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Performance of different scion cultivars after budding on different rootstocks

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Abstract

Citrus is a taxon which includes a wide range of true species and natural hybrids with basic chromosome as nine and consists of the acid members (citron, lemon, lime); the orange group (sour orange, sweet orange); the pummelo grapefruit group (grapefruit, chakotra); the mandarin group (sangtra, satsuma mandarin); papeda group (ichang papeda, khasi papeda) and other species (rangpur lime, calamondin, Indian wild orange). The common growing cultivars of Citrus like Kinnow, Marsh Seedless, Navel Oranges, Red Blush etc. are having varying degree of susceptibility towards foot rot, tristeza virus, scab, exocortis, canker, nematodes, psylla etc. Use of resistant or tolerant cultivars and grafting or budding of high yielding cultivars over good and hardy rootstocks are the only preventive and effective measures for such problems. The most common rootstocks used for budding are sour orange, sweet orange, rough lemon, trifoliate orange, citranges, Rangpur lime and Cleopatra mandarin. Budding of suitable scion cultivars on these rootstocks induce varying degree of success, plant growth and yield. Identification and application of suitable rootstocks is essential for successful bud union and to ensure better translocation of plant growth factors. High degree of bud sprouting, budding success, scion growth and yield has been reported by using sour orange, sweet orange, rough lemon, trifoliate orange, citranges, Rangpur lime and Cleopatra mandarin as rootstock for commercial cultivars of Citrus.

Keywords: *Budding, Citrus, grapefruit, mandarin, oranges, rootstock, rough lemon, scion.*

Introduction

Citrus is one of the most important fruit crops grown throughout the tropical and subtropical world. India is one of the largest producers of citrus fruits andcitrus ranks third in area and production after the mango and banana. The final estimate of National Horticulture Board (NHB) database for year 2017-18 confirms production of 1.255×10^7 MT of citrus fruits from 1.003×10^6 ha of area (N.H.B. Database, 2019). Citrus plants are native to subtropical and

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tropical regions of Asia, Island Southeast Asia, and Near Oceania and they were first domesticated in these areas. A genomic, phylogenic and biogeographical analysis have shown that the center of origin of the genus Citrus is likely the southeast foothills of the Himalayas, in a region stretching from eastern Assam, northern Myanmar to western Yunnan(Wu *et al.,* 2018).*Citrus* is a taxonomic rank to genus and includes a wide range of natural hybrids with common chromosome number of 2n=2x=18. Genus- *Citrus* belongs to class-Dicotyledoneae, subclass-Archichlamydeae, order-Geraniales, suborder-Garaniineae and family-Rutaceae. Taxonomical details of citrus have been elaborated by two unified classification schemes, those of C. Tanaka and W. T. Swingle (Stone *et al.,* 1973; Wang *et al.,* 2017). According to Swingle's system, all citrus fruits and related species belong to subtribe-Citrinae under tribe-Citreae of family-Rutaceae. The true citrus fruits include six genera- *Poncirus*, *Citrus*, *Fortunella*, *Eremocitrus*, *Microcitrus*, and *Clymenia*. Further, genus *Citrus* was divided into two subgenera: *Eucitrus* (citrons, pomelos, mandarins, oranges, grapefruits and lemons) and *Papeda*(Wang *et al.,* 2017; Sharma *et al.,* 2009; Nicolosi, 2007).

Species Diversity in Citrus

According to Swingle system, genus *Citrus* consists of 16 species. According to Tannaka scheme, the cultivars or hybrids of Swingle were upgraded to species status to accommodate 159 species in this genus (Stone *et al.,* 1973; Wang *et al.,* 2017). Tanaka's system has two subgenera, *Archicitrus* with five sections (Papeda, Limonellus, Aruntium, Citrophorum and Cephalocitrus) and *Metacitrus* with three sections (Osmocitrus, Acrumen and Pseudofortunella) (Sharma *et al.,* 2009; Nicolosi *et al.,* 2000). Hodgson had validated only 36 species by moderating the Tanaka's classification and expending the Swingle's system (Stone *et al.,* 1973; Nicolosi,2007): the acid members (citron, lemon, lime); the orange group (myrtle- leaf orange, sour orange, sweet orange); the pummelo grapefruit group (grapefruit, chakotra); the mandarin group (sangtra, satsuma mandarin); papeda group (ichang papeda, khasi papeda) and other species (rangpur lime, calamondin, Indian wild orange). Only 8 citrus species are generally cultivated for edible purposes which are: *C. sinensis, C. reticulata, C. aurantium, C. limon, C. aurantifolia, C. grandis, C. paradisi,* and *C. medica*(Pena *et al.,* 2009). Wu *et al.*(2018) had done genomic analysis and identified just ten ancestral species of citrus among those studied. Of these, seven were native to Asia: pomelo (*Citrus maxima*), the 'pure' mandarins (C. *reticulata* – most mandarin cultivars were hybrids of this species with pomelo), citrons (*C. medica*), micranthas (*C. micrantha*), the Ichang papeda (*C. ichangensis*), the mangshanyegan (*C. mangshanensis*) and the oval (Nagami)

