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EFFECT OF ROOTSTOCK ON PLANT GROWTH, FRUIT YIELD AND QUALITY OF SWEET ORANGE CV. EARLY GOLD UNDER CENTRAL ZONE OF PUNJAB

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ABSTRACT

Research regarding effect of Volkameriana lemon, Benton citrange, C-35 citrange and US-852 rootstocks on field performance of Early Gold variety in terms of vegetative growth, fruit yield and quality was carried out at Punjab Agricultural University – Fruit Research Station, Jallowal. Highest plant height (3.96m) in Early Gold was promoted Volkameriana while US-852 was most efficient to contribute towards dwarfing effect (3.42m). US-852 also exhibited lowest plant spread among all the rootstocks under study. Stock circumference showed significant variation with highest value (62.07cm) in case of plants budded on US-852. Fruit number (224), weight (158g), diameter (6.70cm) and length (6.48cm) was found highest in plants produced on Volkameriana. Juice recovery (46.7%) and rag content (34.9%) was highest in case of US-852 and Volkameriana, respectively. Fruits harvested from plants budded on Volkameriana recorded highest peel thickness (5.00mm). Highest level of acidity (0.68%) was recorded in fruits from plants budded on Volkameriana.

Keywords: Early Gold, Fruit quality, Rootstock, Vegetative growth

Citriculture is one of the leading fruit industries of north-western India which supplies fresh fruits to the state markets and its neighboring countries. The demand for citrus fruits bestowed with diversity of nutritive and medicinal properties is therefore closely associated with nutritional security of the human population.

The agro-climatic conditions of Punjab province of Indian sub-continent are highly congenial for commercial cultivation of different varieties of sweet orange, mandarin, grapefruit, lime and lemon. Currently, the total citrus acreage in the state is 60980 ha. Kinnow mandarin is the chief cultivar of the region occupying more than 90 percent of the total area under citrus varieties (Anonymous, 2020). However, in the present scenario, the marketing of Kinnow fruit is posing serious problems due to its confined harvesting season from mid-January and mid-February. The drawback of restricted harvesting span of this variety is leading to market glut resulting into lower price for the producer. This consequently invites introduction of new suitable citrus varieties with varying harvesting span to break the monoculture of Kinnow. Punjab Agricultural University has recently recommended Early Gold, an early maturing variety of sweet orange (Kumar *et al*., 2018) for commercial cultivation in the state to meet the demand for pre-winter maturing citrus cultivar. The shifting of some area from Kinnow to Early Gold cultivation can play a vital role in enhancing the profitability in citrus cultivation of the region.

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Working out the most compatible stionic combination for specific area is highly important issue for successful orchard establishment. Rootstock choice is one of the major decisions a grower makes, and its implications for fruit production and quality are massive. Drivers of rootstock adoption are wide-ranging. Although the metabolic functions in a grafted plant are divided between the two plant fractions, it is well known that rootstocks greatly influence variety behaviour as it ensures provision of minerals and water for the total plant (Martínez-Cuenca *et al*., 2016). The potent effects of rootstock on the vegetative growth, fruit yield and quality of scion cultivars have been closely investigated and recognized by various previous researchers (Aviles *et al*., 2011; Nasir *et al*., 2011; Gamir *et al*., 2010). In addition to supporting the plant in the soil, the rootstock is accountable for absorption of moisture and nutrients, accommodating storage of carbohydrates and performance of plant under certain soil conditions. They play a significant part in regulating resistance against pests and diseases (Isenalume and Okonokhua, 2014).

