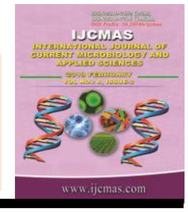
Int.J.Curr.Microbiol.App.Sci (2019) *8*(2): 1089-1104

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 8 Number 02 (2019)**
Journal homepage: http://www.ijcmas.com



Review Article https://doi.org/10.20546/ijcmas.2019.802.128

Influence of Rootstocks on Scion Growth and Vigour, Production, Water Relations, Physiology and Leaf Nutrient Status of Temperate Fruit Crops-A Review

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Keywords

Rootstock, Growth, production, Water relations, Nutrient uptake, Temperate fruits

Article Info

Accepted:
10 January 2019
Available Online:
10 February 2019

A B S T R A C T

Generally the fruit trees are composed of two different parts; rootstock and scion. Rootstocks influence the growth and vigour, production, water relations, physiology and nutrient status of scion leaves grafted or budded onto them. This review describes and discusses the rootstock effects on these parameters of scion cultivars in different temperate fruits more particularly stone fruits.

Introduction

Fruit trees are composed of two different individuals-the rootstock and the scion-growing together as one. A rootstock is a stump, which already has an established, healthy rootsystem, used for grafting a cutting/bud from another plant and the tree part being grafted/budded onto the rootstock is called the scion. The scion is the plant which has the properties desired by the propagator, and the rootstock is the working part which is connected with the soil to nourish the new plant. Two parts will grow together, producing a single tree although genetically it is two different parts. The ideal rootstock should exhibit a high degree of compatibility with scion cultivars, give maximum productive life to the trees, exhibit favourable influence on the performance, bearing and quality of scion variety. The effect of rootstock on scion growth and vigour, fruit yield and quality, water relations, physiology and nutrient status is studied in temperate fruits. This review describes these effects in temperate fruits and more particularly in stone fruits.

