ROOTSTOCKS FOR TROPICAL AND SUB-TROPICAL FRUIT CROPS

Shivaji N. Kolekar Ph.D. Scholar Dr.PDKV Akola

ABSTRACT

Rootstocks play a crucial role in determining orchard efficiency in fruit crops. Combining the desirable attributes of two different plants by budding or grafting can produce different growth effects. This difference can illustrate by comparing the relative importance of rootstocks for precocity, yield, and tree size control, and through contrasts in annual phenological cycles, fruit respiratory behaviour, crop load and canopy management techniques. But these effects on physiological, biochemical and molecular fronts are still not understood. The rootstock effects on scion growth, vigour and habit, as well as scion precocity and abundance of flowering, the propensity of flowers to set fruits and yield efficiency.

The role of rootstocks and its use in different fruit crops has significant impact on fruit crop production by influencing canopy architecture, nutritional uptake, flowering, yield and fruit quality. (Rom *et al*.,1987). Besides, it can also confront biotic and abiotic stresses such as soil pathogens, thermal stress, salinity and nutritional stress (Reddy *et al.*,2003). Rootstocks have a primary role in determining orchard efficiency. They are responsible for water and mineral uptake and provide anchorage for the tree. Rootstocks determine tree size. Rootstocks may provide some degree of tolerance to soils that are sometimes too wet or too dry. Identification and utilization of appropriate rootstocks in crops like citrus, mango and grapes in relation to vigour management, nutrient uptake, soil salinity, and moisture stress and yield efficiency has been already studied in several countries.

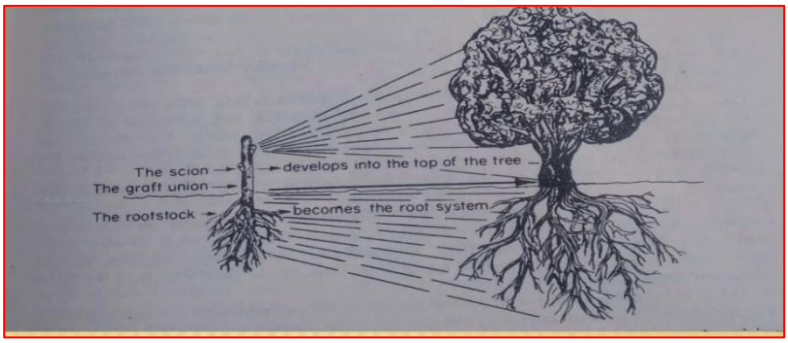
Rootstocks with immense potential for commercial exploitation are yet to be utilized to its full potential most of the commercial fruit crops in India. Therefore, it is important step to find a rootstock with the maximum desirable characteristics to meet the set of environmental conditions where the tree is to be grown. It means a root-stock considered best for a certain variety and environmental conditions may not be a best choice for some other variety and environmental regime. (Nimbolkar *et al.*, 2016). Therefore, the detailed studies on rootstocks for tropical and sub-tropical fruit crops is necessary.

INTRODUCTION:

Rootstocks play a crucial role in determining orchard efficiency in fruit crops. Combining the desirable attributes of two different plants by budding or grafting can produce different growth effects. This difference can illustrate by comparing the relative importance of rootstocks for precocity, yield, and tree size control, and through contrasts in annual phenological cycles, fruit respiratory behaviour, crop load and canopy management techniques. But these effects on physiological, biochemical and molecular fronts are still not understood. The rootstock effects on scion growth, vigour and habit, as well as scion precocity and abundance of flowering, the propensity of flowers to set fruits and yield efficiency.

What is mean by Rootstock?

i. Rootstock is the lower portion of the graft which develops into the root system of the grafted plant.
ii. A rootstock may be a seedling, a rooted cutting or a layered plant.
iii. It is also described a plant which already has an established healthy root system on to which a cutting or bud from another plant is grafted.
iv. The plant part grafted on to the rootstock is usually called as scion.
v. Rootstocks are being used in plant propagation for more than 20 centuries.
vi. The rootstock may be a same or different species from the scion.
vii. The use of rootstock is most commonly associated with fruit crops.



History of Rootstock

i. Although grafting has been practiced for many hundreds of years, most orchard rootstocks in current use were developed in the 20th century.
ii. The budding or grafting of citrus became practice after appearance of Phytopthora foot rot appeared in the Azores in 1842.



Abilities of Rootstock

A. Nursery ability:
- ✓ Ready availability of seed
- ✓ High percentage of polyembrony
- ✓ Good germination and seedling growth
- ✓ Free from pest's attacks and easy budding

B. Soil adaptability:
- ✓ Relative vigour of growth on soils of varied depth, structure, texture, pH, salinity, moisture and nutrient supply.

