryonic mango accessions under a saline-sodic environment. They have observed that the Na^+/K^+ ratio in the stem of tolerant accession registered a lower Na^+/K^+ ratio in GPL-1. Out of these, they have selected GPL-1, GPL-3, and ML-4 rootstock which were extremely tolerance to sodicity with lower mortality compared to others.

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Table 6.Present status of rootstock breeding in fruit crops improvement

Fruit crop	Specific features	Rootstocks	References
Apple	Cold hardiness	M 7, M 26, MM 106, MM 111, G 11, G 30, G 41	[38]
	Woolly aphid resistant	Northern Spy *Malusseiboldii*	[39]

		MM 102, MM 105, MM 106, MM 108, MM 111	
		CG 5179, CG 6210, CG 7707	
	Phytophthora resistant	M 27, MM 111, Ottawa 3, B 9	
	Fire blight resistant	CG 5179, CG 6210, CG 7707, MM 106	
	Dwarfing	M 26, M 27, Ottawa 3, P 2 (Poland), B 9 (Russia)	
Peach	Drought tolerance	GF 677, Almond	[31]
	Iron chlorosis	GF 677, Adesoto, Felinem	[40]
	Salt tolerance	GF 677	[41]
	Tolerance to calcareous soil	GF 677 (Peach × Almond)	[42]
Plum	Root asphyxia	Myrobalan	[43]
	Tolerance to calcareous soil	Marianna GF 8-1	[44]
	Salt tolerance	GF 677	[41]
	Cold hardiness	Myrobalan	[45]
Guava	Tolerance to wilt	*Psidium cattleianum, P. molle*	[2]
	Resistance to wilt and nematodes, dwarfing	*P. friedrichsthalianum*	
	Tolerance to nematodes	*P. guajava* x *P. guinense*	
	Resistance to wilt	*P. molle*x *P. guajava*	
Citrus	Huanglongbing (Greening) tolerance	US-802, US-942	[34]
	Salt tolerance	Carizo	[46]
	Dwarfing	F & A 418, #23, #24	[47]
	Citrus tristeza virus, citrus nematode, *Phytophthora* resistance	US-852	[48]
Grape	Salt tolerance	99-R, 110-R, 1103-P, B-2-56	[49]
		Dogridge, Salt Creek	[50]
		Ramsey, Riparia Glorie	[51]
	Drought tolerance	Borner (*Vitis cinerea*)	[52]
		Olour, Nekkare	[53]
		GPL-1 and ML-2	[54]
Mango	Salt tolerance	Gomera-1 and 3	[55]
		M. zeylanica, M. odorata, M. foetida	[56]
		13-1	[8]
	Dwarfing	Arauca	[57]
		Latra and Mylepelian	[58]
		Vellaicolomban	[59]
		Brodie and Mylepelian	[60]

6. FUTURE STRATEGIES

1) Rootstock evaluation methodology should be standardized for different fruit crops.
2) Seedling propagation is taking more time compared to clonal propagation so vegetative propagation should be followed for rootstock breeding.
3) Preservation and exchange of germplasm create a variation in the fruit crops so further improvement in the rootstock breeding should be taken into consideration.
4) Related to endogenous growth substances such as proline and phenolic contents which are responsible for abiotic and biotic stress management these can be used for influence of rootstock breeding.
5) Molecular analysis of rootstock can play an important role in multiple stress tolerance in rootstock breeding

7. CONCLUSION

Biotic stress tolerance or resistant rootstock can be an alternative option for biotic stress management in fruit crops. Abiotic stress-tolerant or adaptable rootstock developed by rootstock breeding can be recommended in problematic situations. The influence of horticultural traits such as higher yield and fruit quality through rootstock breeding can improve the scion cultivars. By using dwarfing rootstock can be recommended more plants per unit area in commercial orchards. The use of rootstocks which are tolerant or adaptable to adverse climatic situations and biotic stress can be an alternative option for scientists and fruit growers to face the challenges encountered by the fruit industry.

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Comment [KK20]: References should be in alphbetical order

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