RESPONSE OF AUSTRALIAN SWEET ORANGE VARIETIES ON CITRUS ROOTSTOCKS UNDER AGRO-CLIMATIC CONDITIONS OF PESHAWAR, PAKISTAN

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خلاصہ

آسٹریلیا کی مختلف میٹھی اورنج کی اقسام کے روپے کو مختلف جڑوں والے پودے جو پشاور کے زرعی تحقیقی ادارے ترناب میں لگے تھے سے قلم کاری کرا کے دیکھے گے 2013 میں۔ چھے اورنج کی اقسام (Salustiana اور Sour Orange – Troyer citrange – Carrizo کو پشاور میں لگے چار جڑوں والے MeMaham Valeneia Ryan - Arnold citrange – Cox mandarian سے بے ترتیب مکمل بلاک ڈزائین جسمی در عومل شامل تھے۔ اور تین مرتبہ دھرائے تھے سے پیوند کارک کی تجزیہ نے ظاہر کیا کہ میٹھے اورنج کی قسم نے اہمیت کی حامل نشور کو ظاہر کیا چاروں کے ساتھ۔ CaracaraNael قسم نے 84.17% پیوند کی نشو نما کو ظاہر کیا جبلہ موٹائی 6.28mm ، لمبائی 41.18cm پیتوں کی تعداد 68.54 تھی۔ پتی کا علاقہ $33.83cm^2$ اور شاخوں کی تعداد 5.50 تھی نکلنے میں کم دن (35.43) لیئے۔ Ryan میں سب سے زیادہ جڑ کی لمبائی 38.17 جسکا حجم $28.75cm^2$ تھا۔ مختلف جڑ والے پودوں نے پیٹھے اورنج پر مختلف اہمیت اثرات مرتب کیئے۔ سب سے زیادہ 63.33% بڈز نکلیں اسکی موٹائی 7.43mn، اسکی لمبائی 48.33cm پینیوں کی تعداد 67.94، اسکا علاقہ $29.12cm^2$، شاخوں کی تعداد 4.89 تھی یہ پودے 72.22% زندہ ہے۔ Troger citrange پر سب سے کم 39.48 دن نکلے ہیں۔ Cox Mandarin کی سب سے زیادہ 40.56cm جڑ کی لمبائی جسکا حجم 30.28cm تھا۔ cara cara Nawl اورنج جسکی پیوند کابی Trayer Citrange پر کی گئی۔ سب سے زیادہ سوتی زیر مند کاری پتوں کی تعداد پتی کا علاقہ بھی سب سے زیادہ تھا۔ اور اس کے نکلنے میں کم سے کم 30.13 دن لگے۔ cara cara Nawl کو جب Carrizo citrarage سے پیوند کاری کی تو سب سے کم شاخیں نکلیں۔ یہ دیکھا گیا کے نرسری میں جب cara cara Nawl کو Trayer Citrange کے ساتھ پیوند کرنے پر سب سے زیادہ بہتر نتائج حاصل ہوئے پشاور کے اس زرعی فارم کے ماحول میں۔

Abstract

The response of Australian sweet orange varieties budded on different rootstocks under the agro- climatic condition of Peshawar was evaluated at Agricultural Research Institute Tarnab, Peshawar during the year 2013. Six different sweet oranges of scion varieties (Arnold Blood, Ryan, Harvard, Cara Cara Navel, McMahan Valencia and Salustiana) were budded on four different citrus rootstocks (Cox Mandarin, Carrizo Citrange, Troyer Citrange and Sour orange) in Randomized Complete Block Design with two factors, replicated three times. The analysis of data showed a significant variation for growth response of sweet orange varieties budded on four citrus rootstocks. The Cara Cara Navel variety gave maximum bud sprouting (84.17%), buddling thickness (6.28 mm), buddling length (41.18 cm), number of leaves buddling^{-1} (68.54), leaf area (33.83 cm^2) and number of branches (5.50) and took less days to sprouting (35.43). The Ryan variety gave plants with maximum root length (38.17 cm) and root volumes (28.75 cm^3). Different citrus rootstocks used significantly affected the sweet orange varieties. The maximum bud sprouting (63.33%), buddling thickness (7.43 mm), buddling length (48.83 cm), number of leaves buddling^{-1} (67.94), leaf area (29.12 cm^2), number of branches (4.89) and survival (72.22%) was observed in the plants budded on Troyer Citrange rootstock and also took the minimum days to sprouting (39.48). The Cox Mandarin rootstock gave plants with maximum root length (40.56 cm) and root volume (30.28 cm^3). The interaction between Australian sweet orange varieties and citrus rootstocks was also significant on almost all the parameters. The Cara Cara Navel variety budded on Troyer Citrange rootstock gave plants with maximum sprouting, buddling thickness, number of leaves buddling^{-1}, leaf area and also took minimum days to sprouting (30.13). The Cara Cara Navel when budded to Carrizo Citrange resulted in maximum number of branches. The Ryan sweet orange budded on Cox Mandarin rootstock produced plants with maximum root length and volume. The maximum buddling length was observed in Salustiana variety budded on Troyer Citrange. The McMahan Valencia budded on Cox Mandarin gave plants with maximum leaf area and took minimum days to sprouting. Keeping in view the above facts it was concluded that the nursery plant growth performance of variety Cara Cara Navel budded on Troyer Citrange was outstanding among all other scion and rootstocks varieties under the agro-climatic conditions of Peshawar.

