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Tree Vigor, Nutrients Uptake Efficiency and Yield of 'Flordaking' Peach Cultivar as Affected by Different Rootstocks

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Abstract

Peach is the second most important stone fruit crop in Pakistan. Rootstock is of prime importance for yield and quality parameters in peach fruit industry. Current study was conducted to evaluate the effect of three different rootstocks, GF-677, Peshawar Local (PL) and Swat Local (SL), on peach fruit cv. 'Flordaking'. These rootstocks were evaluated regarding trunk cross sectional area (TCSA), date of flowering, fruit growth curve, number of fruit per tree, yield, yield efficiency and fruit size. Soil nutrient status, and the nutrients uptake efficiency of rootstocks for N, P, K, Fe, Zn, Mn and Cu was assessed by tissue analysis. GF-677 rootstock induced largest TCSA, higher number of fruit per tree whereas, GF-677 and PL rootstocks remained at par in yield per tree but higher than that of SL rootstock. However, fruit size was achieved significantly higher by SL rootstock. Regarding nutrients uptake efficiency, GF-677 rootstock showed significantly higher leaf content of N, P, Zn and Mn than PL and SL rootstocks. PL rootstock translocated or captured significantly higher content of K and Cu than rest of the rootstocks. Nevertheless, no significant differences were found for yield efficiency and Fe uptake efficiency by different rootstocks.

INTRODUCTION

As population increases, area under production is also increasing and old cultivars are being replaced by promising and high yielding early varieties in areas according to their suitability. Successful plantation of an orchard demands selection of suitable rootstock and scion cultivar. The root system of fruit plants is as lively as the leaves and have a vital role in plant growth, development and fruiting (Kolesnikov, 1971). The peach seedlings are still main rootstock source for peach throughout the world (Rom, 1983). The combination of a rootstock and scion results in synergetic expression of different genes controlled by both rootstock and scion. Rootstock as mainstay for cultivar tree is not only responsible for scion vigor but increases nutrient uptake and yield efficiency. Therefore, proper rootstock selection along with other pre-harvest measures can help to obtain premium quality fruit as rootstock and scion interaction manipulates water relations, gaseous exchange, minerals uptake, plant size, blossoming, fruit set time, fruit quality and yield efficiency (Schmitt *et al.*, 1989; Nielsen and Kappel, 1996; Goncalves *et al.*, 2003).

The possible factors in achieving desired production and quality fruits, it is imperative to minimize differences in rootstocks and congenial environmental conditions for peaches production. Rootstock incompatibility with scion affects plant capability of nutrient uptake (Lopez-Bucio *et al.*, 2003) which results in mal formed fruits. In Pakistan, PL and SL are widely used rootstocks for peach cultivars. PL is the wild variety of peach which naturally grows in the forests around Peshawar district and similarly SL are grown from the seeds of wild peach plants found naturally in the Swat area of Pakistan. Peshawar Local is an important rootstock for relatively warmer areas and induces vigorous scion-tree with heavy bearing. It has good anchorage and well adapted to the soil and environmental conditions of Pakistan (Ullah *et al.*, 2000). Swat Local rootstock have been evaluated for vigor, yield and compatibility to different scions and found with better results (Ahad *et al.*, 1987) and it has been evolved for relatively colder areas but it is used in warmer areas as well. GF-677 rootstock (a peach-almond hybrid) is also in use but not on large scale. It has been newly introduced in Pakistan and is expected to widen the adaptability of peach cultivars to different areas. It has the ability to withstand iron chlorosis, thrives well in fertility wise poor soils and $CaCO_3$ content of soils (Monticelli *et al.*, 2000; Socias *et al.*, 1995). GF-677 was found best among all peach rootstocks tested (Tsipouridis and Thomidis, 2005) and its importance has been well documented on the basis of its performance in Mediterranean basin (Stylianids *et al.*, 1988). As peaches production wise rank second among stone fruit crops in Pakistan (Tareen *et al.*, 2012) and its area and production is increasing. Therefore, it is necessary to identify suitable rootstocks for better fruit quality and return to the producers. Hence, this study was designed to assess the suitability of three different rootstocks (GF-677, PL and SL) widely available in Pakistan, in terms of compatibility, quality and production of early ripening peach fruit cv. 'Flordaking'. This mainly grown stone crop in the Potohar area ripens in the third week of May.