Rough lemon is the dominant rootstock in Punjab used for the propagation of major citrus species. The extensive use of this stock is due to suitable characters like drought tolerance and extensive root system. However, the susceptibility of rough lemon to *phytophthora* (Georgiou, 2000)is acting as bottleneck in development of citrus industry in the state (Chahal *et al*., 2015). Sensing the requirement of new dependable rootstock for the region, introduction and evaluation of new rootstocks is highly required. Globally, Volkameriana lemon has been considered quality rootstocks for sweet orange cultivars. Citrus varieties

grafted on this rootstock generally show fast vegetative growth. They are also known to produce heavy fruit crop at any age. The trifoliate orange and its hybrids are also widely used as rootstocks world around. The trees grafted on these rootstocks produce compact canopies which assist easy cultural practices, show high productivity per unit of canopy and superior fruit quality. In addition to their cold-hardiness character, they are also preferred rootstocks due to resistance/tolerance against various citrus problems like Tristeza, citrus nematode, etc. These rootstocks are also considered as tolerant to phytophthora, and therefore expected to overcome the problems emerging from this deadly fungus to considerable level.

Keeping in view the significance of newly introduced sweet orange cultivar for commercial cultivation in northwestern India and different roles played by the rootstocks, present study was planned to evaluate the effect of one unifoliate rootstock; Volkameriana lemon and three trifoliate rootstocks; Benton citrange, C-35 citrange and US-852 on field performance of Early Gold orange. The work overviews the response in terms of plant growth, fruit yield and quality promoting characters of scion cultivar tree grafted onto four different commercial rootstocks.

MATERIALS AND METHODS

Plant material

Research work regarding effect of different rootstocks on Early Gold variety of sweet orange (*Citrus sinensis*) was conducted on plants spaced at 25×15 feet during the year 2018. The plants budded on four different rootstocks; Volkameriana lemon, Benton citrange, C-35 citrange and US-852 rootstocks (Table 1.) were supplied by Punjab Agri. Export Corporation Limited (PAGREXCO), imported from USA. These stock/scion combinations were planted at Punjab Agricultural University (PAU), Fruit Research Station, Jallowal (Lattitude, 31° 29' 38" N, Longitude, 75° 37' 40" E. altitude 228 m) located at Jalandhar district of Punjab, India during the year 2005.

Plant growth analysis

Experimental plants were maintained through uniform cultural and plant protection practices as per the recommendations of Punjab Agricultural University. The different stock-scion combinations were studies for vegetative growth parameters along with fruit quality and yield promoting characters. Plant height was measured in meters using collapsible calibrated PVC pole. Tree spread was also recorded in meters in term of east-west and north-south diameters by marking outer edges of the canopy and running measuring tape, tight and straight through the marked position at ground level. Scion and stock circumference were measured in centimeter with the help of measuring tape. Scion circumference was recorded 5cm above the bud union while stock circumference was recorded 5cm below the bud union.

Fruit analysis

Fruit samples were collected during the morning hours at optimum maturity stage (Kumar et al. 2018). Thirty homogenous fruits (based on color and size) from each stionic combination were picked up randomly with clipper from different sides of the plants having uniform growth, and taken to the laboratory for analysis. Each selected fruit had no signs of infection or injury and after selection fruits were lightly scrubbed with a paintbrush in tap water to remove surface contaminants, cleaned with double distilled water and wiped dry at room temperature. Electronic balance was used to work out fruit weight and results were recorded in grams. Fruit size (length and diameter) was recorded in centimeters with the help of digital Vernier calipers (Mitutoyo, Japan). Fruit juice on the basis of fresh weight was extracted from the pulp after squeezing and straining through muslin cloth under aseptic conditions and expressed in percentage. The juice percentage was calculated on the weight basis. Seed number was counted from the remains after extraction of juice. Rag weight was measured using electronic balance and peel thickness was recorded from middle of the line running between stem and stylar end in millimeters with Vernier calipers (Mitutoyo, Japan). Total soluble solids (TSS) were

Table 1. Plant material used during the study

Sr. No.	Scion variety	Botanical Name/Parents	Reference/Source
1.	Early Gold	*Citrus sinensis* (Sweet orange)	Kumar *et al*. 2018
	Rootstock	Botanical Name/Parents	Reference/Source
2.	Volameriana Lemon	*Citrus Volkameriana*	Tsakelidou *et al.*, 2002
3.	Benton Citrange	*Citrus sinensis* X *Poncirus trifoliate*	Anonymous, 2005
4.	C-35 Citrange	*Citrus sinensis* X *Poncirus trifoliate*	Raddatz-Mota *et al*. 2019
5.	US-852	*Citrus reticulata* X *Poncirus trifoliate*	G. McCollum and K. D. Bowman, 2017

Table 2. Effect of rootstocks on vegetative growth and fruit number in Early Gold plants.

