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EFFECT OF STIONIC COMBINATION ON THE GROWTH AND YIELD OF KINNOW MANDARIN (*CITRUS RETICULATA* BLANCO)

WAQAR AHMED, M.A. PERVEZ, M. AMJAD, M. KHALID*, C. M. AYYUB AND M. AZHER NAWAZ

Institute of Horticultural Sciences, University of Agriculture, Faisalabad.
**Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad.*
waqar199@hotmail.com

Abstract

Citrus is a leading fruit crop of Pakistan. Among citrus cultivars, Kinnow is the most prominent and shares about 95% of total citrus production in Pakistan. The monopolized cultivation of Kinnow scion grafted over rough lemon needs a substituted rootstock for higher yield/return and for longer productive tree life. Trials for the selection of suitable rootstock for Kinnow mandarin under subtropical environmental conditions and highly alkaline rhizosphere were carried out in the experimental fruit orchard of the Institute of Horticultural Sciences, University of Agriculture, Faisalabad during 2003-2005. The studies revealed that Volkamer lemon, Brazilian sour orange and Citrumello 4475 were the reliable rootstocks for citriculture industry of the Punjab province.

Introduction

The importance of citrus to agriculture and world's economy is demonstrated by its wide distribution and large-scale production. *Citrus* is an important genus of the family Rutaceae in the plant kingdom. Various species of *Citrus* are believed to be native to tropical and sub-tropical regions of Asia and Malaya archipelago (Hooker, 1872). It is an economically potential fruit and is grown in more than 52 countries of the world. Pakistan is bestowed with suitable climate and soil conditions to grow citrus; where it is grown on an area of 185,400 ha with annual production of 1.67 tones (Anon., 2005). Today Pakistan stands among the top 14 citrus growing countries of the world.

There is no controversy over the importance of citrus rootstock for better citrus production. A successful rootstock should have compatibility between scion and rootstock besides having tolerance against prevalent edaphic and environmental conditions. Rootstocks provide growers with useful tool to manipulate the vigor and production of orchard trees. Effects on tree size, fruit quality, precocity, fruit production and maturity are achieved through complex interrelationship between the roots and canopy of the plant. Castle *et al*., (1988) reported that trees on Trifoliate orange and Carrizo citrange gave the better performance with respect to total soil soluble and the lowest TSS was gained from the trees grafted on Rough lemon. Constantin *et al*., (1979) found that rootstocks significantly influenced the yield, fruit weight, rind thickness, peel colour, juice contents, total soluble solids and titratable acidity of "Owari" Satsuma mandarin when grafted on 16 different rootstocks. Similarly, many workers reported the higher yields of sweet orange on Rough lemon root stock than on other rootstocks (Brawn, 1920; Gardner & Horanic, 1961; Cohen & Reitz, 1963).

Rootstocks directly affect the ability of plants to take up water and nutrients and significantly alter the pattern of canopy development and photosynthesis (Richardson *et al*., 2003). Kinnow mandarin is inclined to progressive decline these days in Pakistan

due to abiotic stresses *viz-a-viz* shortage of irrigation water, dry weather and ever increasing salinity in the root zone along with adverse impact of intercultural practices in the orchards. An unusual important feature of our citrus plantation is the short life span of trees which seldom exceed 25 years. In over 40% cases the decline of trees starts at the age of 10 years which is the prime age of production, whereas it is not uncommon for citrus orchards to remain in production for over 50 years in many other countries. Low productivity and short span of productive life of citrus trees coupled with the foot rot and excessive leaf drop along with twig drying are researchable problems under the adverse environmental conditions. One of the hypotheses directs towards the incompatibility of Rough lemon to Kinnow mandarin under highly alkaline soils of the Punjab province. Among various factors responsible for citrus decline, rootstocks have been considered to be a major contributor with respect to climatic conditions. Today rootstocks related problem in Citriculture has assumed a great significance. Every citrus growing country is faced with this burning problem and is trying to solve it. The rootstock found suitable at one time, may entirely fail in future and that seems to be an original problem of the Punjab province. One of the basic purposes of the present study was to find rootstocks resistant to citrus blight. There is no single rootstock available that can be regarded as an ideal for Kinnow mandarin cultivar under all types of agro-climatic conditions. Therefore selection of proper rootstock for scion variety may lead to the failure and/or success of the orchard. The present project was hence designed as a preliminary effort to investigate a suitable rootstock for Kinnow considering vigour, productivity and fruit quality. The citriculture industry of the Pakistan will have to address all such issues to make the citrus industry sound and internationally competitive, particularly in fresh fruit export market.