Introduction

Citrus belongs to family Rutaceae and subfamily Aurantioideae. It has three important subgenera, i.e., Citrus, Fortunella and Poncirus. Citrus originated from South-East Asia, such as China, Indo-Pak, Thailand, Indonesia and Malaysia (Swingle, 1967). It is an important and largest group of fruits, mainly grown in tropical and subtropical areas. The most commonly used citrus species are sweet orange, lemon, mandarin, lime and grape fruit (Wutscher, 1989). Citrus is one of the most common and major fruits in Pakistan. Due to citrus production, Pakistan has become an important exporter of citrus world over. Most of the production however relies on sweet oranges and Mandarin Kinnow. The 95% of the Kinnow is produced in District Punjab. In Pakistan, citrus is grown on an area of 194500 hectares with an average production of 2101.5 thousand tons while Khyber Pakhtunkhwa contributes an area of 4.1 thousand hectares with a total production of 35.4 thousand tons (MNFSR, 2012).

Sweet Oranges grow well in subtropical areas. Some commonly used sweet orange cultivars are: Musambi, Blood Red, Succari, Pineapple, Jaffa and Valencia late. From nutritional point of view, sweet orange is an important fruit. Sixteen fatty acids have been identified in them forty six aroma compounds are also detected in Blood Red orange Juice. Therefore, Blood Red orange consumption may give us substantial health benefits (Kafkas *et al.,* 2009). The peel of sweet orange shows hypoglycemic, insulin stimulatory and antithyroidal activities, thus it controls glucose level in the blood by enhancing insulin concentration. Its tree can be grown on a variety of soils, such as loam, deep sandy loam and clay loam (Parmar and Kar, 2008). Jalil *et al*. (2013) assessed the effects of time and geographical side budding and color of wrapping material on citrus. Operation was carried out by T-budding of three citrus cultivars (Mandarin Kinnow, Sweet Orange and Valencia Sweet Orange) on rootstock Mexican lime. Results showed that the highest percentage of bud take and graft growth was recorded in both the sweet oranges when budded on 25th September at the north side by using red, green and blue wrapping tape. Muhammad *et al*. (2012) carried out a research on the effect of budding height, the age of bud wood and the stock lopping at different dates on citrus trees. Rough lemon rootstock was T-budded with sweet orange var. Pinecone as scion bud wood. The results concluded that the age of the wood buds and graft height had a negligible effect on bud take success of citrus.

Maria *et al*. (2011) studied the performance of Navelate sweet orange on five rootstocks (Carrizo Citrange, Cleopatra Mandarin, PASQ, Citrus Volkameriana, Troyer Citrange and C-13). It was observed that Volkameriana rootstock produced the maximum sized fruits and had a high fruit production. Canopy volume and TSS content were maximum in plants propagated C-13 rootstock. Waqar *et al*. (2007) examined the nutritional status on the production of Kinnow mandarin scion on nine different foreign and domestic rootstocks. Maximum nitrogen content was observed in Troyer Jambhiri Citrange. Phosphorus was maximum on Jambhiri with Carrizo. Potash was the maximum in Volkameriana scion (grafted on Carrizo rootstock). Mazhar *et al*. (2006) studied the basic propagation of sweet orange cv. Musambi. For this purpose, bud woods of 3 mm and 4 mm was used at two different heights (15 cm and 23 cm). The greatest success rate was achieved when bud wood of 4 mm was grafted at the height of 23 cm. Anwar (2003) examined the impact of different cultivars of sweet orange budded on sour orange rootstock. It was reported that fruits of Musambi species had maximum non-reducing sugars and TSS. Reducing sugar and total sugar were highest in varieties Oilnda Valencia and Sanguinelli. Fruits with rough bark were observed in Moro Blood Hinckely, Valencia late Pineapple, Jaffa, and Blood Red Kozan. The varieties Salustiana, Moro Blood, Cambell Valencia, Rabulus Musambi and Ruby Red had moderately a smooth fruit texture.

Materials And Methods

An experiment, to study the response of Australian sweet orange varieties on different rootstocks under the Peshawar conditions, was conducted at Agricultural Research Institute Tarnab, Peshawar during the year 2013. The experiment was carried out in a screen house. Rootstocks were grown under the Pakistan and Australia Agriculture Sector linkages Project (ASLP) in plastic tubes black polythene plastic bags (10*25 cm) size filled with similar proportions of sand, canal silt and leaf mold (1:1:1). Six Australian imported sweet orange varieties were budded through T-budding technique during the second week of May in 2013 on one year seedlings of four different rootstocks. The experiment was laid out in Randomized Complete Block Design (RCBD) with the following two factors arrangement having three replications.

Factor A Sweet orange Varieties =06= (Arnold Blood, Ryan, Harvard, Cara Cara Navel, McMahan Valencia, Salustiana)

Factor B Citrus Rootstocks =04= (Cox Mandarin, Carrizo Citrange, Troyer Citrange, Sour orange)

There were in total 360 plants used for the experiment. Each treatment was replicated three times, while each replication had 5 plants for each treatment.

The following parameters were studied during the course of the experiment:

Days to sprouting

The number of days was counted from the date of budding to the date of first sprouting for each treatment in each replication.

Percent sprout

Sprouting and successful growth initiation of scion the percent sprout was calculated with the help of following formula.

$$\text{Percent sprout success} = \frac{\text{Sprouted buds}}{\text{Total budded plants}} \times 100$$

Survival percentage

The number of survived budded plants was counted from all treatments in each replication and then calculated the percentages by following formula:

$$\text{Survival percentage} = \frac{\text{Number of survived budded plants}}{\text{Total Number of budded plants}} \times 100$$

Buddling length (cm)

The length of buddling was measured with the help of measuring tape in randomly taken plants from each treatment in each replication and then averages were calculated.

Buddling thickness (mm)

The thickness of buddling was measured with the help of digital vernier calipers in randomly taken plants from each treatment in each replication and then averages were calculated.

Number of branches buddling^{-1}

The number of shoot on each buddling was counted for each treatment in each replication at the end of growth season and then mean was calculated.