Rootstock	Height (m)	East-West spread (m)	North-South spread (m)	Scion circumference (cm)	Stock circumference (cm)	Fruit number/ plant
Volkameriana lemon	3.96^{a}	3.82^{a}	3.74^{a}	54.00^{a}	60.33^{a}	224^{a}
Benton citrange	3.52^{bc}	3.34^{bc}	3.53^{ab}	46.73^{a}	50.80^{b}	216^{ab}
C-35 citrange	3.83^{ab}	3.67^{ab}	3.83^{a}	50.67^{a}	58.84^{a}	198^{b}
US-852	3.42^{c}	2.99^{c}	3.19^{b}	48.77^{a}	62.07^{a}	164^{c}

recorded by digital hand refractometer (Atago, Japan) after making subsequent corrections at 20°C. Total titratable acidity, ascorbic acid and reducing sugar content of juice were determined following standard methods as outlined in A.O.A.C (2000). Fruit yield of Early Gold orange plants budded on different rootstocks was calculated in term of number of fruits per plant by calculating total fruits on each tree under experiment.

Data analysis

Data were analyzed statically to an analysis of variance (ANOVA) and differences among the means were determined for significance at $p<0.05$ by LSD test using the statistical analysis system software version 9.3 (SAS Institute Inc., Cary, NC, USA) at 5% level of probability.

RESULTS AND DISCUSSION

Vegetative growth characters

The data regarding vegetative growth of Early Gold sweet orange plants on four different rootstocks is given in Table 2. The plants grafted on US-852 had lesser growth in terms of height than the Volkameriana lemon and C-35 citrange. Highest level of this parameter was recorded to be 3.96m in Early Gold plants budded on Volkameriana lemon, while minimum was to the tune of 3.42m, registered by the plants budded on US-852. A non-significant variation was recorded between Early Gold plants having rootstocks Volkameriana lemon and C-35 citrange; Benton citrange and C-35 citrange; US-852 and Benton citrange. Earlier compiled works on effect of different rootstocks on scion growth have established Volkameriana as vigour promoting rootstock (Annonymous, 2007), and the specific varietal character of this rootstock might be the reason for the attainment of maximum plant height of Early Gold plants budded on this rootstock. Reduced vegetative growth influenced by particular rootstock has been allied with lower leaf and stem water capacities in the scions plants grafted over them than those propagated onto rootstocks promoting higher plant height, stem thickness and other vegetative characters of the scion. This might be related to the high hydraulic conductivity resistance that may result into water deficit in leaves during the phase of high evaporative demand and stomata closure. Therefore, non-vigorous or slow growth promoting rootstocks are not able to transport sufficient water from soil to stems. Even though the impediment of bud/graft union to moisture carriage and xylem structural characteristics, specifically the count and size (diameter) of vessels, might restrict plant growth, carbohydrate distribution is also significant check involved in plant reaction (Martínez-Cuenca *et al*., 2016).

The examination of plant spread in case of all the rootstocks under study showed significant variations in both east-west and north-south directions. Volkameriana lemon contributed for highest east-west (3.82m) while C-35 citrange for north south spread (3.83m). In the east-west and north-south directions, lowest spread was found in case of US-852 to the tune of 2.99m and 3.19m respectively. Inline findings have been documented by Georgiou (2000) who discovered significant variation in canopy diameter of Nova mandarin plants on different rootstocks like Carrizo, Troyer and Yuma. Non-significant trend was found in scion circumference of Early Gold plants budded on

Table 3. Effect of rootstocks on physical characters of Early Gold fruits.