C. Climatic adaptability:
- ✓ Hardiness
- ✓ Resistant to cold

D. Biotic adaptability:
- ✓ Free from or resistant to various soil borne diseases.
- ✓ Some rootstocks are found superior in one or more of these qualities but inferior in other but none is found outstandingly superior in all respects.
- ✓ Some rootstocks may be superior for one scion variety under given environmental conditions and inferior for other variety.

Importance of rootstock in fruit crops:

i. Impart resistance to biotic and abiotic stresses of scion cultivar
ii. Resistant to adverse soil and climatic conditions
iii. Cold hardiness
iv. Providing strong root system
v. Regulate uptake of moisture and nutrients
vi. Regulate tree vigour and size
vii. Dwarfing effect
viii. Affect flowering, fruit set, fruit drop, fruit size
ix. Affect fruit quality and yield
x. Trees propagated on rootstocks are true to type, comes to bear earlier, precocious.

Types of Rootstock

There are two types of rootstocks used in fruit crops.

A) Seedling rootstocks
B) Clonal rootstocks

A) Seedling rootstocks:

i. These are developed from seeds.
ii. These rootstocks are relatively simple and economical to produce.
iii. Root system developed by seedlings tend to be deeper.
iv. These are mostly used for tropical and sub-tropical fruit crops.
v. Seedling rootstocks have an advantage that the plants don't retain viruses occurring in their parent plants.
vi. Seedling rootstocks have a disadvantage of genetic variation which may lead to variation in performance of scion.

B) Clonal rootstocks

i. Rootstocks propagated vegetatively are known as clonal rootstocks.
ii. These also include those propagated through a zygotic seed (parthenogenetic, polyembryonic and apomictic seeds.)
iii. Each clonal individual plant is genetically same and have identical growth characteristics in a given environment (Hartman *et al*,2002).
iv. Major disadvantage of clonal rootstocks is that; they retain the viruses occurring in the parent plants.
v. They will not produce deeper roots.
vi. These are available in majority for temperate fruits.

Characteristics of an Ideal Rootstock

i. It should be compatible with scion cultivars and give maximum productive life to the trees.
ii. It should be well adapted to the agro-climatic conditions of the particular locality like frost, cold and heat.
iii. It should be resistant to diseases and pests prevalent in the concerned area.
iv. It should be tolerant to adverse soil conditions like salt, alkalinity, acidity and drought.

v. It should have a positive effect on bearing and quality of scion variety.

vi. It should possess good germination capacity, a high degree of polyembryony, ability to attend graft-able size in a short period and free from excessive branching.

vii. Must exhibit favorable and positive influence on the performance, bearing and quality of scion variety.

Stock -Scion Relationships

A rootstock is part of a plant, often an underground part, from which new aboveground growth can be produced, and the plant part grafted onto the rootstock is usually called the scion. All the desired quality should have in the scion. A grafted or budded plant makes a good union to establish a composite plant when stock and scion is fully compatible. Sometimes grafted or budded plant can produce unusual growth patterns which may be different from what would have occurred if each component part of a graftage. This different aspect of rootstocks will influence the performance of a scion cultivar or vice versa is known as stock-scion relationship. They are as follows:

A) Effect of stocks on scion cultivars

B) Effect of scion on rootstock

C) Influence on inter-stock

A) Effect of stocks on scion cultivars

1) On size and growth:

If a scion grafted on dwarf stocks, the scion will grow less vigorously, but if the same scion grafted on very vigorous stocks or rootstocks, the scion will grow very vigorously.Trifoliate orange is considered as dwarfing stocks for grape and sweet oranges. Some of mango rootstocks give dwarfness when grafted on scion cultivars like Kalapade, Olouretc. If guava cultivars grafted on *Psidium pumilum* it will be dwarf in size. Pusa Srijan guava stock, also give dwarfness in Allahabad Safeda, and it is a commercial cultivar of guava.

2) Precocity in flowering and fruiting:

The time taken from planting to fruiting is called precocity and it is affected by rootstocks. Generally, precocity is related to dwarfing stocks or rootstocks and slowness to fruiting with vigorous stocks. Mandarin citrus fruit, when grafted on Citrus jambhiri rootstock is taken less days for fruiting than those grafted on acid lime.

3. Fruit set and yield

When acid limes budded on rough lemon it will increased 70 % of yield compare to those budded on troyer citrange, Rangpur lime or its own stock.

4. Fruit quality

When Sathugudi sweet oranges grafted on Gajanimma rootstocks it bears large but poor quality fruits while on its own stocks, they impart fruits with numerous quality and juice content.The physiological disturbance like 'granulation' in sweet orange is very low if grafted on Cleopatra mandarin seedlings, whereas, rough lemon seedling stocks stimulate high granulation.

5. Nutrient status of scion

Rootstocks also affecting the nutrient behavior of scion. When Sathugudi orange trees budded on C. volkarimariana root stock it gives better nutrient status of all nutrients in the leaves than on its own rootstock or *Cleopatra mandarin* rootstocks.