Plant growth and vigour

Plant growth is the increase in the size of plant by cell division and enlargement including synthesis of new cellular material and organization of subcellular organelles. Plant growth is measured in terms of increase in plant height, plant spread, plant volume and fresh and dry weight of different plant parts. Rootstock and scion cultivar greatly influence the tree vigour. Micke *et al.,* (1996) studied the effect of peach and almond rootstocks on the growth of Carmel and Nonpareil cultivars and observed that Lovell peach rootstock produced larger trees than the other rootstocks. While studying the performance of almond cvs. Colorada and Cion Cebas grafted on Garrigues, Ramillete, Texas apd Bergasa-1 rootstocks, Egea Caballero and Burgos. Kumar (1987) reported that the trees of Dhebar, IXL, Katha, Nonpareil and Merced almond cultivars were more vigorous and larger on wild peach than on behmi and bitter almond rootstocks. Similarly, Gall and Grasselly (1979) while studying the behaviour of 12 almond varieties grafted on almond, peach and peach x almond rootstocks observed that peach seedling and peach x almond rootstocks were superior to almond seedling. Similarly, Donno *et al.,* (1976) reported that early trunk growth in almond cvs. Tuono and Filippo Ceo were faster on the sweet almond seedling rootstock Don Carlo than on bitter almond seedling rootstock, but the difference disappeared after 8-10 years. In peach, rootstocks also exhibited variable effects on scion growth and vigour. Rana *et al.,* (1997a) observed that peach cv. Sharbati budded on plum rootstock had the smallest trunk diameter as compared to plants produced from cuttings or on peach rootstock. Similarly, Bellini *et al.,* (1993) observed reduced tree growth of Maycrest peach and Maria Emila nectarine grafted on plum selections. More vigour and growth was observed in Flavocrest peach plants grafted on Yugoslavian and GF 305 peach rootstocks than those on Rubira and Higama rootstocks (Salvador and Monastra, 1996), in Springlady and Redcal peaches grafted on GF677 than those on Myran rootstock (Bussi *et al.,* 1995), in Maravilha peach grafted on Hansen 536 as compared to those raised on Mrs 2/5 (plum) or PSB2 (peach) rootstock (Car *et al.,* 1995), in Babygold 6 peach on GF677, Oupnishka and peach x almond seedling rootstocks (Mitov and Oyakov, 1989), and in Golden Queen peach on Golden Queen seedlings and Myran Yumir rootstocks (Glucina *et al.,* 1992). In peaches, peach rootstocks induced more vigorous growth than almond rootstock, while peach x almond hybrid induced moderately vigorous growth. Contrary to this, Dozier *et al.,* (1983) concluded that rootstocks did not affect tree height, spread and trunk circumference in peach. Growth and vigour of the plum tree is also influenced by the rootstock used. Sitarek *et al.,* (1995) observed that plum cvs. Empress and Valor grown on Pixy and Wangenheim prune rootstocks were less vigorous than on *P. divaricata* rootstock. Barroso and Renaud (1994) grafted six cultivars of Greengage clones and one cv. of Stanley clone on 8 rootstocks and observed very poor growth with Pixy and Citation *(P. salicina* x Peaches) rootstocks. Renaud and Salesses (1994) observed that plum cv. Greengage grafted on 13 rootstocks were more vigorous than French Prune. Kosina (1994) studied the performance of plum cv. Stanley on 5 Myrobalan clones and on Damas C clone and observed that trees on Myrobalan SE 4040 grew most vigorously than the other rootstocks. Ystass and Froynes (1993) observed highest growth of 'plum cvs. Rivers Early Prolific, Opal, Oullins Gage, Count Althan's Gage and Victoria on Myrobalan B rootstock as compare to Brompton, St. Julien A, St. Julien Seedlings and Marianna rootstocks, Similarly, Stella cherry grafted on GM9, GM6 1/1 and GM 79 was less vigorous than on Colt (Kemp and Wertheim, 1996). Leaf area was appreciably influenced by the rootstocks. Kumar (1987) recorded maximum leaf area in almond trees on wild peach and the minimum on bitter almond. However, irrespective of the rootstock used, Nonpareil attained the maximum leaf area while Afganistan seedling the least. Higher leaf area was also observed in apple plants grafted on M9 and MM106 rootstocks (Makariev *et al.,* 1986), on M4 (Bhatia, 1992) and M25 rootstocks (Chandel and Chauhan, 1994). Fallahi *et al.,* (2001) reported that 'BC-2 Fuji' apple trees on Bud.9 rootstock had shorter limbs and terminal shoots than those on Ottawa 3 and M.7 EMLA. Hrotko *et al.,* (2001) evaluated the trees of plum cultivars 'Stanley', '*Cacanska lepotica'* and 'Althan's Gage' planted on rootstocks; Myrobalan 'C 162/a' seedling, vegetatively propagated Marianna 'GF 8-1', Myrobalan 'MY-BO-1', Myrobalan 'MY-KL-A', 'St Julien' 'GF 655/2', and *Prunus domestica* 'Fehér besztercei' and observed that largest trees in trunk cross sectional area, canopy area and canopy volume were produced on Marianna 'GF 8-1' and Myrobalan 'C 162/a' seedling rootstocks. However trees on Myrobalan 'MY-BO-1' and Myrobalan 'MY-KL-A' were medium sized in comparison to other rootstocks and small tree size was achieved on rootstocks 'St Julien' 'GF 655/2', and *Prunus domestica* 'Fehér besztercei'. Sharma *et al.,* (2004) recorded higher annual shoot growth and leaf area in Non Pareil almond cultivar than Merced cultivar when raised on wild peach than bitter almond rootstocks. Univer *et al.,* (2006) observed that apple rootstocks B.9, B.396 and M. 26 significantly reduced vegetative growth of apple trees whereas trees on rootstock B.545 had the strongest growth. Lanauskas (2006) evaluated two plum cultivars 'Stanley' and 'Kauno Vengrine' on four rootstocks viz. *Prunus ceracifera* seedlings, St. Julien A, St. Julien GF 655/2 and Marianna GF 8/1 and reported that plum trees on St. Julien A and St. Julien GF655/2 reduced tree trunk diameter in comparison to *Prunus cerasifera* seedlings. Tworkoski and Miller (2007) reported that dwarfing rootstock M-9 had the lowest and seedling rootstock had the greatest tree height and trunk diameter in apple. Mestre *et al.,* (2017) studied the growth of peach cv. 'Catherina' fruits raised on seven hexaploid plum rootstocks, as well as one *Prunus persica* seedling and observed that rootstocks GF 655/2 and P. Soto 67 AD proved to be the most dwarfing rootstocks, while Constantí 1 and Monpol were the most invigorating. Milosevic *et al.,* (2011) conducted an experiment to determine the effects of Myrobalan rootstock and Blackthorn interstock on the tree growth of five apricot cultivars and reported that apricots grafted on Myrobalan appears to induce higher tree growth. Sitarek and Bartosiewicz (2011) grafted 'Morden 604' and 'Miodowa' apricot trees on the seedling rootstocks Wangenheim Prune and Erunosid, as well as Polish selection apricot genotypes A4 and M46 were compared with trees of the same cultivars on the standard *P. divaricata* rootstock. They reported that trees of both cultivars on *P. divaricata* and 'M46' had the largest trunk cross-sectional area and the most dwarfing rootstock was 'Wangenheim Prune'. Tworkoski and Fazio (2015) grafted scions of different apple cultivars to Malling (M.7, M.9, and M.27) and Geneva (G.935, G.5087, G.41, and G.11) rootstocks and reported that regardless of scion vigour, trees with G.935 and G.41 rootstocks had the most height and diameter growth. Rather *et al.,* (2018) reported that apple cultivar Vista Bella raised on the MM106 rootstock had the most mean shoot length of the current year, cultivars Vista Bella and Mollies Delicious had highest tree volume however the lowest tree volume was recorded in cultivar Cooper IV. They also reported that cultivars had a significant effect on the TCSA and maximum TCSA was observed in cultivar Starkrimson and minimum in cultivars Vista Bella and Cooper IV. Root growth is also vital to the survival of plants. Main functions of rootsystem are; roots anchor the plant in the soil, roots absorb water and mineral salts from the soil, roots may store food, roots form a passage way for water and dissolved substances from the root into the stem and also for foods from the stem down into the root and the synthesis of plant hormones. Almond seedling rootstocks are vigorous, deep rooted and typically tap rooted with few branches, whereas, peach root system tends to be somewhat shallow rooted, but with larger number of somewhat smaller roots (Kester and Grasselly, 1987). Redhaven peach on GF 677 had greater root number and more roots with greater than 10 mm diameter (Lichev and Govedarov, 1995).