Rootstock	Fruit Weight (g)	Fruit Diameter (cm)	Fruit Length (cm)	Fruit Juice (%)	Rag content (%)	Seed No/ fruit	Peel thickness (mm)
Volkameriana lemon	158^{a}	6.70^{a}	6.48^{a}	40.8^{b}	34.9^{a}	3.12^{a}	5.00^{a}
Benton citrange	147^{ab}	6.39^{b}	6.19^{b}	45.4.^{ab}	33.2^{ab}	3.04^{a}	4.70^{ab}
C-35 citrange	130^{b}	6.22^{b}	6.08^{b}	44.3^{ab}	33.5^{ab}	2.85^{a}	4.67^{ab}
US-852	152^{a}	6.50^{ab}	6.27^{ab}	46.7^{a}	31.4^{b}	3.20^{a}	4.33^{b}

different rootstocks. Highest value was achieved by Volkameriana lemon to the tune of 54.00cm. Thinnest scions of Early Gold were produced by plants budded on Benton citrange and registered value of 46.73cm. Contrarily, Ahmad *et al*. (2006) while working on various stoinic combinations registered substantial deviations in increment of scion girth in Kinnow mandarin as affected by different rootstocks. Significant variations were recorded in stock circumference as highest value for this parameter was achieved by US-852 (62.07cm) followed by Volkameriana lemon (60.33cm), C-35 citrange (58.84cm) and Benton citrange (50.80cm).

The cross-sectional area of the trunk is generally considered to be significantly correlated with the plant mass as well as volume of the canopy. Investigations conducted out on Lane Late variety of orange plants grafted over various type of rootstocks concluded that *C. macrophylla* results into smaller trunk size in comparison to Gou Tou Chen (Citrus hybrid of *Citrus aurantium*) and Cleopatra mandarin (*Citrus reshni*) (Martínez-Cuenca *et al*., 2016).

Fruit number per plant

The data regarding fruit number per plant presented in Table 2 shows that Early Gold (224 fruits/plant) budded on Volkameriana lemon was the most superior combination in promoting this parameter. It was closely followed by plants budded on Benton citrange (216 fruits/plant) and both these combinations registered non-significant variations with each other. Early Gold on US-852 resulted into lowest number of fruits per plant (164 fruits/plant) and it showed significant variation with all the other rootstocks under the study. EL-Sayed *et al.* (2007) while working on performance of Washington Naval orange on two different rootstocks, Volkameriana lemon and sour orange revealed that number of fruits per tree and weight (kg/tree) of Washington navel orange was significantly higher on Volkameriana lemon rootstock than on Sour orange.

Physical characters of fruits: The data presented in Table 3, regarding the effect of different rootstocks on fruit weight of Early Gold reveals that fruits from plants propagated on Volkameriana lemon were the heaviest while those from plants budded on US-852 were next to follow. Both these rootstocks promoted this parameter to the value of 158g and 152g respectively. Fruits harvested from plants budded on C-35 citrange were the lightest with weight of 130g. Statistically, fruit weight in case of Volkameriana lemon, US-852 and Benton citrange was at par with each other. The data regarding fruit size is also provided in the Table 3. The size of fruits was measured in the form of diameter and length. Fruits from plants with Volkameriana lemon as rootstock showed highest diameter of 6.70cm. US-852, Benton citrange and C-35 citrange (6.50cm, 6.39cm and 6.22cm respectively) registered non-significant variation with each other but Benton citrange and C-35 citrange varied significantly with Volkameriana lemon. Investigations on variation in fruit diameter with different rootstocks were also carried out by Giner *et al*. (2011) during their study on Navelate orange. The elaboration of data for fruit length provided similar variations as in case of fruit diameter. Fruits from plants budded on Volkameriana lemon produced length to the tune of 6.48cm followed by US-852 which produced fruit length to the value of 6.27cm. Lowest level of this parameter was found in case of C-35 citrange with 6.08cm.