Number of leaves buddling^{-1}

The total number of leaves plant^{-1} was counted in randomly selected plants from each treatment in each replication and then averages was calculated.

Leaf area (cm^2)

The leaf area was calculated by taking five leaves from each treatment and each replication with the help of leaf area meter and the mean was calculated.

Root volume (cm^3)

The volume of roots was measured by dipping the roots in beaker (water displacement method). It was done in randomly selected plants from each treatment in each replication and then averages were calculated.

Root length (cm)

The length of roots was measured with the help of measuring tape in randomly selected plants from each treatment in each replication and then averages were calculated.

Statistical Procedures

The data recorded was subjected to Analysis of Variance (ANOVA) with technique appropriate for Randomized Complete Block Design (RCBD) with two factors arrangement. Means were compared by using Least Significance Differences (LSD) test. For these analyses computer statistical software "Statistix 8.1" was used (Steel *et al*, 1997).

Results and Discussion

Days to sprouting

Data in Table 1 shows that different sweet orange varieties and citrus rootstocks and their interaction had a significant variation for the number of days taken to bud sprouting. The minimum days to sprouting (35.43) was taken by Cara Cara Navel Variety, while the mean values of Arnold Blood and Harvard were almost same. The means regarding days to sprouting as affected by sweet orange revealed that the maximum days to sprouting (44.75 and 44.58) were given by Ryan and McMahan Valencia varieties, followed by the values (44.44) observed in Harvard variety, which was significantly at par with the days to sprouting (42.38) recorded in Arnold Blood. The sweet orange varieties budded on various rootstocks shows a significant variation regarding number of days to sprouting (Fig.1) however the less number of days (39.84) to sprouting were observed in plants propagated on Troyer Citrange rootstock, which was at par with the number of days (41.37) to sprouting observed on Carrizo Citrange, while the highest number of days (43.78) to sprouting were recorded in plants budded on sour orange. These results showed that among Australian sweet orange varieties, Cara Cara Navel gave the best results, while the Troyer Citrange rootstock among the citrus rootstocks. It might be due to the better compatibility between these species, better graft take success, and suitable climate of Peshawar valley for these exotic citrus species. Another possible reason might be that the Cara Cara Navel and Troyer Citrange species gave maximum sprouting percentage, due to which days to sprouting was also reduced. The obtained results are in confirmative with the findings of Ishfaq *et al.* (2012) who found improvement in the days to sprouting of sweet oranges when budded to different rootstocks.

Sprouting Percentage

Data regarding percent sprout of Australian sweet orange varieties budded on citrus rootstocks is presented in Table 1 revealed that there were a significant variation in sprouting percentage of sweet orange varieties budded on citrus rootstocks and for their interaction. The mean values as referred to sweet orange varieties showed that the maximum sprouting (84.17%) was recorded in Cara Cara Navel, followed by the sprouting (60.83%, 59.17%, 50% and 50%) of Salustiana, Arnold Blood, Ryan, and Harvard respectively, while the minimum sprouting (47.5%) was recorded in McMahan Valencia variety. However, the sprouting percentage of Salustiana and Arnold Blood was significantly the same. The effect of different rootstocks on percent sprouting showed (Fig.2) that the maximum sprouting (63.33%) was observed in plants budded on Troyer Citrange, which was statistically the same with the sprouting (61.67 and 56.11%) recorded in plants produced on Carizo Citrange and Cox Mandarain, respectively. While the minimum sprouting (53.33%) was observed in plants propagated on sour orange rootstock. The sprouting of Cox Mandarin and Sour orange was also the same statistically. According to the results, different exotic sweet orange varieties showed significant variation in their percent sprouting when budded on citrus rootstocks. There might a better graft take success between the varieties and rootstocks so bud sprouted more efficiently. Another reason for such results might be the improved survival percentage of the species used. The Cara Cara Navel variety budded on Troyer Citrange rootstock showed the highest sprouting percentage compared to rest of the sweet orange varieties and citrus rootstocks used. These results are in correspondence to the findings of Pomper *et al.* (2009) who also found a significant difference for sprouting percentage of Papaya fruit when using various rootstocks and scion cultivars. Mohar *et al.* (2011) stated that different sweet orange cultivars showed significant variation in percent sprout of the budded plants. Bakry *et al.* (2005) also found that the minimum sprouting percentage was given by sour orange rootstock.

Survival Percentage

The data regarding survival percentage of Australian sweet orange varieties budded on different citrus rootstocks is presented in Table 1 proved that different Australian varieties and citrus rootstocks significantly affected the survival percentage of the plants, while there interaction had a non significant effect on the survival percentage. The mean data regarding sweet orange varieties showed that the maximum survival percentage (84.72) was recorded in plants of Harvard variety, while the minimum survival percentage (61.11) was observed in Arnold Blood, which was statistically same with the survival percentages (66.67, 65.28, 59.72 and 59.72) of Cara Cara Naval, Ryan, McMahan, Valencia, and Salustiana varieties respectively. There was a significant difference for various rootstocks regarding survival percentage. The maximum survival percentage (72.22) was noted in plants propagated on Troyer Citrange rootstock which was at par with the survival percentage (66.67) recorded in the plants budded on the rootstock Cox Mandarin. While the minimum survival percentage was observed by the plants budded on sour orange, which were in Hormony with survival percentage (62.96, 62.96 and 66.67) noted in plants produced on Carrizo Citrange, Sour Orange and Cox Mandarin respectively. There was a great variation observed in the percent survival of sweet orange cultivars budded on different citrus rootstocks. It might be due to the fact that some of orange varieties had a better graft compatibility with certain rootstocks of citrus used in this study. The Harvard variety and Troyer Citrange rootstock gave the maximum survival of the plants that shows greater bud take success of the two species for

each other. The other varieties, however, might not be compatible to the agro-climatic conditions of Peshawar. Sour orange did not give sufficient survival for the plants of the exotic varieties budded to it. Similar findings were reported by Rehman and Rab (2012) who found that the maximum survival percentage was noted in plants budded on Troyer Citrange. Moreover, Castle *et al.* (2010) worked on 12 citrus rootstocks of citrus and found that Carrizo Citrange and Sour orange induce the lowest percent of survival. Similar results were found by Altaf *et al*. (2008) who also found significant effect of different citrus rootstocks and scion cultivars on the percent plant survival in citrus plants.