6. Disease resistance

In citrus, an appropriate variation exists between the rootstocks in their return to diseases and nematodes. For example, rough lemon stock is tolerant to tristeza, xyloporosis and exocortis but is responsible to gummosis and nematodes. However, troyer citrange is tolerant to gummosis but responsible to exocortis virus disease.

7. Winter hardiness

Grafting of Young grapefruit trees on Rangpur lime succeed on winter injury better than on rough lemon or sour orange. Sweet oranges and mandarins on trifoliate stocks were colder and hardy.

8. Capability to stand out the soil opposing status

Foliate orange shows weak ability on citrus rootstocks, whereas, Rangpur limes, Sweet orange and Sour orange stocks shows medium capability to stand out against more salts in the soil condition.

B) Effect of scion on rootstock

1. Vigor of the stock

Scion cultivar effect on size, nature and form of the stock. When grafted a vigorous scion on weak or dwarf stocks, then the growth of the stocks also induced, but if weak or dwarf scion grafted on vigorous stocks, the growth of the stocks will be decrease. A strong scion always causes the roots to become more resistant to wet, poorly aerated soils.

2. Cold hardiness of the rootstock

Scion affects cold hardiness of citrus roots. Unbudded sour orange seedlings are least affected from winter injury whereas when it is budded on Eureka rootstock, suffered much more from winter injury.

3. Precocity in flowering

A six month or one-year-old mango rootstock seedlings exhibited flowering when its branches were inarched from the tree.

Influence on inter-stock

To use certain dwarfing rootstocks as a vigorous for producing non-vigorous and early bearing trees is in practice. For Amrapali, Anupam variety of mango is recommended as inter-stock, grafted on Mallika stock to stimulate dwarfness, precocity and development in fruit quality. On the other hand, sometimes inter-stock might not effect on desirable characters.

Rootstocks for Citrus

Rootstock role in citrus is well known for its tolerance towards biotic and abiotic stress as well as for increasing yield and quality. A wide variety of rootstocks are available, each having desirable attributes.

Rootstock in Citrus has been a horticultural practice for over a century, it is important to have understanding and full knowledge of rootstocks their characteristics, usefulness and availability. One of the most important factors affecting the performance of citrus grafted trees, is the stock on which scion is worked. The part comprising the root system is called "rootstock" and which comparing shoot system is termed as 'scion'. It has also been well established that the different species/varieties of citrus require different combination of rootstock and scion, which proved fit for one set of agro-climatic conditions. Thus it is evident that rootstocks are of great importance in the intensive cultivation of citrus. Citrus rootstocks have pronounced effects on scion vigor, fruit size, yield, juice content and quality, tolerance to cold, drought, salt, alkalinity and leaf nutrient content. Rootstocks also differ in their ability to soil with different textures, root distribution and mycorrhizal dependency.

Rootstocks research in its infant stages involves only a few rootstocks, primarily rough lemon, sour orange, trifoliate orange, sweet orange and occasionally grapefruit or Cleopatra mandarin. The budding or grafting of citrus became a practice after appearance of Phytophthora foot rot in the Azores in 1842 and it was the transition point of citriculture from seedling to budded trees. Phytophthora was later noted in all the Mediterranean countries, and by about 1935, it had been observed nearly everywhere. Seedlings were gradually replaced so that budding on to rootstock seedlings propagates today virtually all trees.

The selection of rootstocks is very important aspect on which the success of rootstock and scion combination depends. The points include Vigor, Yield, Quality, Probable length of productive life of tree and Compatibility should be considered at the time of rootstock selection.

Table no. 1 Variability in Citrus Rootstocks

Species	Variability
Rough lemon(*C. jambhiri*)	Mithi, lambhiri Kotagiri, Renuka lemon, Florida Rough, Jatti Khatta, Jatti Khatti, Pathancot, lambhiri Nagpur, Khatta, Jallandar Khatti.
Rangpur lime(*C. limonia*)	Brazil orange, Brazilian Rangpur, Florida Rangpur-8748, Khasi lime, L-2 Rangpur lime, Marmalade orange, Pink Fleshed Lime.
Small fruited Mandarin (*C. resin*)	Kodakithuli, Citrus China, Cleopatra mandarin, Soh - seim, Karpura Tenga.
Sour orange (*C.aurantium*)	Karun jamir, Molepuli, Seville orange, Willow leaf sour orange,
Sweet orange(C. limettoides)	Sweet orange Aabbu, Mithanembu, Sweet lime, Mitha.
Trifoliate orange (*Poncirus trifoliata*)	Christensen, English Dwarf, English Large, Flying Dragon, Trifoliate Argentina, Trifoliate Florida, Trifoliate William.
Trifoliate hybrids	Citrangequat, Citrange Morton, Citrumello, Swingle Citrumello, Savage, Troyer Citrange, Carrizo citrange, Rusk citrange.
Kharna Khatta (*C. Karna*)	Karna Khatta, Karna, Soh-sarkar, Karna Nimboo.

