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Evaluation of some Exotic Cultivars of Sweet Orange in Punjab, Pakistan

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ABSTRACT

Citrus industry of Pakistan has been monopolized by a single cultivar Kinnow mandarin. Efforts are being made to diversify the citrus industry by induction of some suitable species like sweet orange, being the best choice after Kinnow mandarin. In the present studies 11 exotic sweet orange cultivars (Salustiana, Emby Gold, Lane Navel, Glane Navel, Hamlin, Tarocco-N, Casa Garande, Hinkley, Marr's Early, Kozan & Musambi) were evaluated at Citrus Research Institute Sargodha (CRIS) Pakistan, for prospective cultivation in Punjab province. The studies comprised of plant growth (plant height, plant spread, stem girth) and development (fruit size, per fruit weight, number of fruits per plant, number of seeds per fruit) and physiochemical properties [juice percentage, total soluble solids (TSS), acidity, TTS/acid ratio, peel thickness, peel weight, rag weight] of the fruits. The experiment was laid out according to randomized complete block design (RCBD), consisting of 11 treatments (cultivars) replicated four times and two trees were taken as an experimental unit; the data were collected and analyzed according to standard analytical techniques. The preliminary results showed that Tarocco-N and Salustiana performed the best in all respects as against Musambi, which is already cultivated as popular sweet orange cultivar in Pakistan. On the basis of this study, it can be recommended that Tarocco-N and Salustiana can be inducted as potential cultivars to diversify the citrus industry of Pakistan.

Key Words: Citrus; Pakistan; Performance; Physiological properties; Sweet orange

INTRODUCTION

Citrus fruits are natives of Southeast Asia (Indonesia & 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 (Shah, 2004). Citrus fruits comprise of about 40% of the total fruits produced in Pakistan, where it is cultivated over an area of 199,400 ha with an annual production of about 2.29 million tons (Anonymous, 2008). 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), while in rest of the world the share of sweet orange cultivars is more than 70%, owing to its more choice of varieties ranging from early maturing to late maturing and very less number of seeds per fruit.

Kinnow has monopolized the citrus industry of Pakistan. If some problems occur with this cultivar then citrus industry of Pakistan may collapse. Moreover, Kinnow is a very late maturing that reduces the total span of availability of citrus fruits in the market, on the other hand fruit processing factories/waxing and grading plant have less time available to process and export the citrus fruits to foreign countries (Albrigo, 2007). In addition to this Kinnow has very high number of seeds per fruit (20-30 seeds/fruit) and cannot be used in the processing industry for juice extraction (Anwar & Ibrahim, 2004). Keeping in view the study was initiated to check the performance of some sweet orange cultivars under the agro climatic conditions of Sargodha, Punjab province to diversify the citrus industry of Pakistan.

MATERIALS AND METHODS

The study was conducted on 6 years old cultivars of sweet orange (*Citrus sinensis* Osbeck L.) trees growing at the Experimental Fruit Garden, Citrus Research Institute Sargodha (CRIS), Punjab, Pakistan. The sweet orange cultivars included Salustiana, Emby Gold, Lane Navel, Glane Navel, Hamlin, Tarocco-N, Casa Garande, Hinkley,

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Marr's Early, Kozan alongwith Musambi. The experimental trees were spaced at about 7 m × 7 m, grafted on rough lemon rootstock (*Citrus jambheri* L.), growing under similar agro climatic conditions and received same cultural practices during the period of investigation. Eighty four uniform trees with no apparent disease incidence were selected for the experiment in the form of a block. A Randomized Complete Block Design (RCBD) was followed with four replications and two trees were selected as a treatment unit.

The vegetative behavior of the experimental trees was assessed by recording height of the plants that was measured by telescopic pole. It was measured from soil level to highest top branch of the tree. To measure the spread of the tree, two observations were taken from East to West and North to South at right angle with the help of measuring tape in a cross section up to the maximum out growth of the plant in each direction and average spread was calculated. Stem girth was measured by a measuring tape, just above the rootstock and scion joint. Fruit weight per tree and total number of fruits per plant (yield) were recorded by weighing and counting total number of fruits per tree at the time of harvest. Fruit diameter was measured by measuring the 10 fruits per cultivar with the help of digital verneir caliper and average fruit diameter was calculated (Nawaz *et al.*, 2008).