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kumquat (*Fortunella margarita* or *C. japonica* var. *margarita*). Three from Australia were identified: the desert lime (*C. glauca*), round lime (*C. australis*) and the finger lime (*C. australasica*). Most of the variants were closely related subspecies or varieties or hybrids and majority of these are hybrids of just three ancestral species, citron (*C. medica*), pomelo (*C. maxima*), and mandarin (*C. reticulata*) (Wu *et al.,* 2018; Curk *et al.,* 2016;Shimizu *et al.,* 2016).The details of some of the species has been given below:

Rough lemon (*Citrus jambhiri* Lush.), also known as 'Jatti khatti', is the common rootstock which is tolerant to tristeza. It is a vigorous rootstock, highly polyembryony, cold hardy and perform well in dry environment as well. Rough lemon is a citron and mandarin hybrid (Curk *et al.,* 2016).The mandarins (*Citrus reticulata* Blanco) are one of the core ancestral citrus taxa, representing a single species, with much of the variation within mandarins being due to hybridization (Wu *et al.,* 2018). These are easily peeled citrus and most of the cultivated mandarins are hybrid with sweet oranges or pumelo. Hybrid mandarins fall on a continuum of increasing pomelo contribution with clementines, sweet and sour oranges and grapefruit (Curk *et al.,* 2014). Kinnow (a King-Willow leaf hybrid), Daisy and W-Murcot are commonly grown mandarin cultivars or hybrids.The orange is a hybrid between pomelo (*Citrus maxima*) and mandarin (*Citrus reticulata*) (Xu *et al.,*2013). The chloroplast genome and therefore the maternal line, is that of pomelo (Velasco and Licciardello, 2014). The sweet orange is the fruit of the citrus species and botanically called as *Citrus* × *sinensis* (L.) Osbeck(Xu *et al.* 2013). Some promising sweet oranges are Early Gold, Blood Red and Jaffa.The grapefruit, botanically *Citrus* × *paradisi*, has probably originated in Barbados as an accidental hybrid between sweet orange (*Citrus sinensis*) and pummelo (or shaddock) (*Citrus maxima* or *Citrus grandis*) (Dowling and Morton, 1987). Star Ruby, Redblush and Marsh Seedless are promising cultivars of grapefruit.*Citrus limon* (L.) Osbeck, also known *Citrus limonia* Osbeck and *Citrus medica* var. *limonum* (Risso) Brandis, is close relative to the Citron. Lemon is hybrid between male citron and female sour orange which in turn are hybrid of pumelo and mandarin hybrids (Wu *et al.,* 2018;Gulsen and Roose, 2001). The Baramasi Kagzi Lime is small fruited acid lime which is clonal derivative of Mexican' lime [*Citrus aurantiifolia* (Christm.) Swingle]. The other clonal derivatives are West Indian' lime, 'Key' lime, Abhayapuri' lime, 'Everglade' lime, 'Egyptian' lime, and 'India' lime(Janick and Paull, 2008; Khan *et al.*, 2017).

Species	Parentage

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Rough lemon	Citron and mandarin hybrid
Mandarin	Mostly true but may be hybrid with pomelo
Sweet orange	Pomelo and mandarin hybrid
Grapefruit	Sweet orange and Pomelo hybrid
Lemon	Sour orange and citron hybrid
Lime	Not available