Yield and quality

Fruit yield is the function of number of fruits produced by a tree and their weight however quality is the degree of excellence. Rootstock and scion combinations have variable influence on tree productivity and fruit quality. Donno *et al.,* (1972, 1976) observed that almond cv. Tuono had more yield on sweet almond than on bitter almond seedling rootstock, however, this difference disappeared after 8-10 years. Higher almond yields were recorded on peach and peach x almond hybrid than on almond rootstock (Gall and Grasselly, 1979), on 2702, 2682, 2147, 8455 and 8475 rootstocks (Popak, 1987), in Carmel and Nonpareil on peach than on almond rootstock (Micke *et al.,* 1996) and Ferragues than Texas and Tuono grafted on almond x peach hybrid GF677 and peach 305 (Monastra, 1976). Higher almond yields were also recorded in Ferragues grafted on almond, peach GF305 and peach x almond GF677 rootstock than in Tuono on almond rootstock (Barbera *et al.,* 1994), Pizzuta d'Avala on Fasciunieddu Spammata (Alberghina, 1992), Colorada and Clone Cebas on Garrigues rootstock (Egea Caballero and Burgos Ortiz, 1991). Nonpareil almond cultivar on peach and bitter almond rootstocks produced higher yields than on Behmi rootstock (Kumar, 1987; Dass, 1990). Highest fruit weight and size in Nonpareil, highest kernel percentage in IXL and Nonpareil, highest fat percentage in katha almond on wild peach rootstock and highest per cent proteins in Afganistan Seedling on bitter almond rootstock have been reported by Kumar (1987). Hrotko *et al.,* (2001) evaluated the plum trees of cultivars ’Stanley’, ‘*Cacanska lepotica*’ and ‘Althan’s Gage’ planted on rootstocks: Myrobalan C 162/a’ seedling, vegetatively propagated Marianna ’GF 8-1’, Myrobalan ’MY-BO-1’, Myrobalan ’MY-KL-A’, ‘St Julien’ ’GF 655/2’, and *Prunus domestica* ’Fehér besztercei’ and observed that ’Stanley’ produced highest yield efficiency on vigorous Marianna GF 8-1, medium yield efficiency was achieved on Myrobalan C 162/a seedling, MY-BO-1, MY-KL-A, and ‘St Julien’ GF 655/2, low efficiency was on semi-dwarf ‘Fehér besztercei’. However fruit weight on trees planted on different rootstocks was not significantly influenced. They found good yield efficiency and fruit weight of ’Althan’s Gage’ on ‘St Julien’ GF 655/2, medium on Marianna GF 8-1 and Myrobalan seedling C 162/a, while the MY-KL-A produced very low. Son and Kuden (2003) studied the influence of seedling and GF-31 rootstocks on the yield and quality of fruits of Tokalolu, Precoce De Tyrinthe, Joubert Foulon, Canino, Sakt 6, Beliana, Priana and Early Kishnevski table apricot cultivars and reported that fruit yields were highest on apricot seedling rootstocks for all cultivars. Fruit weight was also greater on seedling than GF-31. Dates of full blooming and maturation were earlier on grafted seedling rootstocks than those on GF-31. Yahya Al-Hinani and Roper (2004) reported that Gala apple trees on M.26 EMLA had slightly higher yield in comparison to other rootstocks. Sharma *et al.,* (2004) recorded higher yield of green almonds in Non Pareil almond cultivar than Merced cultivar when raised on wild peach than bitter almond rootstocks. Univer *et al.,* (2006) observed that apple rootstocks B.9, B.396 and B.545 were earliest to start cropping than trees on M.26 and E.75. Lanauskas (2006) evaluated two plum cultivars 'Stanley' and 'Kauno Vengrine' raised on four rootstocks viz. *Prunus cerasifera* seedlings, St. Julien A, St. Julien GF 655/2 and Marianna GF 8/1 and recorded highest fruit yield and yield efficiency in trees grafted on *Prunus cerasifera* seedlings. However tested rootstocks had no influence average fruit weight. Wongtanet and Boonprakob (2010) studied the influence of nine peach rootstocks on growth of three scion cultivars and observed significant influence of rootstocks on scion height, branch weight and trunk size. Milosevic *et al.,* (2011) conducted an experiment to determine the effects of Myrobalan rootstock and Blackthorn interstock on the productivity and fruit quality traits of five apricot cultivars and reported that apricots grafted on Myrobalan have better yield and fruit weight when compared with the Blackthorn.

Sitarek and Bartosiewicz. (2011) grafted 'Morden 604' and 'Miodowa' apricot trees on the seedling rootstocks Wangenheim Prune and Erunosid as well as Polish selection apricot genotypes A4 and M46 were compared with trees of the same cultivars on the standard *P. divaricata* rootstock. They reported that rootstock had no effect on the fruiting of 'Morden 604' trees however in Miodowa cultivar, the highest cumulative yields were obtained from trees grafted on P. divaricata and 'M46', and the lowest from those on 'Erunosid'. 'Wangenheim Prune', in comparison to other rootstock significantly reduced the mean fruit weight and the mean content of soluble solids in fruits of 'Morden 604' and 'Miodowa' apricots was not affected by rootstocks. Hajagos *et al.,* (2012) studied combinations of 5 rootstocks ('GiSelA 5', 'GiSelA 6', 'Piku 1', 'PHL-C', and 'Weiroot 158') and 2 scions ('Regina' and 'Kordia') with regards to properties affecting consumer value, fruit appearance, and flavour. They reported that rootstock effect was clearly identifiable in the development of fruit firmness, fruit weight, and sugar and acid content and based on these properties, 'PHL-C' was recommended for 'Kordia' scion. Bartolini *et al.,* (2014) studied the influence of two commercial Prunus rootstocks ('Myrabolan 29/C' and apricot 'Seedling') on fruit entity and quality of 'Pisana' apricot cultivar and reported that rootstocks had no significant influence on the flowering and fruiting entity but rootstock 'Myrabolan 29/C' appeared to induce the highest fruit weight, total antioxidant capacity and total phenols. Ikinci *et al.,* (2014) studied the influence of three quince (BA 29, Quince A and Quince C) and a local European pear seedling rootstocks on fruit quality of Santa Maria pear and observed higher fruit firmness on BA 29 and Quince A.