Material and Methods

The studies were carried out at the Experimental Fruit Garden Sq. # 9 of the Institute of Horticultural Sciences, University of Agriculture, Faisalabad. Nine rootstocks Citrumello 4475, Citrumello 1452, Volkamariana, Yuma citrange, Rough lemon, Mithi, Troyer citrange, Carrizo citrange and Brazilian sour orange were used.

For the physiochemical analysis, 100 fruits of each cultivar were picked during the month of January for all the consecutive years of the study. The analyses of fruit were conducted in Post-Graduate Pomology Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad. The following growth and physiochemical parameters were studied on the plants: Scion girth, rootstock girth, canopy spread, plant height, number of fruits per plant, Juice %, total soluble solids (TSS), acidity % and vitamin-C contents in the juice. Girth measurement was taken at a fixed height of 15 cm above the graft union for scion girth and 15 cm below the graft union for girth of rootstock. The positions were marked with black paint for recurrent observations. Trunk diameters were taken annually in the March, so as to quantify any differential growth rates during the study period. Plant height was measured by telescope pole while canopy spread was calculated using the following formula after measuring the outer peripheral branches of the canopy in East-West and North-South directions.

$$\text{Canopy spread} = 4/3\ \pi\ r^3.$$

Total soluble solids were measured with digital refractometer (ATAGO, RX 5000). Acidity in juice was determined by taking 10 ml of juice from each sample and diluting with distilled water in a 100 ml beaker. 2-3 drops of phenolphthalein were added for end

point. The samples were titrated against N/10 NaOH (Hortwitz, 1960). The results were expressed as percent citric acid

$$= \frac{\text{N/10 NaOH used} \times 0.0064}{\text{Volume or Weight of sample used}} \times 100$$

For the determination of vitamin-C (ascorbic acid) in juice, the method described by Ruck (1961) was used. Ten ml juice was taken into 250 ml conical flask and volume was made up to the mark using 0.4 % Oxalic acid solution. Five ml of filtered aliquot was taken in a flask and titrated against 2, 6, dichlorophenoindophenol dye to a light pink colour which persisted for 10-15 seconds.

Vitamin-C was calculated as:

$$= \frac{1 \times R_1 \times V}{R \times W \times V_1} \times 100 \text{ mg ascorbic acid per 100 ml juice}$$

where

R_1 = ml dye used in titration of aliquot

R = ml dye used in titration of 1 ml of standard ascorbic acid solution prepared by adding 1 ml of 0.l % ascorbic acid + 1.5 ml of 0.4 % oxalic acid.

V_1 = ml of juice used.

V = Volume of aliquot made by addition of 0.4 % Oxalic Acid.

W = ml. of aliquot used for titration.

TSS/acid ratio was calculated by dividing the TSS over acidity

Statistical analysis of data

The experiment was laid out in a Randomized Complete Block Design (RCBD). All data were analyzed statistically using analysis of variance techniques (Steel *et al*. 1996) and the means were separated by Duncan's multiple range test.

Results

Vegetative performance: Rootstock and scion girth is considered very important to determine the degree compatibility of stionic relationship between stock and scion. Sometime rootstock shows incompatibility with scion leading to unbalancing in physiological functions, plant vigor, productivity as well as fruit quality. The observations for this parameter showed significant differences among rootstocks for increment in stock girth. Average maximum rootstock increment over the years was observed in Rough lemon (2.00 cm) followed by Volkamer lemon (1.25 cm) whereas, minimum in Brazilian Sour Orange (BSO) and Mithi showed almost no increment in girth (Table1). The annual increment in girth of all other rootstocks was moderate and remained statistically at par with each other. It showed slower rate of plant growth and this trend depicted that Rough lemon is the most adapted rootstock under highly alkaline soil of the Punjab province, while Volkamer lemon which is a sister rootstock to Rough lemon is also well adapted to alkaline soil conditions and would be a future substitute of Rough lemon rootstock.

Table 1. Effect of Rootstocks on plant features of Kinnow mandarin.

