J. Hortic. Sci.
Vol. 19(2), 2024

https://doi.org/10.24154/jhs.v19i2.2362

Review

Recent advances in rootstock breeding of mango

Sinchana Jain N.R.*, Sankaran M. and Dinesh M.R.
Division of Fruit Crops, ICAR-Indian Institute of Horticultural Research,
Bengaluru - 560 089, India
*Corresponding author Email: sinchanajain317@gmail.com

ABSTRACT

The mango stands as the foremost and highly favored fruit grown in tropical as well as sub-tropical regions due to its exceptional versatility, superior nutritional value, captivating flavor and aroma. Despite its prominence, mango yields fall short compared to other fruit crops due to factors like low-density planting, the use of seedling rootstocks, and alternate bearing. A significant hindrance to widespread mango production is the impact of biotic and abiotic stress, which hampers plant growth, leading to eventual plant death. Mitigating this challenge requires a focus on breeding for an ideal rootstock development. This paper delves into the current landscape of rootstock breeding in various regions worldwide, exploring its critical role in shaping the health, growth, and productivity of mango trees.

Keywords: Abiotic stress, alternate bearing, biotic stress, productivity, rootstock

INTRODUCTION

The mango stands as the foremost and highly favored fruit grown in tropical as well as subtropical regions due to its exceptional versatility, superior nutritional value, captivating flavor and aroma. However the yield of mango falls short when compared to other fruit crops due to multiple factors like low density planting, use of seedling rootstocks, alternative bearing etc. Like any other tropical fruit crops, mangoes have primarily undergone development through natural selection across multiple generations. Nonetheless, given the contemporary preferences and market requirements for fruits, the traditional varieties often struggle to effectively meet these demands. To address this challenge, there is a requirement for organized breeding initiatives aimed at enhancing the productivity along with the fruit quality of mango varieties. These efforts are crucial to empower mangoes to compete effectively in today's dynamic markets. One of the greatest constraints for widespread mango production is biotic and abiotic stress, which results in reduced plant growth which gradually leads to plant death. Mango as a perennial crop is prone to several biotic stresses such as malformation, anthracnose, powdery mildew, fruit fly, leaf hoppers and abiotic stresses such as salinity, alkalinity, and calcareous soils.

Rootstock development in mango encompasses various focal points, such as development of genotypes that confer resistance to unfavorable soil conditions and influence the vigor of the scion. Additionally, other facets comprise the promotion of polyembryony to ensure uniformity, incorporation of dwarfing traits to facilitate HDP, the enhancement of tolerance towards calcareous soils, mitigation of soil-borne challenges, and the establishment of physiological harmony with commercially favored scion cultivars. Given the substantial diversity among cultivars, there consistently exists an opportunity to identify potential sources of resistance. It is prudent to focus on polyembryonic cultivars, which typically exhibit lower variability. These cultivars should be systematically evaluated for their potential to withstand various biotic and abiotic stress factors. The usage of rootstocks offers dual benefits, one is the creation of novel rootstocks with increased tolerance to abiotic stresses and other is the screening of existing polyembryonic varieties to elucidate their potentiality. Generally in most parts of the world, polyembryonic types are used as the rootstocks. The sole exceptions are Bangladesh, India, Pakistan, China, Oman, and Hawaii, where monoembryonic rootstocks are employed. The majority of Indian varieties are monoembryonic, while, a dozen South Indian variants are polyembryonic. Some of the polyembryonic species of mango includes *M. casturi*, *M. odorata*, *M. indica*, *M. laurina* and *M. sylvatica.* Polyembryonic rootstocks used in India are seen in Southern states especially west coastal