Mestre *et al.,* (2017) studied quality of peach cv. 'Catherina' fruits raised on seven hexaploid plum rootstocks, as well as one *Prunus persica* seedling and observed that rootstocks Constantí 1 and Monpol generated greater cumulative yields however, the highest yield efficiency was recorded on GF 655/2 and Montizo, although they did not differ significantly from Adesoto and P. Soto 67 AD. They recorded highest average fruit weight on PM 105 AD and the lowest on GF 655/2. However the highest soluble solids content were observed on the Pollizo rootstocks Adesoto and PM 105 AD, followed by P. Soto 67 AD. Rather *et al.,* (2018) reported that apple fruits harvested from trees on MM-106 were significantly higher in quality parameters like weight, volume and yield compared to those on M-9 rootstock.

Chlorophyll content and photosynthesis

Chlorophyll is a green pigment, present in all green plants which is responsible for the absorption of light to provide energy for photosynthesis which is a chemical process through which plants produce glucose and oxygen form carbon dioxide and water using only light as a source of energy. Rootstocks markedly influence the photosynthetic rate of scion variety. Syrbu *et al.,* (1983) reported that photosynthesis was higher in trees on peach rootstock, medium on almond and apricot and lowest on cherry plum rootstock. Higher rate of photosynthesis in Redhaven peach trees on Lovell rootstock than on Siberian C rootstock (Yadava and McCarry, 1987), on GF677 rootstock than selfrooted plants Cappellini and Antonelli, 1997) was also observed. Apple plants grafted on seedling rootstocks had higher leaf chlorophyll a and b contents (Kultebaev, 1975) and photosynthesis (Barden and Ferree, 1979). Westwood and Zielinski (1966) found more chlorophyll content in Starkrimson than Starking Delicious cultivar of apple. Maximum photosynthetic productivity was found in the leaves of apple trees on dwarfing as compared to those on vigorous rootstocks (Titova and Shishkanu, 1976; Maidebura *et al.,* 1978; Trunov and Muromtsev, 1980). Ferree *et al.,* (1975) reported higher net photosynthesis in the leaves of Red Spur Delicious than in Rich-a-Red apples. Similarly, apple leaves on M9 rootstock had higher leaf chlorophyll content (Rud *et al.,* 1977; Makariev *et al.,* 1986; Chandel and Chauhan, 1994) and photosynthetic intensity (Andryushchenko *et al.,* 1977) as compared to other rootstocks. Fallahi *et al.,* (2001) reported that leaf photosynthesis was lower in the leaves of ‘BC-2 Fuji’ apple trees on Bud.9 rootstock than those on Ottawa 3 and M.7 EMLA rootstocks. Ghazvini *et al.,* (2008) evaluated photosynthetic activity of three Iranian commercial pistachio cultivars on four rootstocks and observed that trees on Sarakhs and *P. atlantica* rootstocks had highest photosynthetic rates. Sharma and Joolka (2002) recoded higher leaf chlorophyll in Non Pareil almond on bitter almond rootstock than on wild peach rootstock however leaf photosynthesis was higher on wild peach rootstock.