MATERIALS AND METHODS

Three rootstocks out of which two indigenous (PL and SL) and a peach-almond hybrid GF-677, were evaluated in present study at Fruit Program of Horticulture Research Institute, National Agricultural Research Center (NARC), Islamabad (lat.33° 37'S; long.73° 06'E). Total 27 peach (*Prunus persica* L. Batsch cv. 'Flordaking') trees five years of age were selected for the study. These trees were grafted on different rootstocks (GF 677, PL and SL), planted in East West direction in square layout system having plant to plant (6 m x 6 m) and row to row (6 m x 6 m) distance. All the selected trees were of uniform size, pests and diseases free and received similar cultural practices. Observations on following parameters were recorded:

Date of Flowering, Fruit Growth

Flowering date was recorded by frequent visits of peach orchard during expected days of flower bud burst. Pink balloon stage of flower buds (PBSFB) and three different stages of flower opening in peach cv. 'Folrdaking' budded on three different rootstocks were recorded. First flower bud burst was visually noted then date for 50% and 80% flower open were recorded. Peach fruit growth data was recorded with some modifications following the method of Bregoli *et. al*. (2002). Fifty fruits from each rootstock were selected and tagged on the tree. Then the diameter of fruit was recorded at weekly intervals. Fruit growth data recording was started after 24 days of full bloom (DAFB) for drawing growth curve till harvest.

Trunk Cross Sectional Area, Yield, Yield Efficiency, Number of Fruits/Tree, Fruit Size

The trunk girths of all three rootstocks were measured at 25 cm above the union of graft and TCSA (trunk cross sectional area) was computed in cm^2. The data was recorded in the dormant season. Cumulative yield of each scion-stock combination was computed for yield data. The yield efficiency of plants was computed as the ratio of yield and cross sectional area of trunk of corresponding year. Number of fruits/tree was recorded by counting the harvested fruits of each replicated tree of each treatment. Individual peach fruit size (maximum and minimum length, diameter and width in mm) was measured using an instrument especially made for fruit size measurement (vernier caliper type, Italy).

Soil Analysis

Soil sampling was carried out from five points in the field in W shape.

Mineral nitrogen, P, K, Fe, Cu, Mn and Zn,

Mineral nitrogen was determined in the soil of peach orchard field by using Keeney and Nelson (1982) method. The same was determined in soil by extraction with 2 M KCL and steam distillation in the presence of MgO and finely ground Devard's alloy. Soil analysis for P (phosphorus), K (potassium), Fe (iron), Cu (copper), Mn (manganese), and Zn (zinc) in peach orchard field were conducted as described by Soltanpour and Workman (1979). Soil was extracted with AB-DTPA solution (pH 7.6). The same extracted solution was used for the analysis of exchangeable K with flamephotometry while available P was determined using spectrophotometry. Fe, Cu, Mn and Zn were analysed with the help of atomic absorption spectrophotometry. Soil sampling was done for two consecutive years (2008 and 2009) of experiments.

Leaf or Tissue Analysis

Total nitrogen, P, K, Fe, Cu, Mn and Zn

Total nitrogen in peach tree leaf or tissue was analysed according to the method of Buresh *et al.* (1982). Total nitrogen was determined by digestion of leaf material in sulfuric acid mixture. Peach tree leaf or tissue analysis for P, K, Fe, Cu, Mn and Zn were done according to the method described by Rashid (1986). Fifty leaves in mid July were randomly selected from each replicated tree of each rootstock at an elevation (height) of about 1.5 meter around the tree canopy. In this regard only mature healthy leaves fully expanded and without any cut were plucked from center to top of the shoots in early hours of the day. Then leaves were placed in treatment wise marked plastic bags and immediately shifted to the laboratory. Analysis of minerals in leaf tissue was recorded using atomic absorption spectrophotometry for iron, copper, manganese and zinc.