Buddling length (cm)

Table 1 shows that data regarding buddling length of Australian sweet orange varieties budded on different citrus rootstocks and their interaction had a significant effect on shoot length. The mean data showed that the maximum buddling length (48.83 cm) was recorded in the plants budded on Troyer Citrange rootstock followed by the buddling length (35.06 cm and 31.22 cm) recorded in the plants budded on Carrizo Citrange and Cox Mandarin rootstock respectively. The less buddling length (23.17 cm) was observed in the plants budded on the sour orange rootstock. The mean regarding sweet orange varieties showed that Cara Cara Navel gave the maximum buddling length (41.18 cm) which was at par with buddling lengths (39.54, 39.52 and 36.98 cm) of Harvard, Salustiana and Ryan Varieties respectively, while the less buddling length (26.68 cm) was observed in Arnold Blood. These results showed significant variation among the sweet orange varieties budded on different citrus rootstocks (Fig.3). Moreover, bud take success or graft compatibility of some varieties can be seen on certain rootstocks. Salustiana variety and Troyer Citrange rootstock gave the maximum buddling lengths. These results are in confirmative the findings of Nawaz *et al.* (2007) who found that Troyer Citrange as the best rootstock for Kinnow mandarin that give maximum buddling length. Similarly, Wutscher and Shull (1975) reported that different rootstocks have a significant effect on the buddling height of the scion cultivars. Similarly, Sanchez *et al.* (2002) stated that rootstock type used for the citrus species induced a significant influence on height of the budded plants. Similarly, Rehman and Rab (2012) also found maximum height of the Troyer Citrange plants.

Buddling thickness (mm)

Data in Table-1 revealed that sweet orange varieties, citrus rootstocks and their interaction had a significant influence on buddling thickness. The means of data (Table-1) showed that the maximum buddling thickness (6.28 mm) was recorded in plants of Cara Cara Naval variety, followed by the buddling thickness of (6.17mm) and (5.66mm) recorded in plants of Harvard and Ryan varieties, where the least buddling thickness (3.98 mm) and (4.98 mm) were observed in plants of Mach Mahan Valencia and Salustiana. The means of buddling thickness as affected by citrus rootstocks showed that the maximum buddling thickness (7.43 mm) was gained by the plants budded on Troyer Citrange while the minimum thickness (3.78 mm) was observed in the plants produced on sour orange rootstock (Fig.4). The variation and stem thickness in different varieties might be due to the variant compatibility potential of varieties on the rootstocks. The bud take success as well as graft compatibility of the Cara Cara Navel might be greater on Troyer Citrange rootstock, which resulted in maximum buddling thickness of the Cara Cara Navel. The findings are in agreement with Georgiou (2000) who reported that the largest tree was obtained by the use of sour orange rootstock. Similar results were also reported by Bevington and Cullis (1990) who reported that the maximum tree growth was recorded in plants when propagated on Troyer Citrange rootstock.

Number of branches buddling^{-1}

The data of branch quantity buddling^{-1} as affected by the citrus rootstocks and sweet orange varieties is presented in Table 2 showed that the different sweet orange varieties, citrus rootstocks and their interaction had a significant effect on number of branches. The maximum number of branches (5.50) was given by Cara Cara Navel, which was at par with the value (4.92) showed in Salustiana variety, followed by the value (3.92, 3.58 and 3.33) given by Arnold Blood, Harvard and Ryan, while the less number of branches (3.17) recorded in McMahan Valencia. Different citrus rootstocks had also a significant effect on number of branches (Fig.5). The means of number of branches as affected by citrus root stocks proved that the branch quantity (4.89) given by the plants budded on Troyer Citrange, which was in harmony with the value (4.61) showed by the plants on Carrizo Citrange, followed by the branch quantity (3.83) observed in the plants budded on Cox Mandarin, while the less number of branches (2.94) given by the plants produced on sour orange rootstock. According to these results, most quantity of shoots or branches were given by sweet orange variety Cara Cara Navel and Troyer Citrange rootstock. The reason might be due to the maximum quantity of leaves per buddling and longest shoot length recorded in these two citrus species. These results are in close agreement to the findings of Khattak (1990) who recorded significant variation in the branch quantity of the citrus varieties budded on different rootstocks.

Number of leaves buddling^{-1}

The data related to the number of leaves buddling^{-1} is presented in Table 2 shows that Australian sweet orange varieties, citrus rootstock and their interaction significantly influenced the number of leaves buddling^{-1} of the budded plants. The mean table revealed the maximum number of leaves (66.94) was observed plants produced on Troyer Citrange rootstock. While the less number of leaves (18.06) was observed in plants propagated on sour orange rootstock. As referred to the different sweet orange varieties, the maximum number of leaves (68.54) was given by Cara Cara Naval, followed by the values buddling^{-1} (42.58, 40.63 and 39.54) recorded in Salustiana, Ryan and McMahan Valencia varieties respectively. The less number of leaves (31.29) buddling^{-1} was observed in the Harvard variety which was par with the value (31.37) given by Arnold Blood. There was a significant variation in the mean values of number of leaves of the studied varieties. The results showed that the Cara Cara Naval variety budded on Troyer Citrange rootstock gave the maximum number of leaves per buddling (Fig.6). It might be due to the maximum shoot (buddling) thickness and compatibility of to these two species. The healthier the shoots resulted in more number of the leaves. Other researchers also found that different rootstocks used for different scion cultivars have an efficient influence on number of leaves of the plants of scion cultivars by (Pomper *et al*., 2009). Rehman and Rab (2012) also found that the maximum numbers of leaves were recorded in Cara Cara Navel variety budded on the Troyer Citrange rootstock.