Average fruit weight was calculated by weighing ten fruits per tree on digital electric balance and average was calculated at the time of harvest.

Juice was extracted and weighed; average juice weight was calculated separately for each treatment. The average juice percentage was obtained from the following formula:

$$\text{Juice \%age} = \frac{\text{Average juice weight}}{\text{Average fruit weight}} \times 100$$

To determine number of seeds per fruit, ten fruits was taken as a sample from each tree of the respective cultivar, fruits were circumcised and the seeds were extracted, counted and average number of seeds per fruit was calculated. Peel weight and rag weight was also taken with help of electric balance and the data were recorded in grams. Peel thickness for every fruit was measured in millimeters by using vernier caliper for selected ten fruits from each treatment and then average peel thickness was calculated.

After filtration of juice 2-3 drops were placed on the prism of digital refractometer and the reading was noted. Acidity in juice was determined by taking 10 mL of juice from each sample and diluted 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.

$$\text{Acidity \%age} = \frac{\text{N/10 NaOH used} \times 0.0064}{\text{Volume or weight of sample used}} \times 100$$

Total soluble solids (TSS)/acid ratio was calculated by dividing the total soluble solids with acidity. Total soluble solids per tree (kg) were calculated by multiplying the total fruit weight per plant, juice percentage/100 and total soluble solids/100 (Bassanezi *et al.*, 2007).

The response of experimental trees to different parameters studied was evaluated by statistical analysis of data using the computer software MSTAT-C (Freed & Scott, 1986), while DMR test was used to compare the differences among the treatment means at 5% probability level.

RESULTS

Various vegetative and reproductive growth parameters showed significant differences for various sweet orange cultivars.

Vegetative growth parameters: Plant growth is measured in terms of plant height, plant spread and stem girth, all these parameters showed significant differences among various cultivars.

Plant height is important vegetative characteristic of citrus trees, as there will be more height, there will be more number of branches and total number of leaves and the leaves serve as the food manufacturing factories of plant. Maximum plant height (280.30 cm) was observed in Tarocco-N followed by Salustiana (275.50 cm) and Musambi (272.36 cm), whereas minimum plant height (208.50 cm) was observed in Glane Navel and Lane Navel (223.80 cm). It is very much clear from the results that Tarocco-N, Salustiana and Musambi performed very well regarding plant height, while Navel Oranges (Glane Navel & Lane Navel) were found to be poor for plant height whereas, all other cultivars were in between them as shown in Table I.

Maximum plant spread was observed in Salustiana (235.50 cm) followed by Emby Gold (234.80 cm) and Musambi (232.50 cm), though all the three were statistically at par with each other, while minimum plant spread was observed in Glane Navel (197.50 cm).

Similarly stem girth, which is an other important indicator of vegetative performance of plants showed that highest stem girth was found in Kozan (29.13 cm) closely followed by Marr's Early (28.75 cm), Salustiana (28.37 cm) and Tarocco-N (28.36 cm), whereas minimum stem girth was observed in Hamlin (26.13 cm) as shown in Table I.

Reproductive parameters: The results for number of fruits per plant indicated significant differences among cultivars. Highest numbers of fruits per plant were observed in Musambi (345.75) followed by Salustiana (321.75) and Tarocco-N (298.75), while lowest numbers of fruits per plant were observed in Glane Navel (87.25) and Lane Navel (89.50). Similarly, results for total fruit weight per plant also depicted significant differences, maximum fruit weight per plant was found in Tarocco-N (69.34 kg) closely followed by Salustiana (67.85 kg) and Musambi (61.59 kg), while lowest fruit weight per plant was observed in Glane Navel (23.42 kg) and Lane Navel (24.23 kg) (Table II).