Table 1 : *Mangifera* species with salient characteristics

Species	Characteristics
M. zeylanica	• Salt resistant rootstock introduced from Srilanka • Bears fruits in clusters
M. laurina	• Exclusively used in Australia to confer resistance to Kensington against Anthracnose and Black spot • Used for mango nectar production
M. decandra	• Tolerant to water logging • Have innumerable long wavy fibres
M. andamanica	• Bears oval/oblong fruits with highly acidic fibrous pulp • Resistant to fruit fly and tolerant to anthracnose
M. comptosperma	• Bears flat fruits with thick skin and hence tolerant to fruit fly • Young fruits can be used as mature fruits turns fibrous and fall off • Has got biomarker for volatile compound that can be used for screening of variety
M. grifitti	• Tolerant flooded condition • Bears red purple colored fruit • Leaves are like miniature cashew leaves
M. odorata	• Bears complete red/dark pink colored inflorescence • Possess firm pulp with highest TSS content i.e. 21.7 ºBrix
M. grifiti	• Used as rootstock in incubated soils • Has labyrinthine seed
M. pentendra	• Five stamen spp. used as good polliniser in breeding programme.
M. minor	• Resistant to anthracnose
M. altissima	• Resistant to leaf hoppers, tip borer and seed borer
M. pajang	• Can be peeled like banana
M. rufocostata, *M. swintonioides*	• Bears fruits in off season

regions which includes Bappakai, Chandrakaran, Goa, Kurukkan, Olour, Bellary, Kasargod, Mazagon, Nileshwar dwarf, Muvandan, Mylepelian, Kitchner, Nekkare, Prior, Vellaikolumban, Salem etc. and some polyembryonic types in world are Combodiana, Carabao, Cecil, Paho, Higgins, Peach, Turpentine, Apricot, Pico, Sabre, Simmonds, Strawberry, Starch etc.

Diversity of *Mangifera* species

India is renowned for its rich and diverse mango species, showcasing a vibrant tapestry of flavors, colors, and textures. With over 1,000 varieties, the country boasts one of the most extensive collections of mangoes in the world. Each region of India contributes to this diversity, cultivating unique cultivars that are cherished both locally and globally. India is the homeland for several species such as *M. indica*, *M. sylvatica* (N-E India), *M. odorata* (Karnataka & Kerala), *M. griffithii*, *M. andamanica*, *M. camptosperma*, *M. nicobarica* (Andaman & Nicobar Islands). *M. indica* shares a close relationship with *M. sylvatica, M. pentandra*, *M. laurina* and *M. minor*. Some of the edible fruit species includes *M. altissima, M. longipes*, *M. caesia*, *M. macrocarpa*, *M. cochinchinensis*, *M. odorata*, *M. zeylanica*, *M. foedita*, *M. pajang*, *M. griffithii*, *M. pentandra*, *M. indica*, *M. sylvatica* and *M. lagenifera.*

Anticipated temperature increases and alterations in precipitation patterns across tropical and sub-tropical regions are projected to result in frequent and erratic occurrences of both heavy rainfall and drought. These changes will also result in parching dry spells and scorching conditions. Simultaneously, the projected rise in sea levels is poised to elevate soil and water salinity levels. This is due to the encroachment of saline water into water tables, further aggravate the challenge of increased salinity in soil and water resources. The escalating temperatures and shifting precipitation patterns will additionally amplify the issues related to pests and diseases that impact mango cultivation (Normand et al., 2015). With all these in concern the mango rootstock breeding is progressing further in an efficient manner. The achievements in mango rootstock breeding so far have been discussed. The main rootstocks used in mango growing countries are presented in Table 2.

Traits of an ideal rootstocks in mango

The ideal rootstock should possess the characteristics such as:

- Salinity tolerance
- Impart dwarfness to scion by altering the scion vigor and tree architecture
- Better nutrient absorption capacity
- Good scion compatibility
- Tolerance to flooding
- Tolerance to pest and diseases

