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EFFECT OF DIFFERENT ROOTSTOCKS ON PLANT NUTRIENT STATUS AND YIELD IN KINNOW MANDARIN (*CITRUS RETICULATA* BLANCO)

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Abstract

Nutritional status and yield of Kinnow mandarin grafted on nine different exotic and local rootstocks was studied. Leaf nutrient status of Nitrogen (N), Phosphorous (P) and Potassium (K) availability in leaves differed significantly among the trees on various rootstocks. Maximum N (2.60 and 2.67%) was recorded on Rough lemon and minimum (2.20 and 2.21%) on Troyer citrange during 2005 and 2006 respectively. P (0.16%) was maximum on Rough lemon while minimum (0.09%) was recorded in Carrizo citrange. As regard K, it ranged from 1.15 to 1.65% on Volkamariana and Carrizo citrange rootstock, respectively. The highest number of fruits per tree were recorded on Brazillian Sour orange (1037.16 fruits) and lowest (184.49 fruits) on Carrizo citrange rootstock. While on weight basis maximum yield (139.52 kg) was recorded in Volkamariana and minimum (27.83 Kg) was in Carrizo citange. For most of the parameters Volakamariana was found to be promising followed by Rough lemon and Mithi whereas all citrange (Carrizo, Yuma and Troyer citarange) rootstocks performed poorly in relation to nutrient uptake and yield.

Introduction

Citrus fruits in all the shapes, sizes and colors are the most attractive, fragrant and appetizing with high nutritional values. It is one of the richest sources of vitamin C and contain 3-4% sugar and minerals such as calcium and magnesium in appreciable amounts, essential for proper health and vigor. These fruits are known to be the natives of Southeast Asia (Indonesia and China) but they are now extensively grown almost throughout the world under tropical and sub-tropical conditions where the soil and climatic regimes are quite favorable for its growth and yield (Shah, 2004). Citrus fruits comprise about 40% of the total fruits produced in Pakistan and it is cultivated over an area of 185,400 hectares with an annual production of about 1.67 milliom ton (Anon., 2005). More than 95% of citrus is being produced in the Punjab province and 70% of citrus grown in Punjab is Kinnow (Niaz *et al.*, 2004). In fact Kinnow has monopolized the citrus industry of Pakistan. The average yield of citrus in Pakistan is 9-10 tons/ha while in other citrus growing countries it goes up to 26 tons/ha. (Anon., 2005). Among the reasons of low yield the optimum concentration of the nutrients in plant body is much more important for proper growth and development of plants. Among the various nutrients nitrogen is of prime importance as it affects the photosynthetic rate, production of carbohydrates and proteins; which in turn control plant growth and development. Phosphorous has a key role as it affects fruit quality and the right balance of nitrogen to phosphorous is important for fruit setting and good quality of fruit. Potassium is the main element in fruit and it has profound effect on fruit quality than any other element. Potassium regulates the opening and closing of stomata and directly related to water use efficacy in plants (Taiz & Zeiger, 2002).

Commercial citrus varities are propagated asexually by budding/grafting on compatible rootstocks. There is no controversy over the importance of citrus rootstock for better citrus production. Rootstocks provide growers with useful tool to manipulate the vigor and performance of orchard trees. Effects on tree size, precocity, fruit production and maturity are achieved through complex interrelationship between the roots and canopy of the plant. Rootstocks directly affect the ability of plants to up take the water and nutrients from the soil. They are also able to significantly alter the pattern of canopy development and functions such as photosynthesis (Richardson *et al.,* 2003).

Besides giving anchorage to the tree, rootstock is also responsible for the absorption of water and nutrients, storage of photosynthates and synthesis of hormones making the scion part more tolerable. More than twenty horticultural characteristics are affected by the rootstock including leaf nutrient status, vigour and size, depth of rooting, low temperature tolerance, adoption to adverse soil conditions, disease resistance and fruit quality (Castle, 1987).