Transpiration and stomatal conductance

First reaction to drought stress in most of the fruit plants is stomatal closure which prevent water loss through transpiration. This stomatal closure is mainly related to soil moisture content and is mainly controlled by chemical signals such as abscisic acid production in dehydrating roots. Rootstock and scion influence tree productivity by affecting tree water balance (Giulivo and Bergamini, 1981). On M7 rootstock, Golden Delicious apple had highest stomatal conductance (Giulivo *et al.,* 1985). Similarly, Starking Delicious on M7 had least stomatal resistance and highest transpiration while a reverse trend was recorded in MM111 rootstock (Chandel and Chauhan, 1992). Stomatal conductance of Empire apple on M26 rootstock was generally lower than on other rootstocks (Olien and Lakso, 1986). However, Alleyne *et al.,* (1989), while comparing water relation of ungrafted container grown M2, M7, M9, M13, M26, MM106 and MM111 rootstocks, found that leaf conductance was higher in M26 than the other rootstocks. Marro and Cereghini (1976) concluded that guard cells in apple trees on M9 were more responsive in controlling transpiration than those on seedling rootstocks. In contrary to this, Barden and Ferree (1979) observed no significant effect of apple clonal rootstocks on stomatal conductance and transpiration of Starking Delicious apple. However, Higgs and Jones (1991) reported highest leaf conductance and the lowest leaf water potential in James

Grieve apple in comparison to fifteen other apple cultivars studied. Sharma *et al.,* (2004) recorded higher leaf stomatal conductance and transpiration rate in Non Pareil almond cultivar than Merced cultivar when raised on wild peach than bitter almond rootstocks.

Stomatal size and density

Stomatal size and density alter water relations in different fruit crops. These parameters are markedly influenced by the rootstock scion combinations. Among the various almond cultivars, Katha had the highest and Afganistan Seedling had the lowest stomatal density, whereas among different rootstocks, wild peach had the maximum and bitter almond the minimum stomatal density in various scion cultivars (Kumar, 1987).However, stomatal length was maximum in almond trees on bitter almond and minimum in those on Behmi rootstock, whereas, stomatal diameter was maximum in trees 'on Behmi and the minimum in those on bitter almond rootstock. In clonal rootstocks of plum, Pathak *et al.,* (1977) observed that stomatal number were more in vigorous rootstock Myrobalan A and less in dwarfing rootstock Damas C. Pejkje (1973) reported that Stanley, California and Imperial cultivars of plum had higher stomatal number per unit leaf area, while Pozegaca selection had the bigger stomata. Sharma and Joolka (2002) recoded higher stomatal density in Non Pareil almond leaves on wild peach rootstock than on bitter almond rootstock.

Abscisic acid and proline contents

Abscisic acid maintains the existence of plants under water stress through stomata closure however proline, a proteinogenic amono acid is used in the biosynthesis of proteins and act as osmoprotectant in stress tolerance. Rootstocks of different fruit crops influence abscisic acid and proline content of scion cultivars grafted onto them. Many workers (Grienenko and Zavalko,1967; Robitaille, 1971) reported that leaves of scion cultivars grafted on dwarfing rootstocks contained higher amounts of growth inhibitors than those on vigorous rootstocks. Yadava and Dayton (1972) studied the relation of endogenous abscisic acid to the dwarfing capacity of M9, M7, M1 and M16 and found a strong inhibitory substance in bioassay at or close to Rf values reported for maximum ABA activity. Highest inhibitor activity was observed in M9 tissue extract while it was progressively lower in M7, M1 and M16 rootstocks. Yadava and Lockard (1977) observed that trees grown on M9 and MM111 rootstocks contained highest and lowest levels of ABA like substances, respectively. Similar observations in Starking Delicious apples grown on M9 rootstock have been recorded by Rana (1985), Chandel and Chauhan (1991) and Robitaille and Carlson (1976). Chandel and Chauhan (1991) also observed higher leaf proline in Starking Delicious apple grown on M9 and MM111 rootstocks. Tworkoski and Fazio (2015) grafted scions of different apple cultivars to Malling (M.7, M.9, and M.27) and Geneva (G.935, G.5087, G.41, and G.11) rootstocks to measure abscisic acid in xylem exudates and found lower ABA in xylem exudate of ‘Fuji’ grown on G.935 and G.41 than G.5087 and G.11 rootstocks. Sharma and Joolka (2004) recoded higher leaf ABA and proline content in Non Pareil almond on bitter almond rootstock than on wild peach rootstock.