Rootstocks	Rootstock girth increment (cm)	Scion girth increment (cm)	Canopy increment (m^3)	Plant height increment (meter)	Fruits per plant (yield)
Citrumello 4475	0.63bc	2.00abc	1.60	0.31b	271.5c
Citrumello 1452	0.50bc	0.75c	0.16	0.26c	579.5b
Volkamariana	1.25ab	1.00bc	0.43	0.38b	920.5a
Yuma Citrange	0.50ab	2.50ab	0.31	0.29c	230.5
Rough lemon	2.00a	3.00a	0.05	0.53a	723.5a
Mithi	0.25bc	0.75c	0.01	0.22c	432.5b
Troyer Citrange	0.75bc	1.00bc	0.09	0.29c	411b
Carrizo Citrange	0.73bc	1.00bc	0.10	0.23c	155.5d
Brazilian sour orange	0.00c	0.75c	0.11	0.11d	1050.25a

As far as scion girth is concerned, the results indicated that Rough lemon had maximum increment (3 cm) followed by Yuma citrange (2.50 cm). Volkamer lemon had an average annual scion increment of 1:00 cm and rubbed it's shoulder with Troyer citrange and Carrizo citrange. Minimum annual increment in scion girth was observed (0.75 cm) for Citrumello 1452, Mithi and Brazilian sour (Table 1). Degree of variability in the compatibility of graft combinations has been observed on the basis of differential growth rates of scion and rootstock i.e., even growth between Rough lemon rootstock and Kinnow scion (Fig. 1). In another case Troyer citrange rootstock had over growth on the Kinnow scion (Fig. 2) while in the stionic combination of Brazillian sour orange (BSO) and Kinnow mandarin, scion had over growth on the rootstock (Fig. 3).

Similar diameter of scion and stock is an ideal indication of congenial relationship which produces a reasonable crop of quantity and quality. It was noticed that Rough lemon was at the top for the induction of increment for scion and stock. Trees on Volkamer lemon were vigorous and had strong union followed by Rough lemon.

Vegetative growth has a profound impact on the reproductive growth of citrus because citrus bears on current season growth emerging from one year old branches. So keeping in view the bearing habit, canopy spread was included as a parameter of study. Data was recorded and canopy increment proved to be non-significant as affected by various rootstocks. However, maximum increment in canopy was observed in Citrumello 4475 (1.60 m^3) followed by Volkamariana rootstocks (0.43 m^3) while a minimum canopy spread was observed in Mithi (0.01 m^3).

Plant height is another important vegetative characteristic of citrus tree. Rough lemon gained a height of (0.53 m) and proved to be superior closely followed by Volkamariana (0.38 m) and Citrumello 4475 (0.31 m), while the minimum increment in plant height was attained by Brazilian sour orange (0.11 m). Volkamariana proved as a very suitable rootstock as it had incorporated vigour to the Kinnow scion.

The results for total number of fruits per plant (yield) indicated a significant difference among rootstock treatments. It was found that Brazilian sour orange had maximum number of fruits (1050.25) closely followed by Volkamer lemon (920.50) and Rough lemon (723.50). Citranges {Troyer (411.00), Yuma (230.50) and Carrizo (155.50)} revealed poor results and Carrizo Citrange (155.50) proved to be the poorest of all. Volkamariana gave bigger sized marketable fruits as compared to Brazilian sour orange; which although produced more fruits but their size was small so Volkamer lemon proved again as a potential candidate to replace Rough lemon as far as yield component is concerned.

Physiochemicl analysis of fruits: Juice percentage in the citrus fruit is considered to be very important. The ultimate demand of customer is higher juice percentage in the fruit. Results regarding the juice percentage revealed a significant difference among different rootstocks. Volkamariana was found to be superior and produced maximum juice percentage (50.84), which was statistically at par with Rough lemon (49.92%) and Mithi (49.12%) followed by Carrizo Citrange (47.33%), Brazilian sour orange (46.73%) and Yuma Citrange (46.51%). Minimum juice %age was recorded in the fruits harvested from the trees grafted on Citrumello 1452 (39.31%). Juice recovery is a qualitative parameter and Volkamer lemon proved itself as a meritorious rootstock.

Data pertaining to TSS revealed significant differences among rootstocks. Maximum total soluble solids were recorded in Mithi (13.57), which was statistically similar to all other rootstocks except Yuma Citrange (11.44), which produced the minimum total soluble solids. Other rootstocks viz., Brazilian Sour orange (13.33), Citrumello 4475 (13.40), Troyer citrange (13.24), Citrumello 1452 (12.48), Carrizo citrange (12.44), Volkamariana (12.19) and Rough lemon (11.84) were statistically at par with respect to total soluble solids (Table 2).