Mineral nutrients are greatly influenced by rootstocks. Different scions exhibit variable quantities of nutrients from different rootstocks. Scion bark of Kinnow contained less nitrogen when compared to rootstock bark where as Potassium was higher in scion and lower in rootstocks bark (Huchche, 1999). Similarly Highest values of nitrogen were associated with the Satsuma on Carrizo citrange and lowest on sour orange (Creste, 1995); Fallah and Rodney (1992) found the lowest value of nitrogen in Red blush grapefruit on *C. macrophylla*. However Araujo *et al.,* (1998) observed no effect of rootstocks on nitrogen and phosphorus contents in the Ponkan mandarin grafted on different rootstocks. Phosphorus contents were high on Sweet orange and Trifoliate orange stocks and lowest on sour orange. Similarly Smith (1975) determined that rootstocks greatly affect the vigour, productivity of plants and quality of the fruit by the differential ratio of absorption and translocation of mineral elements from soil which ultimately affect the overall performance of the plants. As rootstocks profoundly affect nutrients uptake from soil; so this study was initiated to find out the best suited rootstock for Kinnow mandarin under the agro ecological conditions of Punjab-Pakistan.

Materials and Methods

The research trial was conducted at Experimental Fruit Orchard Sq.No.9, University of Agriculture, Faisalabad-Pakistan while laboratory work was carried out in Postgraduate Pomology Lab, Institute of Horticultural Sciences. For this experiment 17 years old, 27 plants of Kinnow mandarin (*Citrus reticulata* Blanco) were selected. These were grafted on the following nine rootstocks viz-a-viz. Citrumello 4475 (*Poncirus trifoliata* (L) Raf × *Citrus paradisi* Macf.), Citrumello 1452 (*Poncirus trifoliata* (L) Raf × *Citrus paradisi* Macf.), Volkamariana (*Citrus jambhiri* Lush. × *Citrus volkamarina*), Yuma citrange (*Poncirus trifoliata* (L) Raf × *Citrus sinensis* (L) Osbeck), Rough lemon (*Citrus jambhiri* Lush.), Mithi (*Citrus jambhiri* Lush.), Troyer citrange (*Poncirus trifoliata* (L) Raf × *Citrus sinensis* (L) Osbeck), Carrizo citrange (*Poncirus trifoliata* (L) Raf × *Citrus sinensis* (L) Osbeck) and Brazillian sour orange (*Citrus aurantium* L.). The experimental plants were planted in the field according to Randomized Complete Block Design (RCBD).

To determine the status of N, P and K in the leaves of each experimental tree, leaf sampling was done by selecting leaves at random from all sides of each tree; 100 mature leaves from branches at shoulder height were collected of 4-6 months old, free from disease and insect pest attack. Leaf samples were washed with detergent and rinsed with distilled water for 2-3 times. The sampled leaves were dried in shade and then oven dried in perforated paper bags at 65°C for 48 hrs. Completely dried leaves were meshed to fine powder and stored in airtight plastic bottles for analysis. Total nitrogen was determined according to the procedure defined by Chapman & Parker (1961); whereas Phosphorous and Potassium analysis were carried out according to the method described by Yoshida *et al.*, (1976).

Yield per tree was recorded by weighing and counting the total number of fruits per tree at the time of harvesting. The trees were applied with the recommended doses of fertilizer of NPK (1000, 500, 500 g) per annum to maintain the plant vigour and growth. Nitrogen was applied in two split doses, spring application during April in combination with Phosphorous and Potassium (500:500:500 g) and again in autumn second dose of Nitrogen was applied in September (500 g). Forty kg of well rotten farm yard manure (FYM) was also applied during December per annum to maintain the organic matter in rhizosphere (Malik., 1994) . All the selected trees were maintained under same set of agro-climatic conditions. Data were collected and analyzed through analysis of variance techniques (Steel *et al.*, 1996).

Results and Discussion

Leaf analysis: The primary purpose of this parameter of study was to evaluate the efficacy of rootstock for nutrient absorption and translocation to Kinnow scion. Leaf analysis was conducted for major elements, N, P and K during October i.e. after the onset of autumn season and again in February i.e. just prior to spring season, during both the years to observe the effect of different rootstocks for nutrient profile of Kinnow scion.