Table 2 : Main rootstocks used in mango growing countries

America & European countries	Rootstock in vogue	Asia, Africa & Australian countries	Rootstock in vogue
Mexico	Criollos	India	Available seedlings
Brazil	Bourbon, Espada, Coquinho, Imbu, Comum Del Cerrado	Pakistan	Chausa sammar bahisht
Peru	Criollo de Cholucanas	China	Available seedlings
Ecuador	Mango blanco, Mango de chupar, Mango de canela	Thailand	Kaew
Costa Rica	Mango Jamaica (syn. mecha) similar to Turpentine	Indonesia	Madu, *M. kasturi*
Venezuela	Bocado	Malaysia	Mangga Telor
Guatemala	Mango criollo	Bangladesh	Bau 6, 7 and 8, Available seedlings
Puerte Rico	Mayaguezano, Pasote	Vietnam	Buoi
Cuba	Mangas blanca and Manga amarilla, Mango Filipino	Sri Lanka	Willard, Karutha, Vellai Colomban, Kohuamba
Colombia	Hilacha	Philippines	Carabao
Dominican Republic	Banilejo	Senegal	Available polyembryonic seedlings
Honduras	Local criollo types	Oman	Sindheri
Haiti	Mango ron	South Africa	Sabre, Peach, Piva
French West Indies	Mango vert	Sudan	Kitchener (Syn. Baladi)
Florida	Turpentine	Egypt	Sukkari (White Sukkary)
Israel	13/1	Ivory Coast	Cat head
Spain	Gomera 3, Gomera 1	Australia	Kensington Pride
Hawaii	Mono embryonic seedlings *M. kasturi*, *M. llalijiwa*	Taiwan	Tsar-Swan, Char-Swam, Jin Hwung
Colombia	Hilacha		

Galan Sauco (2019)

- Tolerance to dry condition
- Better fruit quality
- Strong root systems to withstand heavy wind
- Reducing the juvenility
- Regular availability of seeds
- High degree of polyembryony to ensure homogeneity

Mango rootstocks for salinity

As the human population continues to rise in many mango-producing countries, there is a mounting strain on water and land resources. Consequently, mango cultivation is expanding onto marginal soils and being irrigated with saline water. To counteract this effect, the development of mango rootstocks that can withstand these challenging conditions becomes imperative. Few reported salinity tolerant rootstocks are Criollo de Cholucanas, Hilacha, Piqueno, Bau 6,7,8, Gomera 1, Sukkari, 13/1, ML2, ML6, *M. kasturi* etc. (Galan Sauco 2019).

During 1980, Gazit & Kadman documented the Israeli cultivar '13/1' as the most renowned rootstock recognized for its resilience to elevated pH levels and saline water. The rootstock '13-1' was chosen because of its polyembryonic character and appropriateness for calcareous soils or saline water irrigation. Mango scions grafted onto '13/1' rootstocks demonstrated impressive growth even in soil comprising 20% lime content. Furthermore, three additional cultivars grafted onto '13/1' rootstocks exhibited robust progress in sandy soil containing lime between 10-20% and were irrigated with water at a salinity of 250 ppm.

In 1975, Kadman and colleagues noted that certain polyembryonic rootstocks, specifically 13/1, 8/16, Sandarsha, Warburg, Feisenzon, along with a few monoembryonic cultivars such as 1/7, 7/1, and Has-el-Has, exhibited notable resilience to salinity. Zebda is another cultivar which showed heightened tolerance to salinity in contrast to other cultivars like Alphonso, Taimur, Ewaise and Hindy Bissinara (Morsy, 2003). Regarding their response to salinity, specifically at 50 mM NaCl concentration, certain genotypes like Turpentine, Deorakhio, and Olour exhibited the least decline in biomass, whereas, Kitchener, Mylepelian, and Chandrakaran demonstrated the most significant reduction (Nimbolkar et al., 2018).

Dubey et al. (2007) examined the impact of salinization on two polyembryonic mango rootstocks, namely Kurukan and Olour. Their study revealed that both genotypes could endure salinity levels up to 2.15 dS/m, with mild leaf necrosis and scorching. In another experiment focused on screening mango rootstocks for salinity tolerance, it was observed that the polyembryonic cultivars 'Olour' and 'Bappakkai' exhibited the ability to withstand elevated salinity level (Palaniappan, 2001). The capacity of the mango rootstocks 'Terpentine' and 'Olour' to tolerate salt may be because of their capability to impede the absorption of Na^{+} and Cl^{-} ions, coupled with increased proline accumulation (Pandey et al., 2014).