Importance of rootstocks and budding in *Citrus*

The common growing cultivars of Citrus like Kinnow, Marsh Seedless, Navel Oranges, Red Blush etc. are having varying degree of susceptibility towards foot rot, tristeza virus, scab, exocortis, canker, nematodes, psylla etc. Such problems are greater loss to production of citrus fruit throughout the world resulting lower productivity and even complete damage to orchard. Use of resistant or tolerant cultivars and grafting or budding of high yielding cultivars over good and hardy rootstocks are the only preventive and effective measures for such problems. Different types of citrus rootstocks are: sour orange, sweet orange, rough lemon, trifoliate orange, citranges, Rangpur lime, Cleopatra mandarin. Sour orange is hardy, vigorous and deep rooted in nature. It is resistant to drought, foot rot and viruses as well as susceptible to tristeza virus and scab. The skin of the fruit is thin, smooth, and produces high quality juice. Sweet orange is shallow rooted rootstock and producing large vigorous productive tree. It is susceptible to foot rot and resistant to tristeza and exocortis. Trifoliate orange is a dwarfing rootstock. Fruit is small in size but excellent quality of the fruits. It is susceptible to canker, scab and exocortis and resistant to foot rot, tristeza and nematodes. Citranges is a hybrid of sweet orange and trifoliate orange. It is resistant to tristeza and foot rot and susceptible to exocortis. They are dwarf and highly polyembryonic. Rangpur lime is a vigorous productive trees and hardy rootstock. It is resistant to tristeza and drought conditions but susceptible to exocortis. Cleopatra Mandarin bears small size of the fruit and is tolerant to tristeza, exocortis and foot rot. Rough lemon (*Citrus jambhiri* Lush.) is the common rootstock. In Punjab, rough lemon is known as ‘Jatti khatti’. It is a shrub tree of height up to 10 ft. The branches of tree spreading and spinous habit and bark of the tree is green. Fruits are spherical, small to medium-sized and are more acidic. It is tolerant to tristeza and susceptible to foot rot and scab. It shows highly polyembryony.

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Budding is asexual propagation method. The process of connecting scion, which is a bud, and rootstock in a manner such that they may unite and grow successfully as one plant is termed as budding. The budding has two components; bud and bud uniting part. The point at which scion is joined at rootstock is termed as matrix. Budding is done in spring, summer and rainy season accordingly, March-April, May-June, July-September months are suitable for successful budding. Rootstock 1 to 2-year-old having pencil thickness is selected for budding. T- Budding is very successful for propagating in citrus. Actually, the union of a stock and a scion is an artificially induced relationship; each must depend upon the other and provide essential contribution to carry out the physiological or metabolic functions necessary to sustain each other. The union of the rootstock and the scion must be strong mechanically. When the union of the rootstock and the scion is not strong then the movement of water, nutrients and other substance not across this zone then the chances of the success are higher failure. There are certain characteristics a rootstock must have in addition to the effects it produces upon a scion variety,there must be good compatibility between the stock and the scion.

Success of budding in Citrus

The success of bud taken depends maturity of scion and the rootstocks and their genotype under optimal condition (Fig. 1). The optimum condition ensures good callusing and healing of wounds to improve bud take and further growth of scion. Further, in budding the ease of bark slips also important factors. The personal involved in budding or grafting as determining factor for successful bud taken and is determined by the cross sections of seedlings and buds to ensure union of cambial layers between rootstock and scion and improve translocation of photosynthates. It has been reported that the angular immature buds grafted or budded remain dormant for several months and burst in coming spring or autumn growth flush(Williamson and Jackson, 1994).Kamanga *et al.*(2017) had studied budding and grafting performance in sweet orange and had reported significantly high bud take (90-100%) in grafted plants in comparison to budded plants (25%). However, Lewis and Alexander(2008) had reported 90-100% bud take in sweet orange when budding was done.Rehman*et al.*(2017)had detected the maximum bud sprouting (84.17%) and minimum day of sprouting (35.43) of Cara Cara Navel variety budded on Troyer Citrange.Koli *et al.*(2014) observed that on 15th October budding time, the maximum budding success rate(70.23%), maximum bud taken per cent (75.80%), minimum days required to first sprouting (18.27 days) and minimum days required to 50 per cent sprouting (53.26 days).Bhusari *et al.*(2012) observed maximum budding

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success rate (54.94%) and bud taken (65.78%) under open field conditions as compare to shade net.Jitendra *et al*.(2012)had reported the maximum budding success rate (68.31%) on rough lemon as compared to Rangpur lime, sour orange and Carrizo citrange rootstocks.Shinde*et al*.(2007) noted that the maximum bud take percentage was on *C. macrophylla* (100.0%) followed by Rough lemon Chettali (88.88%) and calamondin (88.33%).Sharma and Sharma(1986) observed bud take and growth in 'Kinnow' mandarin as influenced by type of bud wood and have reported that when round buds without wood were used the bud take of Kinnow on *C. jambhiri* was 98 per cent with better subsequent growth than by using angular buds with or without wood.Seletsu*et al.* (2011)reported the maximum budding success (81.67%) and minimum days for bud sprouting(13.30) in lemon budded on lemon within first week of November.