Regarding juice recovery from the fruits, data was presented on percent basis by weight. Highest juice recovery of 46.7 percent was observed in fruits from plants budded on US-852, it was closely followed by Benton citrange and C-35 citrange which recorded values of 45.4 and 44.3 percent. All these rootstocks influenced juice content in a non-significant manner. Fruits from plants budded on Volkameriana lemon resulted into significantly lower juice recovery (40.8 percent) in comparison to US-852 rootstock. Smith *et al*. (2004) while working on long term performance of Ellendale mandarin recorded significant effect of Troyer on fruit juice percentage in comparison to Mazol and Lockyer, however its effect was statistically at par with Carrizo, Joppa, Parramatta and Emperor. The review of data concerning rag percentage showed that this parameter was statistically influenced in fruits harvested from plants budded on different rootstocks under study. Highest rag content was found in Volkameriana lemon (34.9%) followed by C-35 citrange (33.5%). US-852 resulted into lowest rag content (31.4%) of fruits during the study.

Different citrus rootstocks produce significant effect

Table 4. Effect of rootstocks on biochemical characters of Early Gold fruits.

Rootstock	Total Soluble Solids (%)	Acidity (%)	Reducing Sugars (%)	Ascorbic acid (mg/100ml)
Volkameriana	9.33[a]	0.68[a]	2.14[a]	40.5[a]
Benton	9.50[a]	0.67[a]	2.33[a]	41.8[a]
C-35	9.23[a]	0.63[a]	2.29[a]	42.4[a]
US-852	8.83[a]	0.55[b]	2.23[a]	41.1[a]

on peel thickness of fruits of Early Gold mandarin. The parameter was found to be highest (5.00mm) in fruits harvested from plants budded on Volkameriana Lemon. Benton citrange (4.70mm) and C-35 citrange (4.67mm) were the next to follow which showed non-significant variation with Volkameriana lemon. US-852 recorded significantly thin peel (4.33mm) among all the rootstocks. Non-significant variation was registered in case of seed number, where lowest seed count of 2.85 was found in C-35 citrange and highest of 3.20 in US-852. Average seed number in fruits from plants propagated on Benton citrange and Volkameriana lemon was to the value of 3.04 and 3.12 respectively. Similar to our results, Georgiou (2000) observed significant effect of rootstocks on seed number per fruit in 'Nova' mandarin.

Biochemical characters of fruits

The data presented in Table 4 regarding total soluble solids (TSS) shows that fruits of Early Gold sweet orange failed to register any significant variation in this parameter as influenced by different rootstocks. Fruits from plants budded on Benton citrange showed highest level of this parameter followed by those on Vollkameriana lemon with 9.50 and 9.33 percent respectively. Lowest TSS content of 8.83 percent was observed in US-852. Significant variations were registered for juice acid content of the fruits of Early Gold. Fruits from plants budded on Volkameriana lemon resulted into higher juice acidity (0.68 percent) and were closely followed by those harvested from plants budded on Benton citrange (0.67 percent) and C-35 citrange (0.63 percent). Lowest level of acidity was found in fruits harvested from plants budded on US-852 and documented average value of 0.55 percent. On the contrary, Aviles *et al*. (2011) while working on horticultural performance of Folha Murcha sweet orange recorded non-significant variation in acid content of fruits when budded on eleven different rootstocks. The different type of rootstocks did not produce any significant effect of the reducing sugar and ascorbic acid content of Early Gold fruits. Highest content of reducing sugars (2.33 percent) was found in Benton citrange while lowest (2.14 percent) in Volkameriana lemon. In case of ascorbic acid content, C-35 citrange showed highest (42.4 mg/100ml) positive influence while Volkameriana lemon registered lowest value (40.5 mg/100ml).

In conclusion, the study elaborates the results regarding the effect of different rootstocks on plant growth, fruit yield and quality of Early Gold orange. Propagation of this variety on US-852 resulted in achieving significant dwarfing effect in comparison to Volkameriana rootstock. Significantly higher fruit number per plant was found in Volkameriana and Benton citrange in comparison to C-35 citrange and US-852. Volkameriana rootstock was most suitable for producing heavy fruits with superior size having significantly larger diameter and length. The three trifoliate rootstocks were found suitable for higher juice recovery. Most of the biochemical parameters were at par for all the rootstocks except juice acidity, which was significantly higher in Volkameriana as compared to US-852. Keeping in view the current results, Volkameriana and Benton citrange rootstocks can be explored for achieving superior fruit number per plant and US-852 for comparatively higher density plantation of Early Gold variety of sweet orange.