Leaf Area (cm^2)

Table 2 shows that sweet orange varieties budded on citrus rootstocks and their interaction had a significant effect on the leaf area. The means regarding the sweet orange varieties showed that the maximum leaf area (33.83 cm^2) was recorded in Cara Cara Navel variety, followed by the value (27.66 cm^2) observed in Salustiana, which was the same with the leaf area (24.82 cm^2 and 24.62 cm^2) recorded in Arnold Blood and Ryan. While the less leaf area (19.50 cm^2) was observed in McMahan Valencia variety. A significant variation was recorded regarding leaf area by using different rootstock for various sweet orange varieties (Fig.7). However, the maximum leaf area (29.12 cm^2) was observed in plants budded on Troyer Citrange, followed by the value (26.12 cm^2) recorded in plants produced on Carrizo Citrange, which was at par with the leaf area (24.53 cm^2) given by plants of Cox Mandarin. While the less leaf area (22.29 cm^2) was recorded in the plants budded on sour orange. The present results of leaf area significantly affected by sweet orange varieties and citrus rootstocks showed that variety Cara Cara Navel and Troyer Citrange rootstock resulted in highest leaf area. It might be due to the fact that these species also gave the highest shoot length, diameter, number of leaves and sprouting percentage, due to which it might have increased the leaf area. Similar results were found by Sanchez *et al.* (2002) who stated that rootstock type significantly influenced the leaf area of used citrus species.

Root length (cm)

Table 2 showed that data regarding rootstocks of Australian sweet orange varieties budded on the different citrus rootstock and their interaction had a significant influence on the root length of the plants. The mean table showed that the maximum root length (40.56 cm) given by plants budded on Cox mandarin rootstock followed by the root length (33.00 and 26.56 cm) given by the plants budded on Troyer citrange and Carrizo citrange respectively, while the minimum root length (20.06 cm) was recorded in the plants on the sour orange rootstock. The mean related to the affects of sweet orange varieties on the root length revealed that the maximum root length (38.17 cm) was obtained in the Ryan Variety, followed by McMahan (34.92 cm), Salustiana (30.42 cm), Arnold Blood (27.58 cm) and Cara Cara Naval (25.50 cm). The shorter root length (23.67 cm) was given by Harvard variety. The sweet orange varieties significantly influenced the root length of different citrus rootstocks. It might be due to the fact that the root growth depends upon the shoot growth or canopy of the plants. The better growth of the leaves and shoot growth of the sweet orange varieties resulted the increased root length of the citrus rootstocks. Moreover, the better bud take success of the varieties and rootstocks might have resulted in improved root growth. The present findings are in agreement to the results of Rehman and Rab (2012) that the citrus rootstocks significantly increased the root length of Cox Mandarin (Fig.8).

Root Volume (cm^3)

The data of root volume is given in Table 2 show that different sweet orange varieties, citrus rootstock and their interaction significantly influenced the root volume of the budded plants. Means related to the different rootstocks showed that the maximum root volume (30.28 mL) was recorded on Cox Mandarin rootstock. The minimum root volume (15.39 mL) was given by plants propagated on sour orange root stock. The means regarding different sweet orange varieties showed that the maximum root volume (28.75 mL) was observed in Ryan variety followed by (25.58 mL) in McMahan Valencia (24.67 mL) in Salustiana and (21.58 mL) in Arnold Blood. The less root volume (19.25 mL) was given by Harvard variety which was at par with the value (20.75 mL) in Cara Cara Navel. The increased volume of some citrus rootstocks might be due to the improved above the soil growth of plants of the sweet orange varieties. The reason might also be the better graft compatibility among the rootstocks and varieties used in this study (Fig.9). Similar results had been stated by

Girardi and Filho (2006) who worked on rootstock compatibility of different citrus rootstocks and sweet orange varieties and found significant effect on root growth and volume of the studied plants.

Table 1. Mean data for Days to Sprouting, Sprouting percentage, Survival percentage, Buddling length and Buddling thickness of sweet orange varieties budded on citrus rootstocks

Sweet orange varieties	Days to sprouting	Sprouting percentage	Survival Percentage (%)	Buddling length (cm)	Buddling thickness (mm)
Arnold Blood	42.38bc	59.17 bc	61.11 b	26.68 b	5.18 bc
Ryan	44.75a	50.00 cd	65.28 b	36.98 a	5.66 abc
Harvard	44.44ab	50.00 cd	84.72 a	39.54 a	6.17 ab
Cara Cara Navel	35.43d	84.17 a	66.67 b	41.18 a	6.28 a
McMahan Valencia	44.58a	47.50 d	59.72 b	23.51 b	3.98 d
Salustiana	40.38c	60.83 b	59.72 b	39.52 a	4.98 cd
LSD	**1.67**	**7.82**	**7.48**	**3.61**	**0.85**
Citrus rootstocks					
Troyer Citrange	39.84c	63.33 a	72.22 a	48.83 a	7.43 a
Carrizo Citrange	41.37bc	61.67 a	62.96 b	35.06 b	5.62 b
Sour Orange	43.78a	53.33 b	62.96 b	23.17 d	3.78 d
Cox Mandarin	42.98ab	56.11 ab	66.67 ab	31.22 c	4.68 c
LSD	**2.05**	**9.58**	**9.16**	**4.42**	**1.04**