Leaf Nitrogen status: Nitrogen is one of the most important mineral elements required for plant growth and development. The results revealed significant differences amongst rootstocks while non-significant difference was observed between autumn and spring season flushes (Table 1). The percentage of nitrogen in the spring season leaves was generally higher than autumn season in each case, consequently mean values of spring season was significantly higher over the autumn mean values.

The results showed that maximum nitrogen percentage (2.60 and 2.67%) was found in Rough lemon closely followed by Volkamariana (2.59, 2.60%) and Mithi (2.58, 2.57%). Whereas, the lowest nitrogen percentage (2.20, 2.21; 2.20, 2.25) were found in Troyer citrange and Yuma citrange respectively for 2005 & 2006. It could be visualized from the data that highest nitrogen contents were found in the Rough lemon (2.67) and lowest was recorded in Troyer citrange (2.20). The nitrogen contents thrived in low category for citrus as per standards described by Reuther & Smith (1954). It showed that lemon stocks are well adapted to soil conditions with efficient root system. Citranges are poor performer hence low nitrogen was recorded in all the citrange rootstocks in comparison to the other rootstocks. Low nitrogen contents drastically affected the plant canopy and yield. The same has been reported in other study that Citranges produced lowest yield with lowest canopy volume, more leaf drop and short statured week plants (Ahmed *et al.*, 2006). So they absorb and translocated more of nitrogen to the scion for growth and development. Our results are in consistence with Path *et al.*, (1989). Who reported that rootstocks significantly affect the leaf nitrogen contents.

Table 1. Effect of rootstock on Nitrogen contents (%).

Rootstocks	Nitrogen content (%) 2005			Nitrogen content (%) 2006		
	Spring	Autumn	Mean	Spring	Autumn	Mean
Citrumello 4475	2.52	2.37	2.44 b	2.53	2.38	2.45 bc
Citrumello 1452	2.54	2.39	2.47 b	2.55	2.39	2.47 bc
Volkamariana	2.67	2.52	2.59 a	2.66	2.55	2.60 a
Yuma Citrange	2.40	2.00	2.20 c	2.43	2.07	2.25 b
Rough lemon	2.84	2.51	2.60 a	2.82	2.53	2.67 a
Mithi	2.70	2.47	2.58 a	2.70	2.45	2.57ab
Troyer Citrange	2.36	2.04	2.20 c	2.38	2.05	2.21 d
Carrizo Citrange	2.38	2.20	2.29 c	2.41	2.21	2.31 d
Brazilian Sour Orange	2.59	2.28	2.43 b	2.56	2.30	2.43 c

Means in the column followed by like letters are non-significant; means not followed by like letters differ statistically at 5 percent level of significance.

Table 2. Effect of rootstock on Phosphorous contents (%).

Rootstocks	Phosphorous content (%) 2005			Phosphorous content (%) 2006		
	Spring	Autumn	Mean	Spring	Autumn	Mean
Citrumello 4475	0.12	0.12	0.12 c	0.12	0.11	0.11 cd
Citrumello 1452	0.121667	0.119667	0.12 c	0.12	0.12	0.12 c
Volkamariana	0.145	0.160333	0.15 ab	0.15	0.15	0.15 b
Yuma Citrange	0.106667	0.111667	0.10 cd	0.12	0.11	0.11 cd
Rough lemon	0.166667	0.16	0.16 a	0.16	0.16	0.16 a
Mithi	0.131667	0.151	0.14 b	0.14	0.14	0.14 b
Troyer Citrange	0.103333	0.101	0.10 de	0.11	0.10	0.10 de
Carrizo Citrange	0.103333	0.09	0.09 e	0.10	0.09	0.09 e
Brazilian Sour Orange	0.151667	0.150333	0.15 b	0.15	0.14	0.14 b

Means in the column followed by like letters are non-significant; means not followed by like letters differ statistically at 5 percent level of significance.