Qualities of a good rootstock:

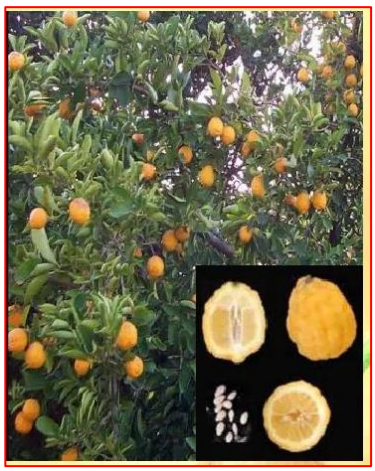
Rootstock is a very vital component of a grafted plant. Once the trees are budded on a certain rootstock and planted in the orchard, it is not possible to change it without incurring serious losses. The good rootstock should have the following qualities

a. The rootstock must exhibit a high degree of congeniality with the scion variety and give maximum economic life to the tree.
b. It should be well adaptable to the agro- climatic conditions of the proposed area.
c. It should be resistant to diseases and pests prevailing in the proposed area.
d. It must exercise favorable influence on the performances hearing and quality of fruits of scion.
e. The stock should also have other desirable qualities like salt tolerance, drought resistant, frost endurance etc. which may be of special significance under certain climatic conditions.

Commonly used rootstocks:

1. Rough lemon (C. jambhiri Lush)

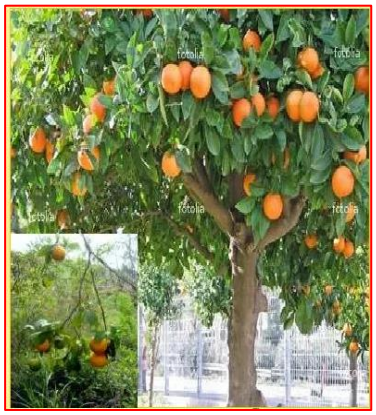
It is probably hybrid origin and is highly polyembryonic, in standard lemon varieties. This is of the most widely used stock in India, S. Africa, Florida and Brazil. Produce large tree, yield high, large fruit, poor cold hardiness, deep rooted, susceptible to foot rot, very susceptible to blight and excess soil moisture, tristeza tolerant, drought susceptible, effects the fruits thickened, Coarseness, lower sugar and acid content of the fruit juice. Best on deep sandy soils but grows well on many types of soil. Rough lemon is tristeza tolerant and susceptible to foot rot and Nematodes. One of its most favourable characteristics is that it grows well as a replant in old citrus soil



Rough lemon

3. Sour Orange (*C. aurantium*)

Sour Orange is the premier citrus rootstock, common throughout the world where tristeza does not preclude its use and especially valued as a rootstock. Trees on Sour orange are moderately vigorous, produce good crop with high TSS and acid content. Sour Orange can be grown on sandy to loam or clay soils. It is well adapted to heavy, often wet type of soil partly because of its moderate resistant to Phytopthora foot rot. Trees on sour orange are essentially unaffected by exocortis or xyloporosis.



Sour Orange

3. Rangpur lime (*C. limonia* Osb.)

Rangpur lime is probably a mandarin hybrid and not a lime like the true acid limes, (*C. aurantifolia* (Christm) Swingle, used as scions. Trees on Rangpur lime are vigorous and highly productive, particularly as young trees and yield medium to large size fruit with low to moderate juice quality. Rangpur lime also grows well in loam and clay loam soils and trees on Rangpur lime have grown well in areas where rough lemon is short-lived and are very salt and lime tolerant. Trees large and vigorous, exocortis sensitive, tristeza tolerant, salt tolerant, high yield, medium fruit quality, tolerant to foot rot and fruit quality is better than rough lemon. Adapted to wide range of soils. Promising for oranges, grapefruit and mandarin.

Rangpur lime

4. Troyer citrange

It is a hybrid of Sweet orange and trifoliate orange and has thus inherited good qualities of worth the parents. It is highly resistant to gummosis and quick decline. The trees bear early and good crops of large size fruit of excellent quality. Trees budded on Troyer citrange are better cold resistant than trees on sour or Sweet orange.

Disadvantages:

- ❖ Adversely affected by high pH
- ❖ Sensitive to soil salinity and water logging.