Table I: Vegetative growth parameters of different cultivars of sweet orange

Cultivar	Plant height (cm)	Plant spread (cm)	Stem girth (cm)
Salustiana	275.50 ab	235.50 a	28.37 abc
Emby Gold	260b c	234.80 a	26.88 cd
Lane Navel	223.80 d	214.30 bcd	27.63 abcd
Glane Navel	208.50 d	197.50 d	28.25 abc
Hamlin	260.50 bc	219.00 abc	26.13 d
Tarocco-N	280.30 a	225.00 abc	28.36 abc
Casa Garande	257.30 c	206.80 cd	28.50 ab
Hinkley	257.50 c	219.80 abc	27.25 bcd
Marr's Early	243.50 c	231.50 ab	28.75 ab
Kozan	245.50 c	225.50 abc	29.13 a
Musambi	272.36 ab	232.50 a	28.16 abc

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

Physio-chemical characteristics: Total soluble solids (TSS) are an important measure of the sugar contents of the fruits as sugars constitute approximately 85% of the soluble solids in citrus fruits (sweet oranges & mandarins) (Wardowski *et al.,* 1979). Significant differences of TSS were observed among various sweet orange cultivars. Maximum TSS was observed in Salustiana (9.50%) followed by Musambi (9.19%) and Tarocco-N (9.12%), while lowest TSS was found in the fruits of Lane Navel and Glane Navel, 7.35% and 7.55%, respectively.

The data pertaining to acidity showed significant effect of cultivars on acidity. Highest fruit juice acidity was observed in Kozan (1.24%) followed by Hinkley (1.20%) and Hamlin (1.11), whereas minimum acidity was found in Musambi (0.55%) and Salustiana (0.39%) (Table II). It indicates that fruits of Musambi and Salustiana are less acidic compared to other cultivars.

Total soluble solids (TSS) per plant were also calculated, which showed significant differences among the cultivars. Maximum TSS per plant was observed in Tarocco-N (3.04 kg) followed by Musambi (2.87 kg) and Salustiana (2.65 kg), while lowest TSS per plant was observed again in Lane and Glane Navel (0.81, 0.83 kg, respectively) (Table II).

Maximum fruit size was observed in Lane Navel (80.30 mm) closely followed by Glane Navel (77.87 mm) whereas, minimum fruit size (67.65 mm) was found in Hamlin. The fruit size of all other cultivars was in between them. Similarly per fruit weight is also another important quality parameter in citrus fruits, the results for per fruit weight also depicted significant differences.

Highest per fruit weight was observed in the fruits of Lane Navel (270.73 g) and Glane Navel (268.48 g), both were statistically at par with each other followed by Hinkley (236.77 g) and Marr's Early (235.03 g), whereas lowest per fruit weight was observed in the fruits of Musambi (178.14 g). The heaviest fruits were observed on the plants of Navel Oranges (Lane Navel, Glane Navel), while lightest fruit were on Musambi trees, but it is worth to mention here that on Navel Oranges (Lane Navel, Glane Navel) the total number of fruits per plant were very less compared to Musambi (Table III).

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 significant differences among different cultivars. Salustiana proved to be superior with a juice percentage of 50.70%, which was statistically at par with Tarocco-N having juice percentage of 50.69% followed by Musambi (49.80%), Glane Navel (48.93%), Emby Gold (48.60%) and Lane Navel (48.11%). Minimum juice percentage was recorded in the fruits of Hamlin (41.06%). Juice recovery is a qualitative parameter, Salustiana and Tarocco-N proved themselves as meritorious cultivars regarding this aspect (Table III).

Peel thickness of citrus fruit is also important fruit quality parameters and in citrus cultivars it varies from cultivar to cultivar. The results for peel thickness depicted significant differences among various cultivars of sweet oranges. Maximum peel thickness was observed in the fruit of Emby Gold (5.27 mm) followed by Hinkley (5.13 mm) and Marr's Early (4.94 mm), while lowest peel thickness was observed in the fruit of Salustiana (4.29 mm).

Peel weight per fruit was also measured, which depicted significant differences among various cultivars, maximum peel weight per fruit was observed in the fruits of Lane Navel (98.66 g) followed by Glane Navel (94.85 g) and Hinkley (89.33 g), whereas minimum peel weight per fruit was observed in Musambi (55.47 g). It is important to note that the peel weight was more in the fruits having larger size and per fruit weight, while less in the fruits having smaller fruit size and per fruit weight.