Leaf Phosphorous status: Phosphorus has a marked influence on fruit quality although it has little effect on yield. The treatments showed significant difference for phosphorous contents (Table 2). Highest P contents were found in Rough lemon (0.16) followed by Volkamariana (0.15) for both the years whereas, lowest phosphorus was recorded in Carrizo citrange (0.09) for both the years. Phosphorus contents were in low to deficient range for the Citranges viz-a-viz Yuma citrange, Troyer citrange and Carrizo citrange in a descending order. While in all other rootstocks the phosphors contents were in optimum range. Moreover, no significant difference for phosphorus was observed during spring and autumn season. The non-significant difference between the seasons could be attributed to its slow release and translocation within the plant body. Optimum level of phosphorus is at least required in plant as the quality of fruit is affected by the phosphorus contents; low quality and low cumulative harvest from citrange stocks is confirmed in this study under various parameters. The observations are in accordance with the findings of Wustcher & Shull (1975, 1976).

Table 3. Effect of rootstock on Potassium contents (%).

Rootstocks	Potassium content (%)-2005			Potassium content (%)-2006		
	Spring	Autumn	Mean	Spring	Autumn	Mean
Citrumello 4475	1.29	1.37	1.33 c	1.29	1.37	1.33 c
Citrumello 1452	1.31	1.38	1.34 c	1.31	1.38	1.34 c
Volkamariana	1.01	1.30	1.15 d	1.01	1.32	1.16 d
Yuma Citrange	1.67	1.46	1.56 ab	1.68	1.44	1.56 ab
Rough lemon	1.20	1.22	1.21 d	1.22	1.24	1.23 d
Mithi	1.13	1.27	1.2 d	1.16	1.27	1.21 d
Troyer Citrange	1.53	1.52	1.52 b	1.53	1.51	1.52 b
Carrizo Citrange	1.74	1.57	1.65 a	1.70	1.57	1.63 a
Brazilian Sour Orange	1.09	1.27	1.18 d	1.12	1.27	1.19 d

Means in the column followed by like letters are non-significant; means not followed by like letters differ statistically at 5 percent level of significance.

Table 4. Effect of rootstock on yield.

Rootstocks	Fruits/plant 2005	Fruits/plant 2006	Average fruit/plant 2005-2006	Fruit Wt. / plant 2005	Fruit Wt. / plant 2006	Average fruits Wt. /plant 2005-2006
Citrumello 4475	479.7 d	548.3 d	513.99	72.10 c	82.98 c	77.12
Citrumello 1452	241.3 f	245.3 f	243.33	36.27 e	42.15 e	39.21
Volkamariana	899.0 b	906.0 b	902.50	138.0 a	138.5 a	139.52
Yuma Citrange	192.7 fg	221.7 f	207.15	28.95 ef	33.52 f	31.23
Rough lemon	664.0 c	725.3 c	694.66	99.80 b	109.7 b	104.75
Mithi	400.7 e	422.3 e	411.49	60.24 d	63.87 d	62.05
Troyer Citrange	359.3 e	361.0 e	360.16	54.00 d	59.64 d	56.82
Carrizo Citrange	153.7 b	215.3 f	184.49	23.10 f	32.57 f	27.83
Brazilian sour orange	1016.0 a	1059.0 a	1037.16	129.0 a	131.5 a	130.24

Means in the same column followed by like letters are non-significant; means not followed by like letters differ statistically on the 5 percent level of significance.

Leaf Potassium status: The rootstocks exhibited significant differences for potassium percentage in Kinnow scion while non significant differences for spring and autumn seasons. Potassium contents of the trees grown on Carrizo citrange (1.65, 1.63) were significantly higher than all other rootstocks. Yuma citrange and Troyer citrange followed in their ranking to Carrizo citrange. Citrumello 1452 & Citrumello 4475 come next to citranges with their values 1.34% and 1.33% respectively for both years. Whereas, minimum K contents were recorded in Volkamer lemon (1.15, 1.16) alongwith Brazillian sour orange and Mithi. Rough lemon also annexed in this category according to their level of significance for both years (Table 3). It was also observed that during 2006 overall K contents were improved in all the rootstocks. These studies otherwise revealed that potassium was available in adequate amount in all trees on various rootstocks. It could be postulated that all the rootstocks had a potential to absorb the potassium in adequate quantity, in relation to the plant requirements.