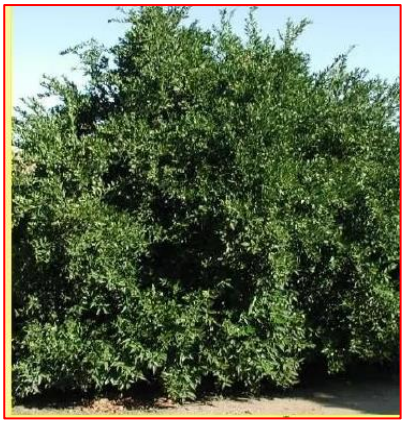
Troyer citrange

5.Cleopatra mandarin (*C. reshni*)

Cleopatra mandarin is one of the most widely and thoroughly studied rootstocks. Among its attributes are tolerance to tristeza, exocortis, xyloporosis, salt, cold and calcareous soils. Cleopatra has been included in many rootstock trials, particularly in areas where sour orange was eventually replaced because of tristeza. Cleopatra is deep rooted with extensive lateral root development on sandy soils but it thrives best on heavier soils or those with a clay layer close to the soil surface. Large tree, fruit size small, fruit quality high, slow growth in nursery, tristeza, salt, cold tolerant, susceptible to foot rot, burrowing nematode and blight is very low. Adapted to a wide variety of soils, used as rootstock for mandarin, Pineapple, Hamlin, Tangelos, oranges and grapefruit.

Disadvantages:

Susceptible to foot rot, burrowing nematode and blight is very low.



Cleopatra mandarin

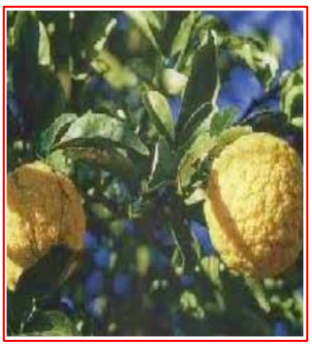
6. Alemow (C. macrophylla Wester)

Alemow is a hybrid species possibly of *citrus celebica* and *C. grandis* native to the Philippines cultivars budded on a lemon produce large, vigorous, grow well on both sandy and high pH, calcareous soils and high yielding trees. *C. macrophylla* have a deep, dense root system that imparts drought tolerance to the scion. It is an excellent rootstock for mandarin, lemons and limes. *C. macrophylla* is better adapted to cool dry climate and it is more tolerant to foot rot than true lemons. It is a classic example of a rootstock that processes outstanding traits along with poor ones. They are the most tolerant to hi of soil boron, chloride and calcium and tend to have high level of leaf m. It is considered Phytopthora resistant.

Alemow

7. Trifoliate orange (*Poncirus trifoliata* (L) Raf)

The genus Poncirus consists of a single deciduous species, *Poncirus trifoliata* and has been a very significant source of rootstock cultivars. Smaller than standard trees, high yield, high fruit quality, good cold hardness, foot rot resistance, tristeza and Phytophthora tolerant, resistant to nematodes, low salt tolerance, used for oranges, grapefruit, has a relatively small root system and soils. It performs poorly in infertile sandy soil, where salinity is a problem. Trifoliate orange is resistant to rot, tristeza, and the citrus nematode. They have shallow root systems consisting of weak lateral root development but abundant fibrous roots.



8.Carrizo citrange:

i. Hybrid of Washington navel orange X *Ponicirus trifoldiata*.
ii. Advantages:
iii. Cold tolerant
iv. Tolerant to tristeza
v. Tolerant to phytopthora and nematode
vi. Disadvantage:
vii. Adversely affected by high pH.

Uses:

i. Fully compatible with navel and Valencia orange varieties.

Carrizo Citrange

9. Flying Dragon:

Potential ultra dwarfing rootstock. Resistant to tristeza virus.Tolerant to xyloporosis, exocortis and gummosis.

10. Karna Khatta:

Suitable semi- vigorous rootstock for Kinnow in India.

11. Soh Sarkar:

Suitable vigorous rootstock for Kinnow in India.

12. Rough lemon, Lemon and Cleopatra mandarin:

Suitable rootstock for sweet orange in India.

13. C. Macrophylla:Resistant to tristeza virus.
14. C. Unshiu:Freeze tolerant.
15. Citron, Kumquat:Highly resistant to citrus canker.
16. Volkmer lemon (C. volkameriana) F & A: Suitable for navel orange, Valencia orange and grape fruit.

Table:2 Characteristics of some selected citrus rootstocks

Rootstocks	**Horticultural performance**		
	Yield	**Quality**	**Plant vigour**
Rangpur lime	G	M	G
Marmalade orange	G	M	G
Rough lemon	G	L	G
Cleopatra mandarin	M	M	M
Sour orange	**G**	**G**	**M**
Sweet lime	M	M	G
Trifoliate orange	L	M	L
Troyer citrange	M	G	M
Carrizo citrange	M	G	M
Sweet orange	G	G	M
Karna Khatta	G	M	M
Nasnaran	M	G	M

G = Good, M = Moderate, L = Poor or low

Table: 3 Characteristics of some selected citrus rootstocks:

Rootstock	Reaction to							
	Yield	**Root rot**	**Citrus nematode**	**Tristeza**	**Exocortis**	**Salt**	**Drought**	**Root system**
Rangpur lime	G	MT	S	R	S	R	R	D
Marmalade orange	G	MT	MT	R	S	R	R	D
Rough lemon	G	S	S	R	R	T	T	D
Cleopatra mandarin	M	T	S	R	R	MT	S	M
Sour orange	G	R	T	HS	T	T	MT	D
Sweet lime	M	S	MT	S	S	S	S	M
Trifoliate orange	L	R	R	R	H	HS	HS	SH
Troyer citrange	M	MT	T	MT	S	HS	HS	SH
Carrizo citrange	M	MT	T	MT	S	HS	HS	SH
Sweet orange	G	HS	HS	MT	R	S	S	M
Karna Khatta	G	S	MT	-	T	T	S	D
Nasnaran	M	S	MT	T	R	HT	S	M

G = Good, M = Moderate, L = Poor or low, R = Resistant, T = Tolerant, MT = Moderately tolerant, S =Susceptible, HS = Highly susceptible, D = Deep, M = Medium, SH = Shallow, - = No information

Rootstocks of Mango

i. In India seed propagation is the chief method of multiplication of rootstock.
ii. Monoembryonic and polyembroyonic both types of rootstocks are uses in propagation of mango.
iii. Dwarfism and tolerance to salinity are two most desired characteristics for a mango rootstock.
iv. Use of non-descriptive mango stones for multiplication of rootstocks has led to enormous variation in the performance of mango clones in the orchards.

Classification of Mango rootstocks are as follows:

A) Polyembronoic
B) Monoembroyonic

A) Polyembronoic rootstocks:
Goa, Olour , Bappakai, Bellary , Kurukan, Mylepalium.

B) Monoembroyonic
Langara, Dashehari, Bombay green, Totapuri red small.

Effect of different mango rootstocks on scion cultivars:

a) Dwarfing effect: -

In India rootstocks with dwarfing effect include Kalapady, Olour, Kerela dwarf,Manjeera, Crepping, Amrapali, Vellaikulamban. Rootstock Vellaikulaban impart dwarfing effect to dashehari and Alphonso where as Olour the same effect to Langra and Himsagar cultivars (Kulkarni,1991).

b) Ability to absorb nutrients: -

Rootstock 13-1 of mango has the capacity to resist the absorption and translocation of Na and Cl and facilitate the absorption of calcium and is known to reduce the incidence of internal fruit breakdown. Amrapali grafted on Kurukkan rootstock has more Cl leaf content than any other rootstock (Dayal *et al*, 2014).

c)Tolerance to salt: -

Mango rootstocks found in India are only moderately tolerant to salt. Polyembryonic rootstocks namely Bappakai, Olour and Kurukkan could withstand higher level of salinity. Mango cultivar 13-1 has been selected as a polyembryonic rootstock for calcareous soils or for irrigation with saline water.

d)Fruit quality and yield:

Influence of rootstock on the fruit quality and yield is reported in many trials done in India. Neelum cultivar get higher total soluble content and yield when grafted on polyembryonic rootstock Bappakai than on other polyembryonic and several other monoembryonic rootstocks. Mylepalium and vellaikulamban rootstocks increased the TSS of the Dashehari cultivar than other rootstocks. Langra grafted on Bappakai rootstock record highest fruits number/plant followed by Vellaikulamban.

Rootstocks of Mango:

To minimize the variability in mango, the poly-embryonic races, known for their uniformity and vigorous growth offer a great scope for use as rootstocks.

Table: 4 Rootstocks of Mango

Sr. No.	Rootstocks	Special features
1	Kurrukan	Salt resistant polyembryonic
2	Olour	Vigorous rootstock
3	Vellaikolamban	Dwarfing and allopolyploid
4	Olour, Villai collumban and Rumani	Dwarfing
5	Moovandan and Nekkare	Salt tolerant
6	Gomera l	Most adaptable in saline conditions where low water quality
7	Species Mangifera minor	Resistant to anthracnose
8	Mangifera zeylanica	Salinity resistance
9	Bappakai and Olour	Salt tolerant for high survival, germination and growth percentage under salt stress condition (Varu and Barad, 2010)
10	Dashehari and Chousa	Salt resistant

Rootstocks of Grape

Table: 5 Recommended grape rootstocks for different situation.

Situation /problem	Rootstock
Water shortage	1103P, 140RU,110R,420A,SO4,99R
Soil EC >2mmhos/cm and water EC>1mmhos/cm	Ramsay, Dogridge B, 140RU, 99R,110R
Soil ESP> 15% and or water SAR >8%	140RU,1613, Ramsay, Dogridge
Free Ca content of soil is >12%	Fercal, 140RU, 420A,SO4
Chloride content of water is >4 meq/lit	Ramsay, Dogridge B,140RU,teleki-5-C
Poor vigor of the variety without any soil/water problem	Ramsay, Dogridge B,140 RU
For increased Nitrogen and Phosphorus uptake	Dogridge B, St. George, 34 EM, Ramsay
For Increased bud break	1613

Table:6 Recommended grape rootstocks

Sr. No.	Rootstocks	Special Features
1	Riparia Gloire, St. George (Rupestris du lot), S04 (Selection Oppenheim), 5BB (Kober), 5C (Teleki), 420A (Millardet et de Grasset), 99R (Richter).	Phylloxera resistance
2	Salt creek and Dogridge	Salt and nematode resistant
3	Temple	Multiple resistant/pierce's disease
4	V. berlandieri	Resistant to Phylloxera, and high lime content in the soils but difficult to propagate vegetatively.
5	V. labrusca	Cold hardy, resistant to many pests and diseases.
6	V. amurensis	Resistant to cold and frost.
7	V. aestivali	Resistant to many fungal diseases but susceptible to Phylloxera, best for hot climatic condition.