The data for rag weight per fruit showed differences among the cultivars. Maximum rag weight was observed in the fruits of Musambi (41.97 g), Hamlin (41.96 g) and Lane Navel (41.81 g), all the three cultivars were statistically at par with each other followed by Glane Navel (39.36 g), whereas minimum rag weight was observed in the fruit of Casa Garande (24.57 g). Here it is imperative to note that the rag weight was more in Musambi fruits, while its per fruit weight and diameter was very less compared to other cultivars which indicate that the fruits of Musambi have more fiber contents (roughages).

The numbers of seeds per fruit were significantly different in various cultivars. Highest numbers of seeds per fruit were observed in Kozan (22.87), Musambi (22.50) and Hinkley (21.25) followed by Casa Garande and Emby Gold having 11.62, 10.12 seed per fruit, respectively whereas minimum numbers of seeds per fruit were found in the fruits of Tarocco-N (0.75), Salustiana (3.12) and Lane Navel (3.12).

DISCUSSION

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 (Ahmed *et al.,* 2006). So keeping in view the bearing habit, plant height, plant spread and stem girth were included as a

Table II: Chemical characteristics and yield of different cultivars of sweet orange

Cultivar	Total soluble solids (TSS)	Acidity (%)	TSS/acid ratio	TSS per plant (kg)	(Fruits/plant)	Total fruit weight/plant (kg)
Salustiana	9.50 a	0.39 g	24.29 a	2.65 ab	321.75 b	67.85 a
Emby Gold	8.62 bcd	0.85 de	10.16 cd	1.83 c	212.75 c	48.22 c
Lane Navel	7.35 f	0.79 e	9.22 cd	0.81 e	89.50 f	24.23 e
Glane Navel	7.55 f	0.79 e	9.55 cd	0.83 e	87.25 h	23.42 e
Hamlin	7.75 ef	1.11 bc	7.03 ef	1.79 c	225.50 c	48.47 c
Tarocco-N	9.12 ab	1.05 c	8.72 de	3.04 a	298.75 bc	69.34 a
Casa Garande	8.96 abc	0.85 de	10.61 c	1.73 c	185.00 fg	39.69 d
Hinkley	8.19 de	1.20 ab	6.84 f	1.85 c	195.25 d	46.23 c
Marr's Early	8.30 de	0.89 d	9.34 cd	1.68 c	172.50 e	40.54 d
Kozan	8.44 cd	1.24 a	6.81 f	1.32 d	143.50 ef	30.80 de
Musambi	9.19 ab	0.55 f	17.01 b	2.87 ab	345.75 a	61.59 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.

Table III: Physical characteristics of fruit of different cultivars of sweet orange

Cultivar	Fruit size (mm)	Per fruit weight (g)	Juice percentage	Peel thickness (mm)	Peel weight (g)	Rag weight (g)	Number of seeds/fruit
Salustiana	72.91 d	210.89 d	50.70 a	4.29 c	76.06 de	34.22 bc	3.12 cd
Emby Gold	73.31 d	226.64 bcd	48.60 ab	5.27 a	88.45 abcd	32.63 bc	10.12 b
Lane Navel	80.30 a	270.73 a	48.11 ab	4.78 abc	98.66 a	41.81 a	3.12 cd
Glane Navel	77.87 ab	268.48 a	48.93 ab	4.92 abc	94.85 ab	39.36 ab	3.50 cd
Hamlin	67.65 e	214.96 cd	41.06 cd	4.68 abc	84.87 bcde	41.96 a	4.37 c
Tarocco-N	77.53 ab	232.09 bcd	50.69 a	4.86 abc	87.95 abcd	33.46 bc	0.75 d
Casa Garande	74.56 cd	214.56 cd	46.69 b	4.49 bc	79.07 cde	24.57 c	11.62 b
Hinkley	73.19 d	236.77 b	44.08 c	5.13 ab	89.33 abc	37.91 b	21.25 a
Marr's Early	76.73 bc	235.03 bc	45.31 bc	4.94 abc	82.35 bcde	36.612 b	9.50 b
Kozan	74.39 cd	214.65 cd	47.61 b	4.38 c	74.58 e	38.06 b	22.87 a
Musambi	69.71 e	178.14 e	49.80 ab	4.57 bc	55.47 f	41.97 a	22.50 a

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.

parameter of study. It was observed that various sweet orange cultivars depicted different results regarding vegetative growth parameters, Salustiana, Tarocco-N and Musambi performed very well, whereas Navel Oranges (Glane Navel & Lane Navel) were found to be poor performer (Table I). The reason of better performance of Salustiana, Tarocco-N and Musambi might be due to their better compatibility with soil and environmental conditions and better absorption of the various nutrients from the soil, as the optimum concentration of the nutrients in plant body is much more important for proper growth and development of plants (Malik, 1994). Nutrients affect the photosynthetic rate, production of carbohydrates and proteins, which in turn control plant growth and development (Taiz & Zeiger, 2002).