Statistical Analysis

Randomized complete block design (RCBD) was used as statistical design having three replicates. Data were statistically analyzed by using analysis of variances (ANOVA) techniques for the validity of analysis and the means were separated using LSD. Statistical analysis was done with the help of MSTAT-C software (Michigan State

University, 1991). For least significant difference, a probability (*p*) of less than 0.05 levels were considered. The experiment was repeated the following year.

RESULTS

Dates of Flower Opening and Fruit Growth

No differences were recorded for pink balloon stage of flower bud (PBSFB) appearing dates among the treatments during the year I (Table 1). For the year II, PBSFB appeared in trees on SL rootstock one day earlier than GF-677 and PL rootstocks (Table 1). First flower bud burst happened on same day in all treatments during both years of experiment. Rootstocks showed no differences among them for 50% flower open during year I, while a day later 50% flower open was observed in trees on SL than rest of two rootstocks. For 80% flower, open trees on SL rootstock remained one day late during year I while two days late than GF-677 and PL rootstocks during year II (Table 1). A double-sigmoid growth curve pattern was shown by fruits of cv. 'Flordaking' on all three different rootstocks, with four stages of growth without any difference during both years of study (Figure). Fruit growth (diameter) was illustrated by a linear increase in fruit size up to 38 dAFB (days after full bloom) during first stage (A), thereafter second stage (B) from 38 to 52 dAFB depicted a low fruit growth with pit hardening. Third stage (C) was characterized as exponential growth from 52 to 59 dAFB. Fourth and last stage (D) showed slight increase in fruit size.

TCSA, Yield, Yield Efficiency, Number of Fruits/Tree, Fruit Size

Effect of three different rootstocks on trunk cross sectional area (TCSA) for peach cv. 'Flordaking' trees was found significantly different (Table 2). Largest trunk cross sectional area was induced by GF-677 rootstock when compared with SL. The rootstocks GF-677 and PL remained statistically at par. Maximum cumulative yield of peach fruit cv. 'Flordaking' was recorded in trees grafted on GF-677 followed by PL, whereas SL was recorded with minimum yield (Table 2). There were no significant differences among the three rootstocks for yield efficiency. The number of fruit per tree was highest in trees on GF-677 followed by PL (Table 2). The trees on SL rootstock had least number of fruit per tree. This experiment evidently showed that the rootstocks significantly affected fruit size of cv. 'Flordaking' (Table 2). Among these GF-677 induced lowest size fruits while SL induced largest size fruits.

Soil and Tissue Minerals Concentrations

Mineral elements status of soil at experimental site (NARC) during year I (2008) and year II (2009) is presented in Table 3. Among the rootstocks tested, leaf content of N was higher in trees on GF-677 than PL and SL rootstocks (Table 4). Leaf P concentration was also higher in trees on GF-677 while PL and SL rootstocks showed no significant difference between them (Table 4). The highest leaf K concentration was found in trees on PL followed by the GF-677 and SL rootstocks. It is evident from results that rootstocks statistically did not affect leaf Fe content of scion cultivar 'Flordaking' (Table 4). However, GF-677 rootstock had higher Fe content. Leaf content of Zn and Mn were significantly higher in trees grafted on GF-677while, SL rootstock was observed with lowest content of same micronutrients. The PL rootstock had highest leaf content of Cu followed by GF-677 and SL rootstocks respectively (Table 4).

DISCUSSION

The effect of rootstocks on flowering time, plant vigor, yield and minerals uptake efficiency have been well documented in previous studies (Nielsen and Kappel, 1996; Goncalves *et al.*, 2003; Knowles *et al.*, 1984; Boyhan *et al.*, 1995; Facteau *et al.*, 1996; Moreno *et al.*, 1996). In this study, however, rootstocks did not significantly affect PBSFB and other three different flowering stages. Similar results have also been reported by Maneethon *et al.* (2007). The fruit growth pattern of cv. 'Flordaking' grafted on three different rootstocks was found non-significant. Other researchers, who tried to regulate the fruit growth pattern, reported that AVG (aminoethoxyvinylglycine) treatments had no effects on altering the fruit growth pattern of peach cv. 'Redhaven' when compared with control (Bregoli *et al.*, 2002). Due to same variety on three different rootstocks might be the reason for non-significant difference.