Table 2. Mean data for Number of branches buddling^{-1}, Number of leaves buddling^{-1}, Leaf area (cm^2), Root length (cm) and of sweet orange varieties budded on citrus rootstocks

Sweet orange varieties	No. of branches buddling^{-1}	No. of leaves buddling^{-1}	Leaf area (cm^2)	Root length (cm)	Root volume (ml)
Arnold Blood	3.92 b	31.37 c	24.82 bc	27.58 cd	21.58 cd
Ryan	3.33 bc	40.63 b	24.62 bc	38.17 a	28.75 a
Harvard	3.58 bc	31.29 c	22.66 cd	23.67 d	19.25 d
Cara Cara Navel	5.50 a	68.54 a	33.83 a	25.50 cd	20.75 d
McMahan Valencia	3.17 c	39.54 b	19.50 d	34.92 ab	25.58 ab
Salustiana	4.92 a	42.58 b	27.66 b	30.42 bc	24.67 bc
LSD	**0.57**	**5.77**	**2.70**	**4.20**	**3.16**
Citrus rootstocks					
Troyer Citrange	4.89 a	67.94 a	29.12 a	33.00 b	26.33 b
Carrizo Citrange	4.61 a	43.53 b	26.12 b	26.56 c	21.72 c
Sour Orange	2.94 c	18.06 c	22.29 c	20.06 d	15.39 d
Cox Mandarin	3.83 b	39.78 b	24.53 bc	40.56 a	30.28 a
LSD	**0.70**	**7.06**	**3.30**	**5.14**	**3.87**

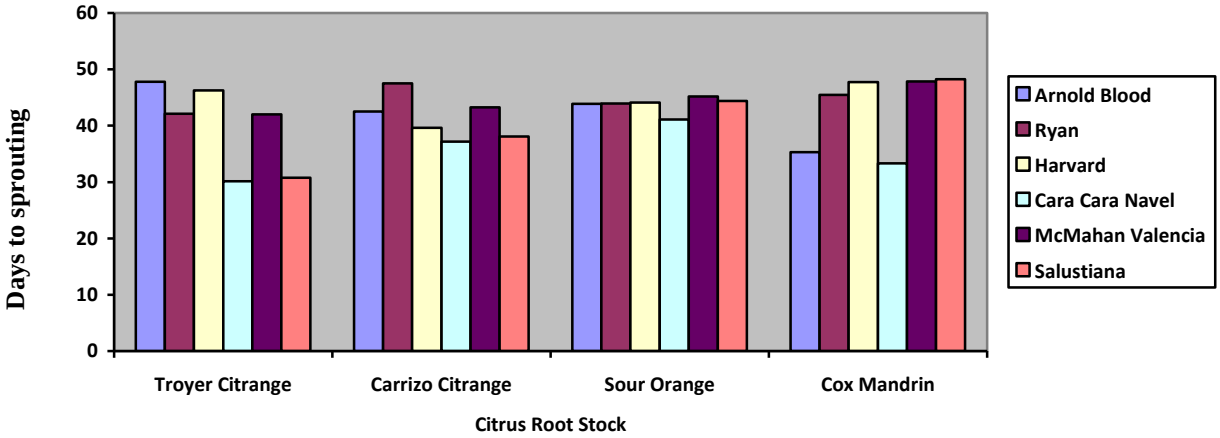

Fig.1. Interaction between sweet orange varieties budded on citrus rootstocks for days to sprouting.

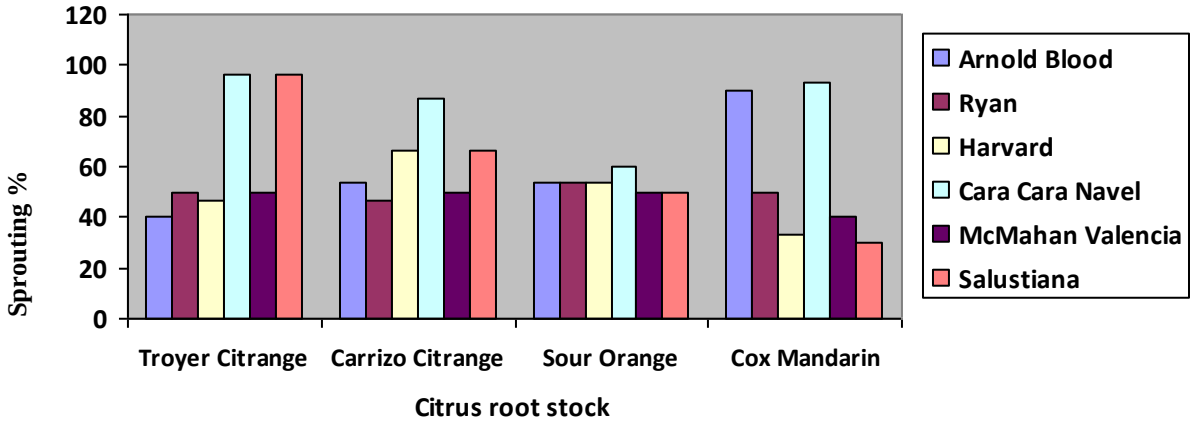

Fig.2. Interaction between sweet orange varieties budded on citrus rootstocks for Sprouting percentage.