The Gomera 1, Gomera 2, and Gomera 3 varieties originating from Spain demonstrate resilience to salinity. When grafted onto Gomera-1 rootstock, the Osteen cultivar showcased enhanced salinity tolerance due to its ability to regulate the absorption and translocation of Na^{+} and Cl^{-} ions from the roots to the upper parts. Consequently, Gomera 1 emerged as a highly versatile rootstock in saline environments, rendering it a viable choice for regions with low water quality (Duran Zuazo et al., 2003). Among the evaluated factors, including canopy volume, trunk cross-sectional area, diameter and height, Gomera 3 exhibited the most substantial measurements, reflecting its vigorous nature. Notably, the combinations of Gomera 1 with Osteen and Gomera 3 with Keitt demonstrated the highest fruit yield, offering encouraging prospects to enhance subtropical mango productivity (Duran Zuazo et al., 2006)

Extensive research has resulted in the recognition of two salt stress-tolerant rootstocks, namely ML-2 and ML-6, which are well-suited for mango cultivation in regions characterized by salt-affected sodic soils. Analysis of the Na+/K+ ratio in meristem tips and leaves revealed that 'ML-2' and 'ML-6' used an efficient Na+ exclusion strategy achieved by enhanced K+ intake. The heightened buildup of proline and phenolics in conjunction with elevated SOD and POD activities in 'ML-2' and 'ML-6' contributed to their enhanced resilience in the face of salt-induced stress conditions (Damodaran et al., 2018). Employing a strategy of pyramiding and stacking multiple genes responsible for diverse facets of salt tolerance, coupled with the identification of QTLs that are for salt tolerance in rootstock such as 13-1 and *M. zeylanica*, holds the potential to yield deeper insights into the mechanisms underlying salt tolerance in mango.

Mango rootstocks for dwarfness

The phenomenon of dwarfism is set to streamline contemporary high-density mango cultivation systems, which are already well-established in nations such as Mexico, Egypt, India, South Africa, and various others. This alteration in tree growth vigor, coupled with adjustments to mango tree structure and a reduction in the juvenile phase, contributes to prolific flowering. These changes align with the objective of producing more condensed and rapidly yielding mango varieties, ideally suited for the demands of high-density planting techniques. Dwarfing can manifest as an inherent trait of a variety or be incorporated into the scion cultivar through rootstock. Characteristics like greater phenolic content, a higher phloem/xylem ratio, and a lower number of developing shoots resulting to flushes have been linked with dwarfing (Singh et al., 1986; Iyer & Kurian, 1992). There exists a correlation between trunk cross-sectional area and both vigor and the cumulative fruit yield in mango trees (Reddy et al., 2003). Such indicators could serve as valuable criteria in deciding on the dwarfing features in a breeding program.

Numerous mango cultivars, such as Piva, Pinita, Saigon 119, Kom and Banilejo (Galan Sauco, 2019), as well as Indian varieties like 'Janardan Pasand', 'Kerala Dwarf', 'Creeping', 'Amrapali' and 'Manjeera' (Iyer & Subramanyam, 1986; Iyer & Degani, 1997), have been identified as potential parental candidates in a breeding program focused on developing dwarf mango varieties. As per Sharma & Majumdar's (1988) research, recessive gene governs dwarfing in Indian cultivars. Pinto & Byrne (1993) discovered that 'Imperial' and 'Amrapali' as male parents had a high propensity to pass on the dwarf characteristic to their progeny, yet the canopies of the progeny were often spreading or dense. In the Australian National Mango Breeding Programme, 'Creeping' has been utilised as a female parent, effectively reducing tree vigour in its progeny; nevertheless, small fruit size and bunch bearing are also characteristics of the progeny.