Carbohydrates content

Metabolism of sugars is crucial for abiotic stress tolerance in plants. Sugars are also the most important regulators that facilitate many physiological processes, such as photosynthesis, flowering, seed germination, senescence and other under various abiotic stresses. Rootstock and scion combinations exhibit significant influence on carbohydrate content. Nyujto and Brunner (1964) in apricot, observed that rootstocks inducing more vigorous growth had a lower carbohydrate content than those inducing less vigorous growth. Cherry plum trees on apricot resulted in higher leaf carbohydrate accumulation than on almond or cherry plum rootstock (Lishchuk, 1975). Layne and Ward (1978) reported higher levels of total carbohydrates and reducing sugars in apical shoots of Redhaven peach when grafted on Sibarian C rootstock than on Harrow Blood seedlings. Napoleon cherry on Mazzard rootstock had significantly lower starch content above and below the graft union than those on Mahaleb (Carison and Kyung, 1969). However, sour cherry grown on their own roots had higher sugar content than on Skorospelka and Brunner seedling rootstocks (Strelets, 1978). In apple, Brown *et al.,* (1985) noted that the trees on MM111 rootstock contained significantly higher carbohydrates than those on M9 rootstock. However, Starking Delicious apple trees grown on M9 had the highest while those on M25 had the lowest leaf carbohydrate content (Chandel and Chauhan, 1991). Red Spur Delicious apples on M4 rootstock had the highest leaf total sugar than in Vance Delicious, whereas, Vance Delicious apples had higher leaf starch content on MM106 than in Red Spur Delicious (Bhatia, 1992).

Nutrient uptake

Rootstocks influence the nutrient content in the leaves of scion cultivar in different temperate fruit crops. The effect of rootstocks on the uptake of different nutrients by scion cultivar is reviewed as under:

Nitrogen

Nitrogen is an essential component of protein, chlorophyll and protoplasm and stimulate vegetative and root growth in fruit plants. Rootstocks exert marked influence on the N status of scion cultivar. Almond trees on wild peach rootstock had higher leaf N (Holves *et al.,* 1985; Dass, 1990; Upadhayay and Ananda, 1991). Significantly higher leaf N content has been recorded in own rooted Redhaven than in Redhaven peach on Bailey, in Loring on Siberian C than on Nemaguard (Couvillon, 1982), in Italian prune on plum than on peach (Chaplin *et al.,* 1972) and sweet cherry cv. Bing on Mazzard than those raised on GI *195/1* and *196/4* rootstocks (Neilsen and Kappel, 1996). However, Knowles *et al.,* (1984) found only small and inconsistent difference in foliar N content of Loring and Redhaven peach trees on 5 seedling rootstocks. No significant difference in the N content of plum grown from suckers, on MyrobaJan (Dzamic *et al.,* 1966) and seedling rootstocks (Vitanova, 1982) could be recorded. Sharma *et al.,* (2007) recorded higher leaf N content in almond leaves raised on wild peach than on bitter almond rootstock.

Phosphorus

Phosphorus is a component of energy compounds ADP and ATP and is important for growth, flowering, fruiting and seed formation in fruit plants. In almond, rootstocks did not show any significant differences in leaf P (Dass, 1990; Upadhayay and Ananda, 1991). However, on hybrids as well as commercial rootstocks, the leaves of compatible rootstock scion combinations had higher P^{32} concentrations than those on ungrafted plants used as control. Leaves of incompatible combinations had lower P^{32} concentration than the control (Mitasov *et al.,* 1973). Stanley plum trees grown on Zhlta Dzhanka *(Prunus cerasifera*) rootstock had reduced leaf P content (Vitanova, 1982). There was higher accumulation of P in scion leaves of plum on bitter almond and Behmi rootstocks (Sharma, 1988) and in Bing sweet cherry on GM9 than on GM 61/1 rootstock (Neilsen and Kappel, 1996). However, Hanson and Perry (1986) in an experiment with Montmorency cherries on seedling Mazzard and Mahaleb rootstock, found lower concentrations of leaf P on Mazzard than on Mahaleb rootstock. Sharma *et al.,* (2007) recorded higher leaf P content in almond leaves raised on wild peach than on bitter almond rootstock.