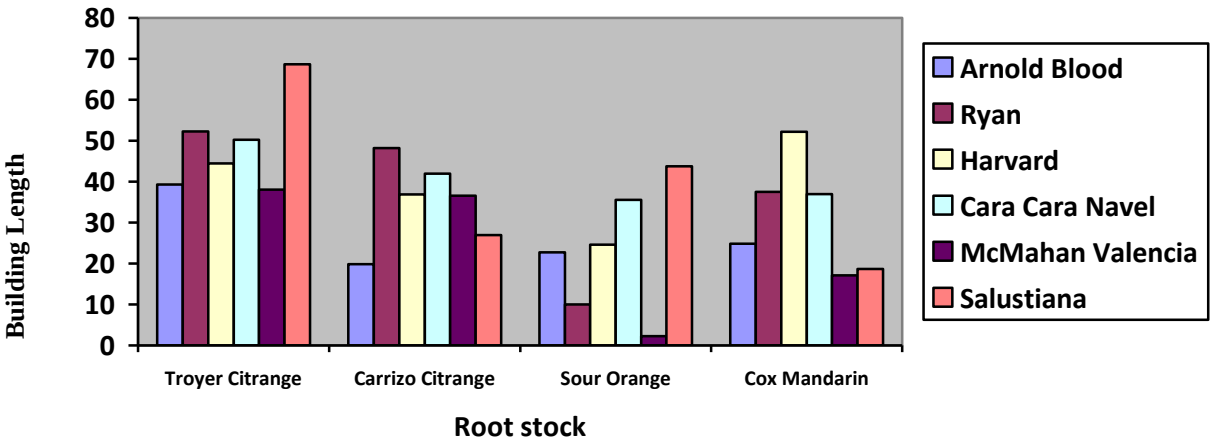

Fig.3. Interaction between sweet orange varieties budded on citrus rootstocks for Buddling Length.

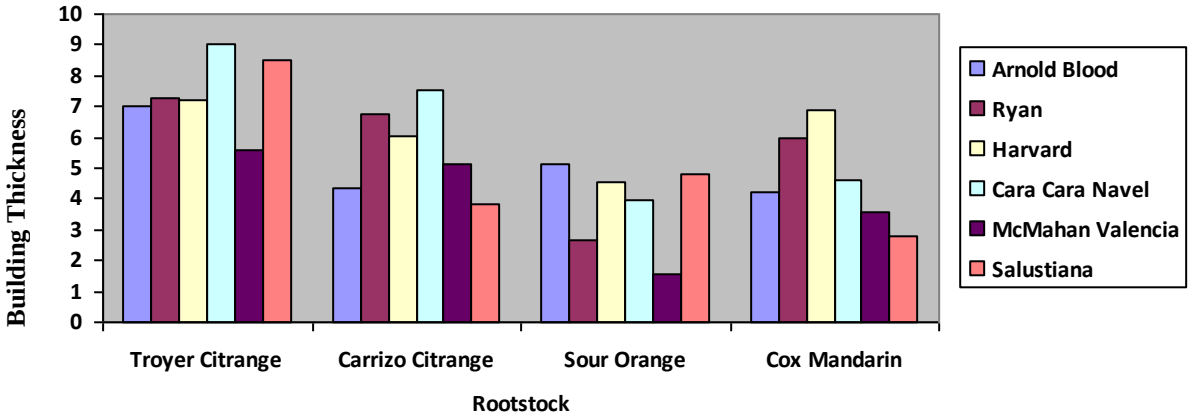

Fig.4. Interaction between sweet orange varieties budded on citrus rootstocks for Buddling Thickness.

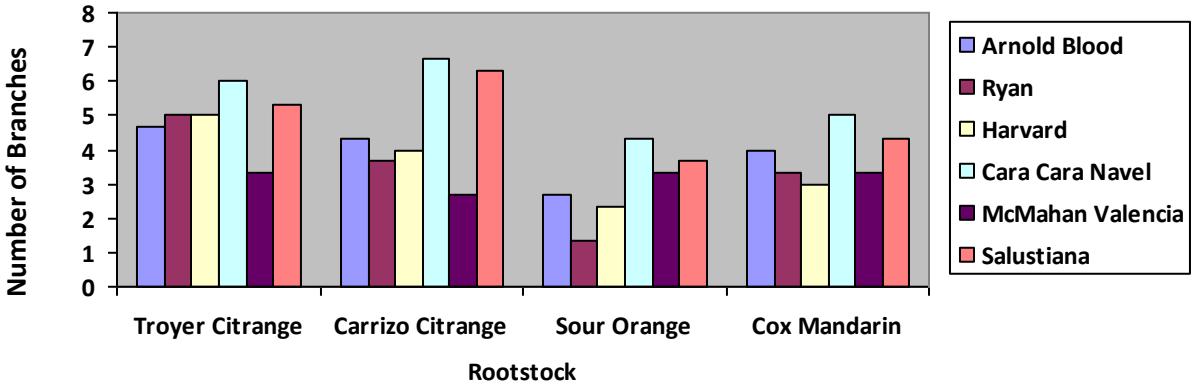

Fig.5. Interaction between sweet orange varieties budded on citrus rootstocks for Number of Branches.

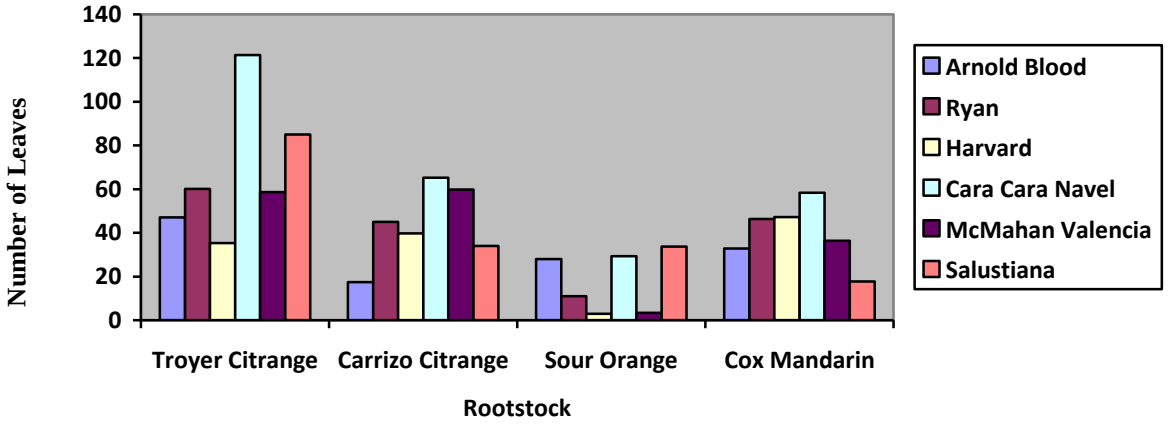

Fig. 6. Interaction between sweet orange varieties budded on citrus rootstocks for Number of Leaves.

