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Variation of sweet orange (*Citrus sinensis* L. Osbeck) accessions in India and identification of high yielding types

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ABSTRACT

Tree growth, production, and fruit quality of the eight sweet orange accessions were compared with the commercial sweet orange varieties Jaffa and Valencia Late. After 10 years of evaluation all strains showed better growth than check cultivars under Delhi conditions. Among the selections, MS-13 showed the lowest and MS-7 the highest canopy volume after 10 years growth. None of the selection covered the soil surface area allotted to tree growth even after 10 years growth. Accessions MS-13 (31.07 kg/tree/year), MS-7 (23.36 kg/tree/year) and MS-3 (20.35 kg/tree/year) and MS-5 (17.51 kg/tree/year) were the most productive selections. Total soluble solids and acidity among the accessions were very close to check cultivars. All the accessions had more than 40% juice recovery, however, MS- 16, MS-17, MS-2 and MS-1 had the higher juice content. Based on overall performance, MS-5, MS-13, MS-17, and MS-7 found promising selections for citrus industry.

Key words: Sweet orange, superior selection, quality, vigour, yield.

INTRODUCTION

Citrus fruits rank first in international fruit trade in terms of value. Citrus fruits and juices have several beneficial health and nutritive properties. They are rich in vit.C or ascorbic acid and folic acid, as well as a good source of fibre. They are fat-, sodium- and cholesterol-free. In addition they contain potassium, calcium, folate, thiamin, niacin, vitamin B_6, phosphorus, magnesium and copper. They may help to reduce the risk of heart diseases and some types of cancer.

Indian citrus industry is lacking high yielding, disease-free scion varieties of different citrus species. Hence, the productivity of citrus in our country is low as compared to other countries. There is urgent need to collect and identified superior high yielding seedlings of commercial citrus species. In India, first systematic attempt to explore and collect citrus variability from different regions and conservation was made by Bhattacharya and Dutta (1) and valuable species were identified. Later, Verma *et al.* (11) surveyed Uttar Pradesh hills and collected 54 collections of different citrus specie and wild relative of citrus species and observed variations with respect to physico-chemical qualities. Singh *et al*. (10) collected several types of citrus from Mizoram and Tripura hills, Khasi, Jaintia and Garo hills of Meghalaya. A superior clone of acid lime ARL-1 was selected from Arunachal Pradesh from the variability (Dubey, 4). Among some selections, 64-82 Navel, a chance seedling of Anjiang Dehongtiancheng, has large, high quality, seedless, orange-red and easily peeled fruits with juicy flesh (Chen and Zeng, 2). Chen and Chen (3) identified Jinshuigan as chance seedling of Penggan mandarin variety, which was precocious, and productive.

A large genetic base and availability of nucellar seedlings, seedlings origin plantation, some clones/ variants of commercial citrus species have been found to have higher yield with quality fruits. It is believed that India has the highest diversity of citrus among south Asian countries. Despite this diversity, little research has been carried out to select superior high yielding clone/variants in commercial cultivars of citrus. Genetic variability in citrus is considered to be the result of many factors, such as hybridization, mutation, and type of reproduction (mostly apomictic). This large genetic diversity in India gives an opportunity to select desirable clones having high nutritive value and good processing quality. Since sweet orange is the most representative and recognizable species of this group (Novelli *et al*., 7). Hence, the present study was conducted to collect and select superior high yielding sweet orange accessions.

MATERIALS AND METHODS

A sweet orange collection orchard was established during 2003, with the strains and cultivars described below, in a spacing of 4 m × 4 m, at the Main Garden of Division of Fruits and Horticultural Technology, IARI, New Delhi, India, located at 77°12'E longitude, 28°40'N latitude and an altitude of 228.6 m above mean sea level. The region has typical subtropical climatic conditions characterized by hot and dry summer followed by cold winter. May and June are the hottest

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months with the maximum temperature varied between 41.5 to 44.5°C, and December and January being the coolest months, with the temperature ranging between 11.2 to 18.2°C. This belongs to trans-Gangetic plains of agro-climatic zones of India. Sunshine hour varied from 1.2 in January to 10.9 in June. Trees were grown in a deep, sandy loam soil having pH 7.4, $EC_{(1:2)}$ 0.30 dS m^{-1}, a cation exchange capacity (CEC) 10.72 cmol kg^{-1}, organic carbon 0.48%, soil N, 245.23 kg/ha, P_2O_5, 56.72 kg/ha, K_2O 575.82 kg/ha, and Ca and Mg soil accessions contents were also observed. The sweet orange used were given in Table 1 with Jaffa and Valencia commercial cultivars were used as control.

A flood irrigation system was utilized during the first 5 years and later was changed to a drip irrigation system at 6 l h^{-1} of water per tree discharge, during 4-6 h, thrice a week. Well decomposed farm yard manure (40 kg $plant^{-1}$) was applied during January and chemical fertilizers were applied in split during March and August at the rate of 600 g N, 300 g P_2O_5 and 600 g K_2O $tree^{-1}$ $year^{-1}$. Recommended plant protection measures were adapted for controlling pests and diseases.

Table 1. Sweet orange accessions used in study.