Scion growth and related attributes in budding of *Citrus*

The growth of different scion cultivars depends on the successful callusing and union of vascular systems of graft components, scion and rootstock. Perfect connectivity ensures movement of nutrients and water from root to shoot components through xylary components and translocation of photosynthates and other growth factors through phloem. Further, graft compatibility between scion and rootstocks also ensures better transportation of these materials through vascular system. In addition, age of graft components, method of budding, time of budding and selection of components have also significant influence of performance of scion cultivars. These factors are determining for better vegetative growth and yield in scion cultivars (Fig. 2). Ginandjar *et al.* (2018)noted that the age of rootstock and budding method individually had a very major effect on thenumber of leaves, on the high percentage of shoots and no significant effect on the stem bud. Gill *et al*. (2017) had reported higher rootstock and scion girth in Volkameriana rootstocks grafted by Daisy Mandarin, however maximum compatibility of Mandarin was reported with Rough Lemon rootstock with 0.87 scion: stock ratio. The better scion: stock ratio is associated with proportionate growth of rootstocks and scion due to efficient distribution of photosynthesis. Volkameriana rootstocks has been reported to be a vigorous rootstock imparting maximum plant height and canopy value. Kumar *et al.*(2017)had also confirmed the growth of kinnow was better on Jatti Khati as compared to Troyer citrange rootstock and is attributed with better shoot growth, increased number of leaves and branches. Rehman*et al.* (2017)concluded the better growth of Cara Cara Navel variety budded on the Troyer Citrange as compare to other varieties and also confirmrd the maximum number of branches when Cara Cara Navel was budded on Carrizo

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Citrange. Chahal*et al.* (2015)reported that Volkameriana cultivar was more vigorous than other rootstocks while Trovita budded on Volkameriana showed maximum yield efficiency.Jitendra *et al*.(2012) had also reported highest scion length (17.97), plant height (43.584), leaf area (19.06), RWC of leaves (51.74%) and chlorophyll content (0.194mg/g) of Nagpur Mandarin budded over rough lemon rootstock and confirmed vigrous growth of scion cultivars over rough lemon rootstock as a result of effective nutrient supply.Shinde*et al.*(2007)had reported that sweet orange shows vigorous growth on Jambhiri local, Sohmyndong, Rough lemon Chettali and Nemutenga rootstocks.Sonkar *et al.* (2004)had reported that the Troyer Citrange (Chethalli), CHES Rough lemon, Cleoptra Mandarin and Schaub Rough Lemon were the vigorous rootstocks for acid lime seedling and also record dwarfing effect in acid lime budded on Cleopatra Mandarin (Coorg) rootstock.Chohan *et al.* (2000)had also reportedvigorous effect inBlood Red cultivar of sweet orangebudded on rough lemonrootstocksthrough inducing heavy branching.

Leaves related attributes in budding of *Citrus*

Leaves are functional centres for all metabolic activities which ensures growth and development of a plant. The expansion of leaves and their number depends on the successful union of vascular systems of graft components, age of graft components, method of budding, time of budding and selection of graft components. Kumar *et al.* (2017) noted that maximum leaf area (166.24 cm^2), fresh mass (4.36 g) and dry matter (1.85 g) and minimum leaf area (85.07 cm^2), fresh mass (2.50 g) and dry matter (0.92g)on rough lemon rootstock. Total chlorophyll (1.87 mg g^{-1}FW) was significantly higher in leaf of Kinnow on rough lemon as compare to other rootstocks which is attributed with high photosynthetic activities and better vegetative growth.Koli *et al.* (2014)noted that maximum leaf area (15.23 cm^2), number of leaves on sprout shoots (15.23) and chlorophyll content (3.704 mg/g) in Nagpur Mandarin which is attributed with high photosynthetic activities and better vegetative growth.Jitendra *et al.* (2012)had also noted the maximum leafarea (19.958 cm^2), relative water content in leaves (51.744%) and chlorophyll content (0.194 mg/g) of Nagpur mandarin on rough lemon as compared to Rangpur lime, sour orange and Carrizo citrange rootstocks due to strong scion-stock association.Highchlorophyll content in leaves, maximum leaf area and RWC of leaves has been reported by various authors in different scion cultivars budded on Rough lemon rootstocks.Cruz *et al.*(2007) found the leaf water potential of citrus decreased under conditions of high temperature.