The cultivar 'Alphanso' produced increased yields per unit canopy volume and per unit land and reduced tree vigour when 'Vellaikulamban' is used as a rootstock (Reddy et al., 2003). Gawankar et al. (2010) reported notable outcomes related to the use of Vellaikolamban rootstock. It led to a considerable decrease in plant volume, with reductions of 39.1% observed in the scion cv. Alphonso, followed by 24.9% in Ratna, and 26.5% in cv. Kesar. For both Alphonso and Ratna cultivars, this reduction in canopy volume had direct implications on fruit yield. Interestingly, the lower canopy volume in the instance of cv. Kesar resulted in a higher yield.

At ICAR-CISH Lucknow, India the 'Rumani' rootstock displayed modest growth characteristics when paired with the 'Dashehari' scion. Conversely, the 'Vellaikolamban' rootstock exhibited the lowest growth performance and fruit yield with the 'Alphanso' scion. In a distinct setting at ICAR-IIHR, Bengaluru, India, the 'Olour' rootstock yielded the highest fruit yield and canopy height, whereas the 'Vellaikolamban' rootstock imparted dwarfing tendencies to the 'Alphonso' scion compared to the robust rootstocks 'Olour', 'Bappakai', and 'Muvandan'. Notably, the more vigorous rootstocks resulted in the highest cumulative fruit yields, while, the 'Vellaikolamban' rootstock, known for its dwarfing effect, produced the highest fruit yield per unit canopy volume at ICAR-IIHR, Bengaluru, India.

Dayal et al. (2016) documented that the 'K-5' rootstock restricted the vigor of Dushehari, Pusa Surya and Pusa Arunima cultivars, while, it bolstered the vigor of Mallika and Amrapali cultivars. Conversely, the Olour rootstock encouraged growth in Dushehari, Pusa Surya and Pusa Arunima, while curbing growth in Mallika and Amrapali. Dubey et al. (2021) reported that in general 'K-2' and 'K-5' rootstocks reduced the lateral and vertical growth of Amrapali, Pusa Surya and Pusa Arunima scions. Distinct criteria, including stem growth, bark percentage, and the area occupied by vessel roots, offer a means to categorize mango rootstocks into different classes based on their vigor. In line with this approach, Totapuri red small and Olour were categorized as dwarfing rootstocks, while Chausa and Kurukkan were classified as vigorous alternatives (Majumder et al., 1972). The Manila variety displayed a larger canopy area when grafted onto rootstocks like Gomera, Julie, and Criollo. Conversely, the Thomas rootstock induced dwarfing in trees, rendering it a suitable choice for high-density planting scenarios with a population of 400 trees per hectare (Martinez et al., 2019). Irrespective of the scion cultivar, the use of Amrapali as a rootstock resulted in a reduction of the tree height by 70 centimeters. (Varghas-Ramos et al., 2014). Mizani et al. (2018) worked on reducing the vigor of NMBP-1243 and NMBP-4069. Seven out of thirteen dwarfing rootstocks maintained consistency for canopy width, canopy length, scion rootstock trunk diameters and tree height. Thus, these rootstocks can be successfully used in further breeding programmes.

Rootstocks for mango wilt

Mango wilt is caused by *Ceratocystis fimbriata* and it is transmitted by beetle. Its influence is not limited to specific plant ages. It can infect the plants at any point in their lifecycle, ranging from the early seedling stage to well-established centennial trees. Furthermore, the disease can infiltrate both the root system and the crown. From 1989 to 1997, extensive research conducted in Brazil led to the identification and evaluation of multiple rootstock and scion varieties exhibiting resistance to mango wilt. Notably, among the outcomes, the IAC 100 Bourban, mutant of Bourban, IAC 101 Coquinho and IAC 102 Touro showcased commendable resistance against mango wilt (Rossetto et al., 1997). The cultivars ‘Voutpa,’ ‘Espada Vemhelha,’ ‘Manga D’agua,’ and ‘Carabao’ stand out as the notable varieties resistant to wilt (Rossetto & Ribeiro, 1990; Carvalho et al., 2004).