It is difficult to make overall generalization for the various rootstocks and elements, because in some instance a particular rootstock induced high level of one element and low level of other. However, it appears that rootstocks inducing vigorous growth in the scion such as Rough lemon or ‘Palestine’ sweet lime (Castle & Krezdorn, 1973) generally have higher leaf N and K contents than those less vigour inducing rootstocks like Trifoliate orange. Graham & Syvertsen (1985) also observed that leaf N and P contents were positively correlated with root hydraulic conductivity of rootstocks.

Our result are in consonance with the results of Sharples & Hilgeman (1972) and Path *et al.,* (1989) that rootstock affect the potassium percentage of scion leaves. So it could be concluded on the basis of studies that hydraulic conductance of rootstock- scion and environmental conditions along with soil reaction in the rhizosphere drastically affect the absorption and translocation of nutrients in the plant body.

Yield (Fruits tree^{-1}): The results indicated highly significant differences amongst rootstocks; the Brazillian sour orange exceeded all other rootstock during both the years by having 1037.16 fruits/tree followed Volkamer lemon and Rough lemon with average number of fruits 902.50 and 694.66 respectively while, Carrizo citrange bear the least fruits/plant (184.49) as shown in Table 4. The study revealed that citrange rootstocks could not produce satisfactory fruit and they are poor performer in this respect. While Brazillian sour orange produced highest number of fruits but the weight is comparatively less and size was too small so the most of fruits were not of commercial grade. Citrumello 4475 also performed quite well for the production of total number of fruits per tree. The observations are in accordance with the findings of Path *et al*., (1989), and Wustcher and Shull (1976) who reported that rootstocks widely affect the yield. Whereas, Volkamer lemon and Rough lemon produced moderate to good number of fruits with marketable size. So it could be easily inferred that Volkamer lemon could be a suitable rootstocks for Kinnow mandarin as an alternative to Rough lemon.

Fruit weight Kg (Yield tree^{-1}): The results indicated that maximum fruit wight/tree was observed in Volkamer lemon (139.52 kg) followed by Brazillian sour orange with a total weight of 130.24 kg, both these rootstocks were statistically at par whereas, Rough lemon ranked at 3rd position having a total weight of 104.75kg. Carrizo citrange showed least average fruit weight of 27.83 kg; similarly Yuma citrange and Troyer citrange have low fruit weight of 31.23kg and 56.82 kg respectively (Table 4). The data profile indicated that Citranges performed poorly for total fruit weight and lemon rootstocks produced excellent results. It could be visualized and compared from the Table 4 of fruit yield that plants on some rootstocks had more number of fruits than others but has less yield on weight basis as the plants on Brazillian sour orange showed maximum number of fruit i.e.; 1037.16 than Volkamer lemon (902.50) but had less yield in weight (130.24 kg) as compared to Volkamarina (139.52 kg). It is also confirmed by the information procured that yield in Volkamer lemon was least affected by the seasonal variation for the period of study so this parameter suggests that Volkamer lemon is suitable rootstocks for prolific bearing Kinnow mandarin. Regarding this parameter of study our results are closely related to Georgiou (2000) and Jaskani, *et al.,* (2006) who observed that rootstocks widely affect the fruit size in citrus.

Conclusion

Our studies revealed that Volkamer lemon and Brazillian sour orange are reliable rootstocks for citriculture industry of Pakistan as they performed better than other rootstocks for nutritional and yield parameters as in another study these rootstocks have been already tested for the horticultural traits (fruit size, total soluble solids, sugars, number of seeds per fruit, acidity, vitamin-C etc.) and showed excellent results (Ahmed *et al*., 2006). So these could be used against the standard Rough lemon stock which is exclusively used in Pakistan. It is of particular interest that Volakmer lemon was found to be more vigorous and it showed meritorious properties; it can be used as a substitute of Rough lemon. Selection of rootstocks in response to nutrient use efficiency there is a need to exploit the existing genetic diversity among citrus species. In addition to this genetic engineering may have a role in creating novel genetic variation that can be used in breeding programs using marker assisted selection (MAS) to improve the nutrient uptake and utilization in the citrus species.

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