Fig. 1. Rough lemon-even Bud union configuration with Kinnow scion

Fig. 2. Overgrowth of Troyer citrange rootstock on Kinnow scion

Fig. 3. Overgrowth of Kinnow scion on Brazilian sour orange rootstock

Fig. 4. Vigorous Volkamer lemon tree

The data pertaining to acidity showed a significant effect of treatments on acidity (Table 2). Citrumello 4475 had the maximum acidity (1.13%), which was statistically at par with the Citrumello 1452 (1.02%), Yuma Citrange (1.09%), Carrizo Citrange (1.02%), Troyer Citrange (1.02%) and Brazilian sour orange (1.14%). Minimum acidity (0.88%) was recorded in fruits of Rough lemon. The chemical analysis was carried out during January at the peak fruit maturity of Kinnow mandarin during the consecutive years.

Table 2. Effect of Rootstocks on Chemical Properties of Kinnow mandarin.

Rootstocks	Juice percentage	Total Soluble Solids (TSS)	Acidity % age	Vitamin-C	TSS/Acid ratio
Citrumello 4475	44.38c	13.4a	1.13a	29.94c	11.85 bc
Citrumello 1452	39.31c	12.48a	1.02a	32.98ab	12.23 b
Volkamariana	50.84a	12.19ab	0.94ab	33.43a	12.96 b
Yuma Citrange	46.51b	11.44b	1.09a	33.9a	10.49 c
Rough lemon	49.92a	11.84b	0.88b	33.9a	13.45 a
Mithi	49.12a	13.57a	0.96ab	33.45a	14.13 a
Troyer Citrange	43.69b	13.24a	1.02a	31.55	12.98 b
Carrizo Citrange	47.33b	12.44a	1.02a	33.74a	12.19 b
Brazilian sour orange	46.73b	13.33a	1.14a	31.77b	11.69 bc

Citrus is believed to be the efficient source of Vit. C, which is a powerful antioxidant. Statistically significant differences were observed among the rootstocks for vitamin C contents. The data revealed that maximum vitamin C (33.90 mg) was recorded for trees grafted on Rough lemon and Yuma Citrange followed by Carrizo Citrange (33.74 mg), Mithi (33.45 mg), Volkamariana (33.43 mg) and Citrumello 1452 (32.98 mg). Minimum vitamin-C was recorded for trees on Citrumello 4475 (29.94 mg).

Mean values of the TSS / acid ratio showed a maximum ratio in the Mithi rootstock (14.13) which is statistically significant and close to the Rough lemon rootstock (13.45) while different to all other rootstocks. Minimum value of TSS / acid ratio was found (10.49) in Yuma citrange, which is at par with the Brazilian sour orange (11.69) and Citrumello 4475 rootstock (11.85).

Discussion

Rootstocks and scion girth equilibrium is very important for the compatibility of rootstocks with the scion. Sometimes rootstock shows incompatibility with scion. In the present study rootstock cause unbalancing in physiological functioning, plant vigor, productivity as well as fruit quality. Stock and scion stem girth was significantly affected by the various rootstocks under study. Although it has been demonstrated by earlier work that rootstock has a profound impact on the vegetative behaviour of the scion depending upon the compatibility; even then variation in the impact of rootstock on scion is beyond the compatibility and it is also influenced by the environmental stresses; weaker rootstocks become more weaker as in this case citrange rootstocks incorporated very little vigour to the Kinnow scion and produced less yield with poor quality of fruits. Vigours rootstocks like Rough lemon and Volkamer lemon performed equally well along with Brazilian sour orange. Maximum rootstock girth was observed in Rough Lemon (2.0 cm) followed by Volkamer lemon (1.25). This vigorous increment of the girth shows the compatibility of Rough lemon and Volkamer lemon with Kinnow scion. This trend showed that these rootstocks are physiologically compatible and actively growing under the alkaline soil conditions as already reported by the Castle *et al.,* (1988) who described that Volkamer lemon is resistant to *Phytophthora* and alkaline soil conditions.

The vegetative performance of Volkamer lemon was comparatively better in terms of plant spread and plant height (Fig .4). So it could be inferred that Volkamer lemon is a promising rootstock for Kinnow mandarin under the dry climate of the Punjab province. Environmental influences on the performance of rootstocks has been described by Moeen (2000) and Noda *et al*., (2001), but the variability is mainly due to weathering agents and intercultural practices on the plants. The climate of the Punjab province is very harsh during summer season and vigorous rootstock is required to sustain the spring flushes. So according to these studies Volkamer lemon proved quite satisfactory and could be used as a substitute rootstock for existing Rough lemon as rootstock in Citriculture industry of Pakistan.