Rootstocks for other economic traits

The ‘Bombay Green’ variety is reportedly resistant to bacterial canker, according to Om Prakash & Srivastava (1987). As per Rossetto et al. (1997) report, IAC 107 Tiete and IAC 103 Mococa have sufficient natural resistance against fruit fly damage. Dubey et al. (2021) stated that ‘K-3’ and ‘Kurukkan’ rootstocks reduce the fruit density of scion; ‘K-2’ reduces photosynthetic rate, intercellular $Co_{2,}$ leaf nutrient content and transpiration rate. In spite of all these variations, rootstocks lack the capacity to alter the fruit quality except for Vitamin C content wherein ‘K-5’ and ‘Kurukkan’ rootstocks stimulated it. Vazquez-Luna et al. (2011) worked on identifying the rootstock which imparts resistance to Manila mango variety against the fruit fly *Anastrepha oblique.* The rootstock criollo enhanced the 3-carene levels, firmness as well as main flavonoids content, resulting in greater resistance although it did not impart significant effect on soluble solids, growth, or citric acid. Another disease ‘Seca’ caused by the fungi *Ceratocystis fimbriata* results in the sudden death of the tree. Some of the rootstocks shown resistance to this disease are ‘IAC 106 Jasmin’, ‘IAC 102 Touro’, ‘IAC 104 Dura’ and ‘IAC 101Coquinho’ (Rosetto et al., 1997). The autotetraploid ‘Gomera 1’ has been recognized as a drought resistant rootstock, holding substantial economic promise for semi-arid regions as reported by Perera-Castro et al. (2023).

CONCLUSION

Across the globe, the foremost contributors to plant loss are biotic (wilt) and abiotic stresses, with salinity, drought, temperature fluctuations, and oxidative stress standing out prominently. Hence, the acceleration and comprehensive adoption of rootstock breeding targeting the mitigation of biotic and abiotic stresses is imperative. Mango rootstock breeding stands as a pivotal pursuit in its cultivation. As mango cultivation faces ever-evolving challenges, from adverse soil conditions to changing climate patterns, the significance of identifying resilient and adaptable rootstocks becomes paramount. Through the integration of traditional breeding and modern techniques such as marker assisted breeding and genetic engineering, the potential to enhance mango productivity, quality, and overall competitiveness in today’s markets is within reach. By harnessing the power of scientific research and innovative approaches, the journey of mango rootstock breeding holds the promise of ensuring a thriving and sustainable future for mango cultivation worldwide.

REFERENCE

Carvalho, C. R. L., Rossetto, C. J., Mantovani, D. M. B., Morgano, M. A., Castro, J. V. D., & Bortoletto, N. (2004). Evaluation of mango cultivars selected by “InstitutoAgronomico de Campinas” compared to others of commercial importance. *Revista Brasileira de Fruticultura*, *26*, 264-271. http://dx.doi.org/10.1590/S0100-29452004000200021

Damodaran, T., Rajan, S., Jha, S. K., Misra, V. K., & Sahu, A. (2018). Screening polyembryonic mango accessions for salt tolerance and assessing dynamics of sodium (Na^+), potassium (K^+), and antioxidants. *Fruits*, *73*(4), 228–235. http://dx.doi.org/10.17660/th2018/73.4.4

Dayal, V., Dubey, A. K., Singh, S. K., Sharma, R. M., Dahuja, A., & Kaur, C. (2016). Growth, yield and physiology of mango (*Mangifera* *indica* L.) cultivars as affected by polyembryonic rootstocks. *Scientia Horticulturae*, *199*, 186–197. https://doi.org/10.1016/j.scienta.2015.12.042

Dubey, A. K., Manish, S., Sharma, Y. K., Pandey, R. N., & Deshmukh, P. S. (2007). Dry mass production and distribution of nutrients in two mango rootstocks as affected by salinity. *Indian Journal of Horticulture*, *64*(4), 385-390.