TCSA is regarded as an important agronomical parameter which indicates good scion-stock compatibility, plant adaptability to the area and soil conditions by demonstrating high tree vigor with greater TCSA. The study under discussion revealed significant effect of rootstocks on TCSA of trees of peach cv. 'Flordaking'. The greater tree vigor and yield was shown by GF-677 followed by PL and this could be attributed to their efficient uptake of minerals. The SL showed lowest TCSA and yield and this could be attributed to its origin which is relatively colder than the origin of GF-677 and PL. The GF-677 proved its potential over two indigenous seedling rootstocks (PL or SL). Similar results have also been reported by Tsipouridis and Thomidis (2005) that GF-677 exhibited greatest potential in respect to girth expansion and yield when compared with other rootstocks. The reason for higher number of fruits per tree from trees on GF-677 might be due to the stock and scion compatibility and adaptability of the stock-scion to the growing area. Fruit size plays an important role in fruit acceptability. Mostly medium sized fruits are considered having good quality and nutritional values. Several researchers have reported the effect of rootstocks on fruit size (Giorgi *et al.*, 2005; Facteau *et al.*, 1996; Jimenez *et al.*, 2007; Cantin *et al.*, 2010). In this study, rootstocks showed significant effects on fruit size of peach fruit cv. 'Flordaking'. The rootstock SL was recorded with increased fruit size and this might be due to low yield and less number of fruit. Earlier, it has been documented that peach fruit size is proportional to number of fruit (Walsh *et al.*, 2007). Our findings are supported by those of Giorgi *et al.* (2005) who stated that GF-677 rootstock had small sized fruits with better fruit quality than 'Ishtara'. Another study also revealed that sweet cherry fruit size was significantly affected by rootstocks (Facteau *et al.*, 1996).

The trends of leaf macro and micro-nutrients levels revealed the potential of GF-677 rootstock, in relation to its effect on scion tree of peach cv. 'Flordaking'. Nitrogen is an indispensable mineral for plant development, growth and it is integral part of many compounds in plant cells. Optimum N levels and efficient uptake ensures balanced scion vigor and ultimately good quality fruit. In this study, regarding N uptake efficiency of rootstocks, GF-677 rootstock showed significantly higher leaf content of N as compared to other rootstocks. Other researchers have also documented that leaf N concentration was significantly higher in trees on GF-677 than on rest of rootstocks tested in respective studies (Zarrouk *et al.*, 2005). The P concentration was also significantly higher in leaves of trees on GF-677 and intermediate in PL rootstock. The findings of our study are in agreement with the results of Toit *et al.* (1995) who documented that GF-677 rootstock had best capability to efficiently uptake the minerals. The same effects have also been reported by Jimenez *et al.* (2007) that leaf P concentration in cherry trees was significantly altered by the rootstocks. The rootstock PL was observed with highest leaf K concentration than GF-677 and SL respectively. The K has been reported that it increases fruit size as much as 8% (George *et al.*, 1988). That is why increased fruit size of fruits on PL than GF-677 could be attributed to higher leaf K concentration in trees on PL rootstock.

The rootstocks effect on leaf Fe concentration was found statistically non-significant. However, trees grafted on GF-677 showed higher Fe concentration than rest of rootstocks. Iron has mobility in plant cells with ease and it transfers energy during respiration and photosynthesis. The tendency of higher leaf Zn and Mn concentration was also observed in trees on GF-677 when compared with rest of two rootstocks. The results of this study are also in agreement with those of Tsipouridis and Thomidis (2005) and Zarrouk *et al.* (2005) who stated that leaf Mn concentration was found higher on GF-677 than rest of rootstocks. The PL rootstock was recorded with significantly higher leaf Cu concentration when compared with GF-677 and SL rootstocks. Other researchers, based on their findings ranked GF-677 rootstock as intermediate for Cu absorption (Tsipouridis *et al.*, 2005; Tsipouridis and Thomidis, 2005).