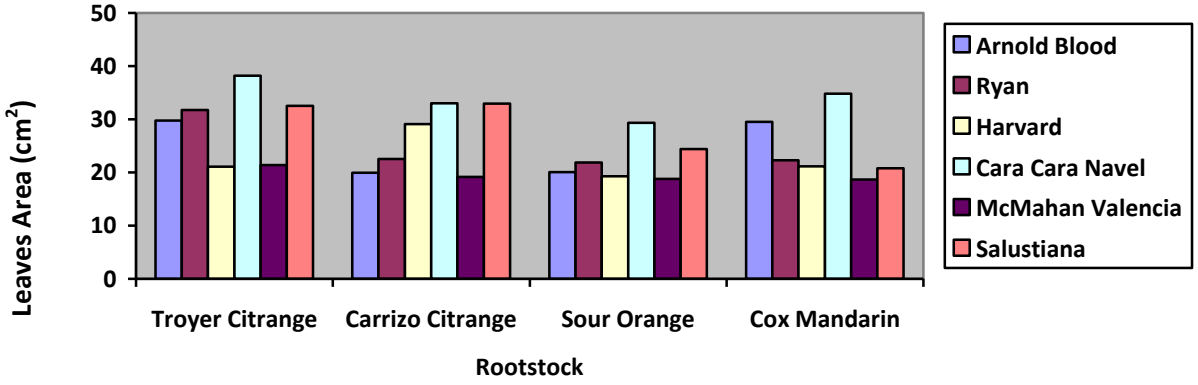

Fig. 7.Interaction between sweet orange varieties budded on citrus rootstocks for Leaves area (cm^2).

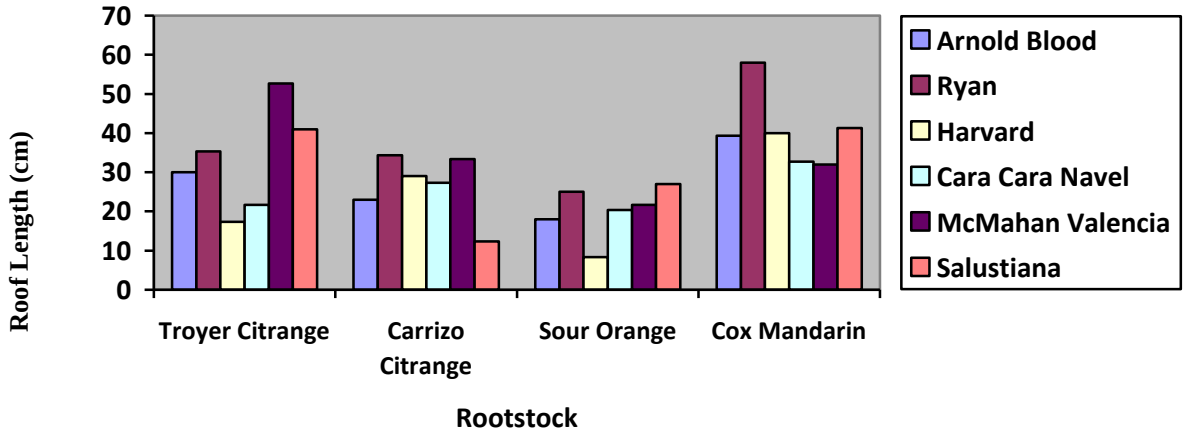

Fig. 8. Interaction between sweet orange varieties budded on citrus rootstocks for Root length (cm).

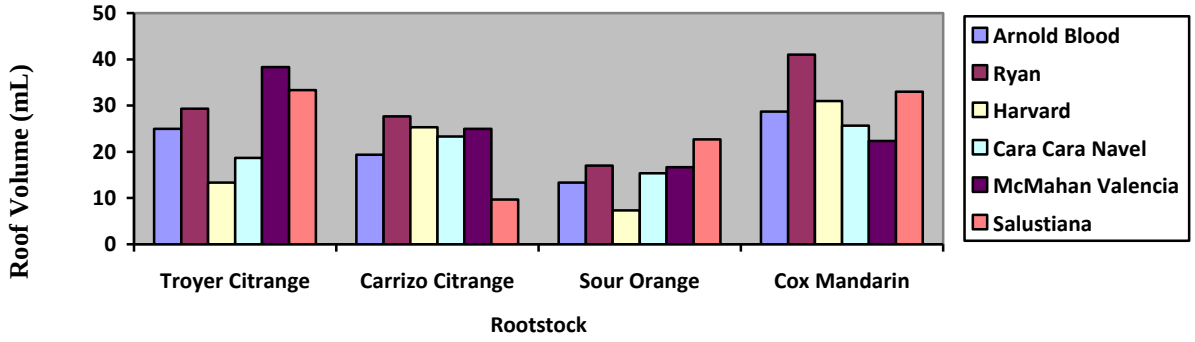

Fig.9. Interaction between sweet orange varieties budded on citrus rootstocks for Root volume (mL).

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