LITERATURE CITED

Anonymous, 2020. *Package of Practices for Fruit Crops*, Punjab Agricultural University, Ludhiana. pp 1. PAU Ludhiana Academic Press.

Anonymous, 2007. *Volkameriana Rootstock fact sheet*. NSW Department of Primary Industries, Australia.

Anonymous, 2005. *Benton citrange. Rootstock fact sheet*. NSW Department of Primary Industries, Australia.

A O A C 2000. Official Methods of Analysis (17th Edn.), Association of Official Analytical Chemists, Washington, DC.

Aviles T C, Filho F A A M, Stuchi E S, Silva S R and Nunez E E 2011. Horticultural performance of Folha Murcha sweet orange onto twelve rootstocks. *Sci Hortic*, **129**: 259-65.

Chahal T S, Sidhu G S and Rattanpal H S 2015. Variability in growth characters of Carrizo cuttings at different stages of development. *Int J Agri Sci* **7**(10): 724-26.

EL-Sayed S A, El-Saiada S A G and Ennab H A 2007. Yield and fruit quality of Washington navel orange as affected by Sour orange and Volkamer lemon rootstocks. *J Agric Sci Mansoura Univ*, **32** (11): 9217 – 26.

Gamir J R, Millo E P, Forner J B and Giner M A F 2010. Citrus rootstock responses to water stress. *Sci Hortic* **126**: 95-102.

Georgiou A 2000. Performance of 'Nova' mandarin on eleven rootstocks in Cyprus. *Sci Hortic* **84**: 115-26.

Giner M A F, Hueso J J, Aguera J M, Legua P and Forner J B 2011. Effect of citrus rootstocks on growth, yield and fruit quality of Navelate orange. *J Food Agri & Env* **9**(2): 400-03.

Isenalume O P and Okonokhua B O 2014. Comparative effects of seed storage methods on the development of established rough lemon (Citrus jambhiri Lush) rootstock seedlings in the nursery. *Nigerian J Agri Food Env* **10**: 123-27.

Kawase K, Iwagaki I and Takahara T 1987. Rootstock Studies for Citrus Varieties in Japan. *Jpn Agric Res Q* **20**(4): 253-59.

Kumar A, Pathania S and Sharma P K 2018. Rootstock evaluation for sweet orange cv. Early Gold in arid irrigated region of Punjab. *Indian J Hort* **75**(1): 34-38.

McCollum G and Bowman K D 2017. Rootstock effects on fruit quality among 'Ray Ruby' grapefruit trees grown in the Indian River District of Florida. *HortSci* **52**(4):541–46.

Martínez-Cuenca M R, Primo-Capella A and Forner-Giner M A 2016. Influence of Rootstock on Citrus Tree Growth: Effects on Photosynthesis and Carbohydrate Distribution, Plant Size, Yield, Fruit Quality, and Dwarfing Genotypes. *Plant Growth* 107-129.

Nasir M A, Makon M N K, Khan A R, Ahmad S and Ishfaq M 2011. Effect of different rootstocks on vegetative growth and canopy of Kinnow Mandarin plants. *J Agric Res* **49**: 65-71.

Raddatz-Mota D, Franco-Mora O, Mendoza-Espinoza J A, Rodriguez-Verastegui L L, Leon-Sanchez F D and Rivera-Cabrera F 2019. Effect of different rootstocks on Persian lime (*Citrus latifolia* T.) postharvest quality. *Sci Hortic* **257**: 108716.

Smith M W, Shaw R G, Chapman J C, Turner J O, Lee L S, McRae K B, Jorgensen K R and Mungomery W V 2004. Long-term performance of Ellendale mandarin on seven commercial rootstocks in sub-tropical Australia. *Sci Hortic* **102**: 75-89.

Tsakelidou K, Papanikolaou X and Protopapadakis E 2002. Rootstock effects on the yields, tree and fruit characteristics of the mandarin cultivar `clementine' on the island of Rhodes. *Expl Agric* **38**: 351-58.