The effect of rootstocks on yield, nutrients uptake was documented (Bielicki *et al.*, 2000; Chun and Fallahi, 2001; Caruso *et al.*, 1996, 1997). It is evident from the experiment that rootstocks significantly affected TCSA, yield, number of fruit, fruit size and nutrient absorption of peach cv. 'Flordaking'. The yield and fruit size of cherry cultivar 'Bing' was strongly affected by the rootstocks (Facteau *et al.*, 1996).

To examine the effect of rootstocks on macro and micro-nutrients, as to determine a suitable rootstock for early maturing peach cv. 'Flordaking', the results of the study suggest that GF-677 and wild seedling PL proved the best. So, in the light of these findings the best combination of rootstock and cultivar by applying only the required fertilizers resulting in judicious use of fertilizers (better quality fruits, minimizing inputs and pollution), in return will improve peach industry.

CONCLUSION

The rootstocks GF-677, Peshawar Local and Swat Local have been found to affect the tree vigor, yield, fruit number and size, as well as altered the nutrients uptake efficiency of peach cv. 'Flordaking'. These three major rootstocks were evaluated for their adaptability to climatic and soil conditions by measuring the mentioned parameters. GF-677 was found the most suitable among the three rootstocks whereas PL also showed better performance by having increased yield, good tree vigor and remained efficient in some macro-micro nutrients uptake. Hence, rootstocks GF-677 and PL performed well from all aspects i.e., they suited well in the climatic conditions of rainfed area of Islamabad, resultantly thrived well with higher yield and better efficiency of nutrients uptake while SL rootstock did not meet most of mentioned criterions.

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Table 1: Effect of rootstocks on different stages of flowering time of peach cv. 'flordaking' during 2008.

Treatments	**Pink balloon stage of flower buds**	**1st flower bud burst**	**50% flower bloom**	**80% flower bloom**
Year I (2008)				
GF-677	23-02-2008	26-02-2008	29-02-2008	03-3-2008
P L	23-02-2008	26-02-2008	29-02-2008	03-3-2008
S L	23-02-2008	26-02-2008	29-02-2008	04-3-2008
Year II (2009)				
GF-677	21-2-2009	24-02-2009	27-02-2009	1-3-2009
P L	21-2-2009	24-02-2009	27-02-2009	1-3-2009
S L	20-2-2009	24-02-2009	28-02-2009	3-3-2009

PL – Peshawar Local; SL – Swat Local

Table 2: Effect of rootstocks on TCSA, yield per tree, yield efficiency, number of fruit per tree and fruit size of peach cv. 'flordaking' during two years of experiment.

Rootstocks	**TCSA cm^2**	**Yield/tree (kg)**	**Yield efficiency**	**Number of fruit/tree**	**Fruit size in mm (diameter)**
GF-677	1841.9a	51.85a	0.0308a	343.50a	60.697c
PL	1317.3a	43.44b	0.0357a	282.67b	65.545b
SL	755.1b	30.68c	0.0308a	198.67c	73.372a
CV (%)	19.36	9.38	18.72	8.85	4.78
LSD	558.77	4.9121	0.0178	30.348	3.9629

For each rootstock, means having the different letters in each column are significantly different at $P \leq 0.05$.

Table 3: Mineral elements status of soil at experimental site (NARC) during two years of experiment (2008 and 2009).

Soil depths (cm)	**N% (mineral)**	**P mg kg^{-1}**	**K mg kg^{-1}**	**Fe mg kg^{-1}**	**Zn mg kg^{-1}**	**Cu mg kg^{-1}**	**Mn mg kg^{-1}**
Year I (2008)							
0-15	0.006	8.6	110	2.40	1.21	1.18	1.49
15-30	0.004	8.0	85	2.32	1.27	1.34	1.41
30-60	0.004	6.0	70	2.36	1.13	0.90	1.69
60-90	0.003	5.2	70	2.46	1.39	1.10	1.89
Year II (2009)							
0-15	0.007	8.9	113	2.52	1.19	1.23	1.52
15-30	0.005	8.5	87	2.36	1.29	1.3	1.46
30-60	0.005	6.7	72	2.36	1.11	0.97	1.67
60-90	0.004	5.6	71	2.48	1.42	1.16	1.93

Table 4: Effect of rootstocks on leaf nutrients concentration of peach cv. 'Flordaking' during two years of experiment (2008 and 2009).