Potassium

Potassium is an enzyme activator, regulate water relations and improve photosynthesis and development in fruit plants. Leaf K content is markedly influenced by different rootstocks. Leaf K content was lower in Carmel and Nonpareil almond grafted on almond than on Nemaguard and Lovell peach rootstocks (Micke *et al.,* 1996), in almond on almond than on peach rootstock (Holeves *et al.,* 1985), in Bing Sweet cherry on GM9 than on GM61/1 rootstock (Neilsen and Kappel, 1996). However, Dass (1990) and Upadhayay and Ananda (1991) observed higher leaf K levels in almond plants on bitter almond rootstock. Fallahi *et al.,* (2001) reported that ‘BC-2 Fuji’ apple trees on M.7 EMLA rootstock had significantly higher leaf K than those on Ottawa 3 and Bud-9 rootstocks. Sharma *et al.,* (2007) recorded higher leaf K content in almond leaves raised on wild peach than on bitter almond rootstock.

Calcium

Calcium is a constituent of cell wall and is important in the formation of cell membrane. Rootstocks produce variable effects on leaf Ca contents of scion cultivar. Higher leaf Ca content was estimated in almond trees on wild peach than on bitter almond rootstock (Dass, 1990; Upadhayay and Ananda, 1991), on almond than on peach rootstock (Micke *et al.,* 1996). Peach trees on Siberian C rootstock had reduced foliar Ca levels than on other rootstocks (Werner and Young, 1987). Whereas, Car *et al.,* (1995) found higher leaf Ca content of Maravilha peach on Hansen 536 than on Harrow Blood; Mrs 2/5 or PSB2 rootstocks. Similarly Vitanova (1982) reported lower Ca content of Stanley plum raised on M"tna Boyaka Rakiinitsa *(Prunus domestica*) rootstock. However, Sharma (1988) observed higher accumulation of leaf Ca on Behmi and Myrobalan B rootstocks. Hanson and Perry (1986) found that the leaves of the Montmorency cherry on Mazzard contained higher Ca content than on Mahaleb. Similarly, Rozpara *et al.,* (1989) observed lower Ca content in the leaves of sweet cherry grafted on *Prunus mahaleb* as compared to those on *Prunus avium* rootstocks. Fallahi *et al.,* (2001) reported that ‘BC-2 Fuji’ apple trees on Bud-9 rootstock had significantly higher leaf Ca than those on M.7 EMLA and Ottawa 3 and rootstocks. Sharma *et al.,* (2007) recorded higher leaf Ca content in almond leaves raised on wild peach than on bitter almond rootstock.

Magnesium

Magnesium regulates the processes of photosynthesis and carbohydrates metabolism and is also associated with protein synthesis. Mg content of the scion leaves was also influenced by the rootstock used. Higher leaf Mg in almond grafted on wild peach than on bitter almond and Behmi rootstocks (Dass, 1990) and on peach than on almond rootstock (Holeves *et al.,* 1985; Micke *et al.,* 1996) has also been recorded. However, Upadhayay and Ananda (1991) observed that rootstock did not influence leaf Mg content in the scion cultivars of almond. It has also been observed that there was higher accumulation of Mg in the leaves of plum on Behmi and Myrobalan rootstock (Sharma, 1988), Bing Sweet cherry on GM9 than on GM61/1 rootstock (Neilsen and Kappel, 1996), Sweet cherry on *Prunus avium* than on *Prunus mahaleb* rootstock (Rozpara *et al., 1989)* and Montmorency cherry on Mahaleb than on Mazzard rootstock (Hanson and Perry, 1986). Fallahi *et al.*, (2001) reported that 'BC-2 Fuji' apple trees on M.7 EMLA rootstock had significantly higher leaf K than those on Ottawa 3 and Bud-9 rootstocks. Sharma *et al.,* (2007) recorded higher leaf Mg content in almond leaves raised on wild peach than on bitter almond rootstock.

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How to cite this article:

Sharma, M.K., Rifat Bhat, N. Nazir, A. Khalil, S.A. Simnani and Sundouri, A.S. 2019. Techniques for Determination of Vitamin B_6, Vitamin C and Variability in Areca Nut (*Areca catechu*) Samples of Karnataka, India. *Int.J.Curr.Microbiol.App.Sci.* 8(02): 1089-1104.
doi: https://doi.org/10.20546/ijcmas.2019.802.128