As for as yield parameters (number of fruits per plant & fruit weight per plant) are concerned, Tarocco-N, Salustiana and Musambi excelled other cultivars where as Navel oranges (Glane & Lane Navel) performed very poorly (Table II). It is also worth to note that although Tarocco-N was at 3rd position as number of fruits per plant was concerned, but it was at the top in the total fruit weight per plant, indicating its heavier fruits. It might be due to better in built character (genetic make up) or might be due to the better adaptability of Tarocco-N to the soil and environmental conditions (Nawaz *et al.*, 2007). The TSS to acid ratio is crucial, as it constitutes a measure of balance between sugars and acids. TSS/acid ratio serves as an indication of palatability of the juice. High values indicate sweeter fruit whereas, very high values may be indicative of insipid tasting juice (Wardowski *et al.*, 1979). Here it is worth to note that although acidity of Tarocco-N was higher compared to Musambi and Tarocco-N but TSS per plant of Tarocco-N was more compared to both of these cultivars because the juice recovery (%) was more and the total fruit weight per plant on the plant of Tarocco-N was higher compared to Musambi and Salustiana. Our findings were found to be in close consonance with that of Augusti *et al.* (2002).

Fruit diameter and per fruit weight are of commercial importance for citrus fruits marketing and trade/business. It is generally considered that in citrus with excessive increase in size the quality is impaired, while on the other side small sized fruits are of low quality (Nawaz *et al.*, 2008). As for as fruit size and per fruit weight are concerned Navel Oranges were found to be at top but the yield of Navel Oranges was very less so they can not be recommended for commercial cultivation on the other hand Tarocco-N and Salustiana showed meritorious properties having better fruit size alongwith reasonable yield potential and can be cultivated as commercial cultivars to get better returns and to fulfill the orange requirement of our country.

Generally citrus fruits with less number of seeds per fruit are processed, because most efficient processing machines fail to extract juice from highly seeded citrus fruits. Processing machines separate seed core from fruits, but even then, some seeds are crushed in juice that requires de-bittering, which is a costly process and makes the juice expensive (Anwar & Ibrahim, 2004). Internationally, the citrus fruits having less than five seeds per fruit are

considered seedless, if we follow these criteria then out of eleven sweet orange cultivars tested five cultivars (Tarocco-N, Salustiana, Lane Navel, Glane Navel & Hamlin) were seedless in present study (Table III). Tarocco-N and Salustiana's performance was comparatively better than other cultivars so they can be preferred for cultivation.

Juice recovery is a qualitative parameter and is considered to be very important, Salustiana and Tarocco-N proved as potential cultivars in this regards. Geographically, Pakistan is located at a convenient distance from major markets Middle East, Europe and Far East. Saudi Arabia alone imports more than 10,000 tones of frozen concentrate of orange juice (FCOJ) and about 300,000 tones of fresh citrus fruits (FAO, 2004). Europe and Japan are the biggest consumers of concentrated orange juices. Brazil, being the leading producer and exporter of concentrated orange juice has built "container farms" in these markets. If Pakistan wants to capture its export share of fresh, as well as of concentrate juice of citrus in such international markets, then we have to think about increasing the area and production of sweet oranges and of course, processing and export. There is a need for long term plan to introduce sweet orange cultivars in our citrus industry and develop effective package of production technology to fulfill the requirement and to compete the world market.

CONCLUSION

The studies revealed that Tarocco-N and Salustiana performed very well regarding, vegetative, reproductive and physiochemical characteristics of the fruit, as well as yield. Both of these cultivars can be recommended to the farming community of Pakistan for commercial cultivation as they have meritorious properties, have very less number of seeds per fruit and appreciable amount of juice and can successfully be used for the fresh market, as well as in processing industry for the production of fresh and frozen concentrated juices (FCJ).

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