Dubey, A. K., Sharma, R. M., Deepak, & Amrenderkumar. (2021). Long term performance of mango varieties on five polyembryonic rootstocks under subtropical conditions: effect on vigour, yield, fruit quality and nutrient acquisition. *Scientia Horticulturae*, *280*, 109944. https://doi.org/10.1016/j.scienta.2021.109944

Duran Zuazo, V. H., Martinez-Raya, A., & Aguilar Ruiz, J. (2003). Salt tolerance of mango rootstocks (*Magnifera indica* L. cv. Osteen). *Spanish Journal of Agricultural Researc*h, *1*(1), 67-78. http://dx.doi.org/10.5424/sjar/2003011-10

Duran Zuazo, V. H., Pleguezuelo, C. R. R., & Tarifa, D. F. (2006). Fruit yield, growth and leaf-nutrient status of mango trees grafted on two rootstocks in a marginal growing area (South-East Spain). *Fruits*, *61*, 163-170. http://dx.doi.org/10.1051/fruits:2006014

Galan sauco, V. (2019). Mango rootstock, A review. Proceedings of the 12th International Mango Symposium. *Acta Horticulturae*, *1244*. https://doi.org/10.17660/ActaHortic.2019.1244.1

Gawankar, M. S., Salvi, B. R., Chavan, S. A., & Dalvi, N. V. (2010). Comparative performance of mango varieties grafted on Vellaikolamban and mixed rootstock. *Journal of Horticultural Science, 5*(2), 114-116. https://doi.org/10.24154/jhs.v5i2.456

Gazit, S., & Kadman, A. (1980). Mango rootstock selection. *Horticultural Science*, *15*(5), 669. https://doi.org/10.21273/HORTSCI.15.5.669

Iyer, C. P. A., & Degani, C. (1997). Classical breeding and genetics. *In* R. E. Litz (Eds.). The Mango, botany, production and uses (pp. 49-68). CAB International: Wallingford.

Iyer, C. P. A., & Kurian, R. M. (1992). Stem anatomical characters in relation to tree vigour in mango (*Mangifera indica* L.). *Scientia Horticulturae*, *50*, 245-253. https://doi.org/10.1016/0304-4238(92)90177-e

Iyer, C. P. A., & Subramanyam, M. D. (1986). Creeping, a promising genotype for introduction of dwarfness in mango. *Indian Journal of Horticulture*, *43*, 221-223.

Kadman, A., Gazit, S., & Ziv, G. (1975). Selection of mango rootstocks for adverse water and soil conditions in arid areas. *Acta Horticulturae*, *57*, 81-87. https://doi.org/10.17660/ActaHortic.1976.57.10

Majumdar, P. K., Chakladar, B. P., & Mukherjee, S. K. (1972). Selection and classification of mango rootstocks in the nursery stage. *Acta Horticulturae*, *24*, 101-106. https://doi.org/10.17660/ActaHortic.1972.24.17

Martinez, A. R. Peralta-Antonio, N., Rebolledo-Martinez, L., Becerril-Roman, E. A., & Rebolledo-Garcia, R. L. (2019). Effect of rootstock in tree growth, dry matter, flowering, yield and quality of 'Manila' mango. *Scientia Horticulturae*, *251*, 155–161. http://dx.doi.org/10.1016/j.scienta.2019.03.012

Mizani, A., Bally, I., Ibell, P. T., Wright, C., Maddox, C., & Kolala, R. (2018). Identifying vigour controlling rootstocks for mango. Proc. XI International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems. *Acta Horticulturae*, 167-174. https://doi.org/10.17660/actahortic.2018.1228.25

morsy, m. h. (2003). growth ability of mango cultivars irrigated with saline water. Proceedings on greenhouse salinity, *Acta Horticulturae*, *609*, 475-482. https://doi.org/10.17660/ActaHortic.2003.609.73

Nimbolkar, P. K., Kurian, R. K., Upreti, K. K., Laxman, R. H., & Varalakshmi, L. R. (2018). Seed germination and seedling growth responses of polyembryonic mango (*Mangifera indica* L.) genotypes to salinity stress. *International Journal of Chemical Studies*, *6*(2), 3641-3648. http://dx.doi.org/10.13140/RG.2.2.21124.55682

Normand, F., Lauri, P. E., & Legave, J. M. (2015). Climate change and its probable effects on mango production and cultivation. *Acta Horticulturae*, *1075*(1075), 21–32. http://dx.doi.org/10.17660/ActaHortic.2015.1075.1

Om Prakash, & Srivastava, K. C. (1987). Mango diseases and their management-a world review. In Today and Tomorrow's Printers & Publishers, Review of Tropical Plant Pathology Supplement No.1, New Delhi. (pp. 175).