Rootstocks of Guava

Table: 7 Suitablerootstocks of guava for different purpose

Rootstocks	Specific features
Pusa Srijan (aneuploidy tetrasomic, 2n+2)	Potential for dwarfing, resistant to wilt.
P. friendrichsthalianum	Dwarfing, resistant to wilt and nematode
P. molle	Resistant to guava wilt
P. Pumilium , P. cujavilis	Highly dwarf high sugar content.
Crioula	New guava rootstock, it is tolerant to pests and diseases, especially guava rust (*Puccinia psidii),* tolerant to salinity.
Psidium cattleianum	Tolerant for low temp.

Rootstocks of Sapota

Table: 8 Suitable rootstocks for sapota

Rootstocks	Specific features
Ryan or Khirni / Pala (*Manilkara hexandra*)	Commercial rootstock in India.
Chrysophyllum lanceolatum	Wider soil adaptability.

Species like have been reported as rootstocks for sapota.(Bose,1985).
1.Mimusops kauki (Adams apple)
2.Madhuka lattifolia (Mahua)
3.Bassia longifolia (Mee tree)
4.Chrysophyllum cainito (star apple)
5.Sideroxylon dulicifolium (Miracular fruit)

Rootstocks of Avocado

Table: 9 Suitable rootstocks for avocado

Rootstocks	Specific features
Duke -7, Zentmyer, Uzi and Steddom	Tolerant to phytophthora root rot
Nachlat	Tolerant to lime
Pollock	Tolerant to salinity

Dwarfing Rootstocks suitable for fruit crops

Root stocks are known to have a profound effect on the tree vigour, precocity, and quality of fruits, productivity and longevity of varieties grafted on them. Dwarfing can be due to the rootstock or the scion, or both.

Table: 10 Dwarfing Rootstocks for fruit crops

Crop	Dwarfing Rootstock
Mango	Vellaikolumban (Alphonso), Olour (Himsagar and Langra)
Guava	Pusa srijan, *Psidium friedrichsthalianum*.
Citrus	Trifoliate orange, Sour orange, Flying Dragon

Table: 12 Worldwide Resistant / tolerant rootstocks in fruit crops

Crop	Rootstocks	Resistance/Tolerance traits
Mango	Carabao	Resistant to wilt
	Gomera-1,13/3,Kurukan,Olour, Bappakkai and 13-1	Tolerant to salinity
Guava	*P.friedrichsthalianum, P.cattleianumvar.lucidum,P. guineense*	Resistance to root-knot nematode
	Crioula	Tolerant to salinity
Grapes	Ramsey, Dog Ridge, Harmony and Freedom	Resistance to root-knot nematodes
	UCD GRN1 and VR O39-16	Resistance to the root lesion nematode
	Ramsey,Riparia Glorie, 5C	screened for salt tolerant
	Ramsey and 1103 Paulsen	Tolerance of phylloxera and nematodes
	140Ru	Tolerance to water deficit condition
	Beta and 3309C	Cold hardiness
	A15 and A17	Tolerance to alkalinity
	Hybrids of *V. berlandieri x V. riparia*	Tolerance to drought
	196-17, CH-1, CH-2	Tolerance to salinity
Avocado	G755C13-1	Salinity tolerance
	Duke 7 and G6	Resistance to P. cinnamomi
Citrus	*C. Macrophylla*, Mandarin Clemenules trees grafted on Carrizo performed well	Resistance to salinity
	Pearl, Mosambi x Kinnow & Mosambi x Nagpur, Star ruby and ruby red	Resistant against citrus pyslla
	A 418 (*Troyer citrange* X Cleopatra mandarin)	Dwarfing rootstock
	US 852 Hybrid Selection	Phytophthora resistance

Challenges in rootstocks utilization in fruit production

i. Research on rootstock should be updated regularly on their targets considering the changes in grower's and environmental requirements.
ii. Low vigour rootstocks predominate in many rootstock breeding projects of different fruit species; however, semi dwarf and moderately vigorous rootstocks also may be applicable in sustainable systems, where year-round grass cover and weed competition should be considered.
iii. Increasing fruit growing in new regions will require a different approach in rootstock research.
iv. Climate change increases the importance of rootstock adaptability to temperature extremes, cold tolerance, winter hardiness, drought tolerance, water-logging, efficient water utilization and adaptability to suboptimal soil conditions.