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Conclusion

Identification and application of suitable rootstocks is essential for successful bud union and to ensure better translocation of plant growth factors. High degree of bud sprouting, budding success, scion growth and yield has been reported by using sour orange, sweet orange, rough lemon, trifoliate orange, citranges, Rangpur lime and Cleopatra mandarin as rootstock for commercial cultivars of Citrus.

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Figure 1: Sprouting of buds of different cultivars budded on Rough Lemon rootstock

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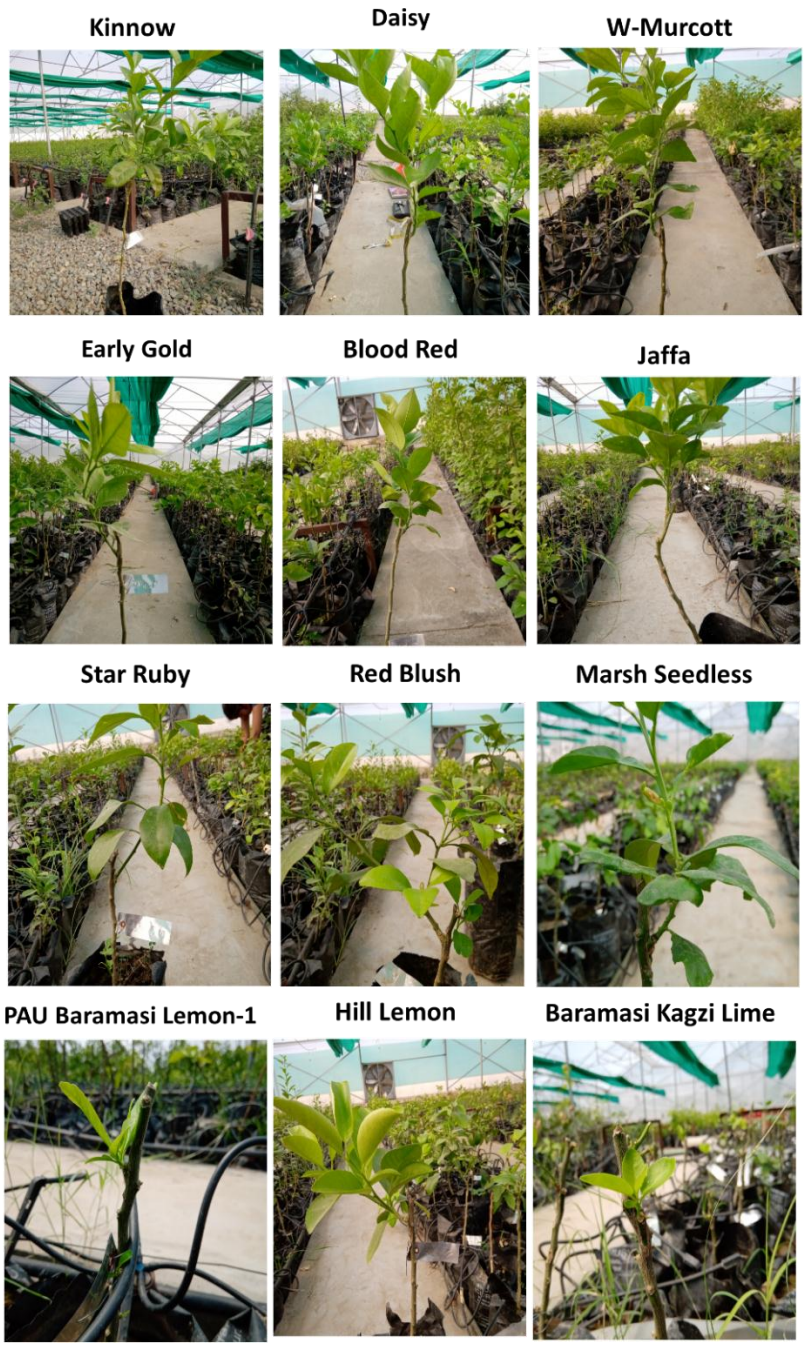

Figure 2: Growth of scion buds of different cultivars on Rough Lemon rootstock