Rootstocks	**% N**	**% P**	**% K**	**Fe mg kg^{-1}**	**Zn mg kg^{-1}**	**Cu mg kg^{-1}**	**Mn mg kg^{-1}**
GF-677	2.79a	0.37a	1.92b	230.80a	27.83a	15.08b	96.34a
PL	2.56ab	0.34b	2.48a	228.86a	22.83b	24.10a	87.66b
SL	2.31b	0.34b	0.88c	227.66a	18.16c	14.75c	57.50c
CV%	9.51	5.68	9.56	13.10	10.14	14.90	6.01
LSD	0.3031	0.0251	0.2108	3.1530	2.9023	3.3407	6.0326

For each rootstock, means having the different letters in each column are significantly different at *P≤0.05*.

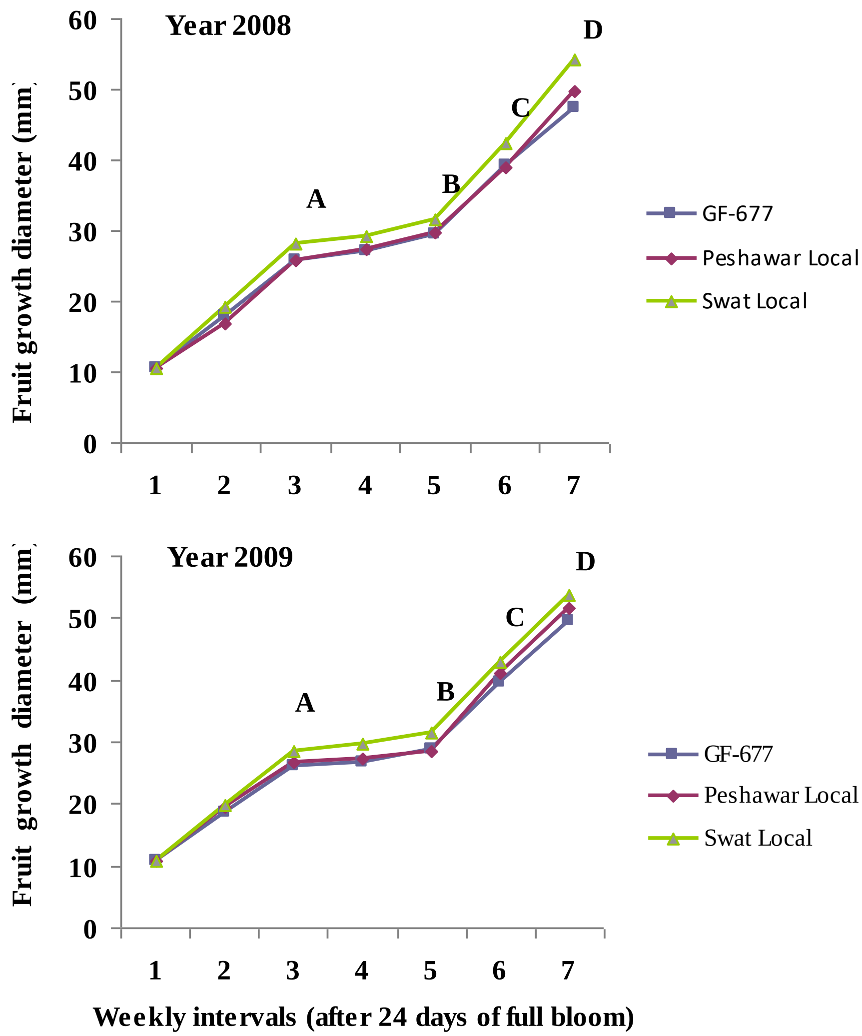

Figure: Effect of rootstocks on growth pattern of peach fruit cv. 'Flordaking' during two years of experiment.