Plant canopy development pattern is very much in line with the increment in stem girth and plant height of various rootstocks under study. Kinnow Mandarin has a natural tendency of compact canopy and this character is more or less maintained on all types of rootstocks in the study. Volkamariana proved to be consistent in the increment of canopy spread as against all other rootstocks whereby their response was quite inconsistent during the course of studies. Our results are in agreement with those of Kumar *et al*., (1994) who reported that under arid environmental conditions, vigorous rootstocks are required to give a boost to citrus plants.

Fruit yield is of prime concern to orchardists. They grow the plants for better yield and good quality fruit production. Although the Brazilian sour orange produced much higher number of fruits with well blended quality traits, the smaller sized fruits were not of marketable grade. Volkamer lemon produced good quality marketable sized moderate number of fruits and proved itself as a reliable rootstock for Kinnow mandarin. Our results were closely related to those of Georgiou (2000) who also observed maximum yield from the trees on Brazilian sour orange (BSO) and Volkamariana rootstock.

Volkamariana proved better as far qualitative characteristics are concerned. Maximum juice percentage (50.84) was observed in the fruits on Volkamer lemon while the Rough lemon contained 49.92% juice and the other rootstocks proved inferior for this parameter of study. Granulation/riciness was also observed in the juice vesicles of fruits harvested from Rough lemon and all the three citrange rootstock, whereas no granulation / riciness was observed in the fruits harvested from Volkamer lemon stock. It could be the reason of more juice recovery in fruits on Volkamariana rootstock. Volkamariana proved better in terms of qualitative characteristics. Recovery of high juice contents in Volkamariana again showed that it could be used as a substitute rootstock.

Kinnow is considered to be full of vitamin-C and other elements like Mg, Fe and Ca. Total soluble solids (TSS), acidity and ascorbic acid have their importance in standardizing the citrus fruit quality parameters. The excellent performance of Bazillion sour orange is due to inherent characteristics of sour orange. Across the world various strains of sour orange are extensively used because of qualitative traits, although its cultivation is banned in various countries due to its susceptibility to citrus tristeza virus (CTV). Even then it could be inferred from the results that Volkamariana rubs its shoulder with Bazillion sour orange for this trait and is equally good for its commercial cultivation.

According to the results, there was a negligible impact of rootstock on acidity percentage; but still it is valid information to make a baseline for the selection of perspective rootstock. Although acidity is graft transmissible factor and affected by rootstocks as determined by Castle *et al.* (1988), it is highly regulated by environmental conditions. Homogeneous mildly cool environment during fruit ripening could be attributed to negligible influence of rootstocks for this parameter of study.

According to the results presented here the impact of Vit. C assimilation is graft transmissible and thus the rootstocks like citrange and Brazilian sour orange have moderate amount of Vit. C as against Rough lemon, Volkamer lemon and Mithi (Table 2). Our observations regarding TSS, acidity and Vitamin-C were in consonance with the findings of Jianguo *et al*., (2001) and Wutscher & Hill (1995) that rootstocks affect TSS, acidity and Vitamin-C significantly.

Total soluble solids / acid ratio is affected by the various rootstocks. As shown in the results, maximum TSS / acid ratio was recorded in Mithi and minimum ratio was observed in Yuma citrange (Table 2). As TSS / acid ratio is a flavoring factor, so these results depicted that with increase in the ratio there was a decrease in the acidity so with low TSS / acid ratio, quality of fruit is poor and taste of fruit becomes watery and insipid. Again the ratio is used to determine the fruit maturity standards, so where the ratio is high, fruit will mature earlier. Zekri (2000) reported that higher the Brix: acid ratio the earlier is the fruit maturity.

The results showed that although Rough lemon has meritorious characteristics for its commercial cultivation, the susceptibility of Rough lemon to even weaker strains of *Phytophthora* is a demerit and a cause of low productivity, shortened age of plant, early tree decline and poor quality of fruits. The situation of *Phytophthora* attack aggravated even more on Rough lemon under high alkaline soil conditions with less availability of

irrigational water. In contrast, Volkamer lemon was comparatively resistant to *Phytophthora* (Castle *et al*., 1988) and as a vigorous rootstock suitable to our agro-climatic conditions. Further trials are underway in this regard to certify the performance of various rootstocks and particularly the perspective rootstock Volkamer lemon, Brazilian sour orange and Citrumello 4475 for the widening of choice of rootstock uses in Citriculture industry of Pakistan.

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