Palaniappan. (2001). Germplasm screening for salinity stress in tropical fruit species. Regional training course 'characterization, evaluation and conservation of tropical fruits genetic resources', organized by IPGRI, ICAR and IIHR.

Pandey, P., Singh, A. K., Dubey, A. K., & Dahuja, A. (2014). Biochemical and salt ion uptake responses of seven mango (*Mangifera indica* L.) rootstocks to NaCl stress. *Journal of Horticultural Science & Biotechnology*, *89*(4), 367–372. https://doi.org/10.1080/14620316.2014.11513094

Perera-Castro, A. V., Hernandez, B., Grajal-Martin, M. J., & Gonzalez-Rodriguez, A. M. (2023). Assessment of drought stress tolerance of *Mangifera indica* L. Autotetraploids. *Agronomy*, *13*, 277. https://doi.org/10.3390/agronomy13010277

Pinto, A. C. Q. & Byrne, D. H. (1993). Mango hybridization studies in tropical savannah (cerrados) of Brazil central region. *Acta Horticulturae*, *341*, 98-106. https://doi.org/10.17660/ActaHortic.1993.341.9

Reddy, Y. T. R., Kurian, R. M., Ramachander, P. R., Singh, G., & Kohli, R. R. (2003). Long-term effects of rootstocks on growth and fruit yielding patterns of 'Alphonso' mango (*Mangifera indica* L.) *Scientia Horticulturae*, *97*, 95-108. https://ui.adsabs.harvard.edu/link_gateway/2003ScHor..97...95R/doi:10.1016/S0304-4238(02)00025-0

Rossetto, C. J., Ribeiro, I. J. A., Gallo, P. B., Soares, N. B., Sabino, J. C., Martins, A. L. M., Bortoletto, M., & Paulo, E. M. (1997). Mango breeding for resistance to diseases and pests. Proceedings of the 5th International mango symposium. *Acta Horticulturae*, (pp. 299-304). https://doi.org/10.17660/ActaHortic.1997.455.39

Rossetto, C. J., & Ribeiro, I. J. A. (1990). Mango wilt. XII. Recommendations for control. *Revista de Agricultura* (*Piracicaba*), *65*, 173-180.

Singh, N. P., Srivastava, R. P., & Chadha, K. L. (1986). Screening of dwarfing mango rootstocks at nursery stage on the basis of anatomical characters. *Indian Journal of Horticulture*, *43*, 18-22.

Sharma, D. K., & Majumder, P. K. (1988). Further studies on inheritance in mango. *Acta Horticulture*, *231*, 106-111.

Vargas-Ramos, V. H., Pinto, A. C. Q., Junqueira, N. T. V., Gomes, A. C., Andrade, S. M. R., & Cordeiro, M. C. R. (2014). Effect of mono and polyembrionic rootstocks on growth, yield and fruit quality of four mango cultivars in the central region of Brazil. *Acta Horticulturae*, *645*, 201-207. http://dx.doi.org/10.17660/ActaHortic.2004.645.18

Vazquez-luna, A., Rivera-cabrera, F., Perez-flores, L. J., & Diaz-sobac, R. (2011). Effect of rootstock on mango fruit susceptibility to infestation by *Anastrepha oblique. Journal of Economic Entomology*, *104*(6), 1991-1998. https://doi.org/10.1603/ec11223

(***Received : 11.12.2023; Revised : 19.08.2024; Accepted : 25.08.2024)***