Future thrust

i. There is urge to develop new rootstocks which will imparts those qualities in scion cultivar which will provide dwarfing effect, required canopy and ultimately quality fruit yield.
ii. To initiate investigation to select suitable rootstock suiting to prevailing soil and climatic conditions for fruit crops.
iii. There is a need to evolve rootstocks tolerant to biotic and abiotic stresses in different tropical and subtropical fruit crops.

Conclusion

i. Rootstocks development is an open unended process.
ii. Recent advances in rootstocks management play a crucial role in determining orchard efficiency and sustainability in fruit crops.
iii. Rootstocks can influence precocity/ juvenility, yield, tree size control, disease resistance or tolerance, fruit respiratory behavior, crop load and canopy management techniques.
iv. Using dwarf rootstock through high density planting, yield can be increased in per unit area.

References

Bhullar, 1.S. and lP. Nauriyal (1975). Effect of different rootstocks on vigour, yield andfruit quality of Blood Red Orange. Indian 1. Hort., 32: 45-49.

Bose, TK, Mitra, SK Sadhu, MK Das, P Sanyal, D and Parthasarathy, VA. 2005.Propagation of tropical and subtropical horticultural crops vol1 (3rd revised edition), NayaUdyog Publication, Kolkata, pp;101 -104.

Chadha K L, Singh H P. Citriculture scenario of India. in Citriculture in North- western India: Proceedings of Citrus Show-cum-Seminar. Prospects and Problems of Kinnow Cultivation (K.S. Gill, J.S. Kanwar and R. Singh, eds.). Punjab Agricultural University, Ludhiana, 1990, 21-64.

Chadha, K.L. and H.P. Singh (1996). Description, Classification and Cataloguing ofgenetic resChandan, P. M., Kadam, J. H. and Ambad, S. N. Effect of different polyembryonic and monoembryonic rootstocks on performance of Dashehari mango. *Inst. J. Agril. Sci.*, 2006,2(2):pp. 594-595.ources of citrus in India. Consultancy Report, IPGRI-APO, Singapore.

De, T.C., K.M. Bujarbaruah, D.S. Yadav, Y.P. Sharma, RK. Patel, R.K.Yadav and A.N.Shylesha (2006). Citrus Rejuvenation Packages in North East India. Research BulletinNo.22, ICAR Research Complex for NEH Region, Umiam, Meghalaya, Pp.24.\

Gunjate RT. Advances in mango culture in India. Acta Hort. 820:69-78 Litz, R.E. 2009. Mango. Wiley Publishers, 2009, 530.

Hartmann, HT, Kester, DE, Davies Jr., FT and Geneve, RL. 2002. Plant Propagation Principle and Practices (6thedn.). Prentice Hall of India Pvt. Ltd. New Delhi.

Lal N, Singh A, Gupta AK, Marboh ES, Kumar A and Nath V. 2019. Precocious Flowering and Dwarf NRCL-29-A New Genetic Stock of Litchi (*Litchi chinensis* Sonn.). *Chemical Science Reviews & Letters*, 8 (32): 206-210.

Nimbolkar P. K., Awachare C, N Reddy Y.T., Chander S. and Hussain, F.2016.*Journal of Agricultural Engineering and Food Technology* Volume 3, Issue 3; July-September, 2016 pp. 183-188.

Rajput, CB S and Haribabu, RS. 1995. *Citriculture*. Kalyani Publisher, New Delhi. pp.147.

Reddy, Y. T. N., Reju, M., Kurian, P. R., Ramachander, Gorakh Singh and Kohli, R. R. Long term effects of rootstocks on growth, fruit yielding patterns of Alphonso mango (*M. indica*) *Scientia Hort*., 2003, 97(2): pp. 95-108.

Singh, H.P. and K.L. Chadha (1993). *Genetic resources of citrus*. Pp. 95-122. In:*Advances in Horticulture-Fruit Crops* (K.L. Chadha and O.P. Pareeks eds.), Vol 2,Malhotra Publishing House, New Delhi.

Ribeiro IJA, Rossetto CJ, Donadio LC, Sabino JC, Martins AIM, Gallo PB *et al*. Mango Wilt. XIV Selection of mango (*Mangifera indica* L.) rootstocks resistant to the mango wilt Fungus Ceratocystis fimbriata Ell & Halst. In *International Symposium on Tropical Fruits*, 370, 1993, 159-166.

Rossetto CJ, Ribeiro IJA, Gallo PB, Soares NB, Sabino JC, Martins ALM *et al*. Mango breeding for resistance to diseases and pests. In Vth International Mango Symposium. 1996; 455:299-304.

Rom, R. C., Carlson, R. F. Rootstocks for fruit crops. New York, Wiley and Sons. 1987, pp. 494.