Name	Accession No.
MS-1	IC-273848
MS-2	IC-273849
MS-3	IC-273850
MS-5	IC-273862
MS-7	IC-274861
MS-13	IC-274693
MS-16	IC-274710
MS-17	IC-274712
Jaffa	Commercial check cultivar
Valencia	Commercial check cultivar

Vegetative growth, *viz*., Tree height and canopy spread (N-E and E-W were recorded annually for 5 years. Canopy volume (CV) was calculated as follows: CV = ¾π. a^2b; where, a = ½ (E-W spread + N-S spread); b = ½ height. Both yield by tree (kg/tree) and estimated yield (tonne/ha) were recorded annually during 5 years of production. Fruiting efficiency (fruits/ m^3 CV) and yield efficiency (kg/ m^3 CV) were also estimated. Quality parameters, *viz*., fruit weight, rind thickness, juice (%) and seeds per fruit were recorded. Juice percentage was calculated by the difference between fruit and juice weights. Two samples of 10 fruits per selection were collected to determine total soluble solids, acidity and ascorbic acid contents during the 2008-2013. Total eight sweet orange accessions and two check cultivars were considered as treatment and three replications per treatment were included for growth and yield parameters using one tree as an experimental unit. For fruit quality parameters, ten replications per treatment were included. Data were analysed using SAS statistical package in a complete randomized design.

RESULTS AND DISCUSSION

Final plant height after 9th year growth was recorded maximum in MS-3, which was at par with MS-7 and MS-17. The minimum plant height was recorded in Valencia after 9th year growth. However, canopy volume was found higher in MS-7 followed by MS-3 (Table 2). Other accessions had intermediate canopy volume. The lowest canopy volume was recorded

Table 2. Plant height, canopy volume, fruiting density and yield efficiency of different sweet orange accessions (2012-13).

Accession	Plant height (m)	Canopy volume (m^3)	Fruiting density (fruits/m^3)	Yield efficiency (kg/m^3)
MS-1	3.13^{ed}	55.84^{e}	0.67^{f}	0.13f
MS-2	2.30^{f}	35.13^{f}	0.62^{f}	0.11^{f}
MS-3	3.70^{a}	84.41^{b}	0.82^{e}	0.24^{c}
MS-5	3.15^{edc}	80.84^{c}	0.89^{e}	0.22^{dce}
MS-7	3.55^{ba}	101.82^{a}	0.84^{e}	0.23^{dc}
MS-13	2.80^{e}	64.85^{d}	1.84^{c}	0.49^{a}
MS-16	3.10^{edc}	65.37^{d}	1.35^{d}	0.20^{e}
MS-17	3.50^{bac}	55.45^{e}	0.68^{f}	0.25^{c}
Jaffa*	2.23^{f}	23.69^{g}	2.03^{b}	0.27^{c}
Valencia*	1.50^{g}	18.86^{h}	3.23^{a}	0.44^{b}
LSD (P ≤ 0.05)	0.36	3.52	0.12	0.03

*Commercial sweet orange cultivars taken as check.

in Valencia. Based on plant height, MS-7 and MS-3 seems to be vigorous, while other accessions seem to be semi-vigorous as compared to Jaffa and Valencia. Among different selections, MS-2, MS-17, MS-13 and MS-16 trees developed a lower canopy volume either due to their smaller height or canopy diameter or both. In this study, all the selections showed better growth than standard check cultivars Valencia and Jaffa in terms of plant height and canopy volume. This indicates that these selections were better adapted to climatic conditions of north India as compared to Jaffa and Valencia. Compared to other accessions, more yield realization could be obtained by using high density planting in selection MS-17, MS-2, MS-13 and MS-16 since they had moderate vigour.

Fruiting efficiency was found greater in Valencia followed by Jaffa and MS-13 and MS-16. While lowest efficiency was recorded in MS-2 (Table 2). Contrary to this, yield efficiency was found the highest in MS-13 followed by Valencia and Jaffa which was statistically *at par* with MS-17, MS-3 and MS-7. All the selections showed a superior yield than Valencia and Jaffa (Table 3). Data pertaining to yield/tree showed that MS-5 trees showed a higher fruit yield during the first year of the fruiting, while in the third year, it produced comparatively lower yield to the MS-3, MS-7 and MS-13. From second to fifth year of fruiting, MS-13 produced significantly and consistently higher yield than other selections and check cultivars. MS-3 was consistently the least productive selection during the first two years of fruiting, thereafter trees of MS-3 produced the higher yield than other accessions except MS-13 and MS-7. During fifth year of fruiting, accessions MS-13, MS-7, MS-3 and MS-5 produced higher yield than others . Except accessions MS-2, all the selections had higher yield as compared to both check cvs Jaffa and Valencia during fifth year of fruiting. Accessions MS-13, MS-7 MS-3 and MS-5 showed the highest yield during the fifth year of fruiting. As compared to check Jaffa, MS-13, MS-7, MS-3 and MS-5 had higher yield by 3.8-, 2.80- 2.50- and 2.10-fold during fifth year of fruiting. After five years of growth, the estimated yield per hectare was the highest in MS-5 followed by MS-7 and MS-2 (Table 4). Rest of the accessions had lower estimated yield than check cv. Valencia. During 6th, 7th 8th and 9th year of growth, all the accessions produced higher estimated yield as of check cultivars. However, among strains, MS-13, MS-7, MS-16 and MS-3 had higher estimated yield during 8th year of growth. However, MS-13, MS-7 and MS-5 gave higher yield during 9th year of growth. During 9th year of growth, MS-13 had 3.8-fold higher yield than cv. Valencia and 4.6-fold higher than Jaffa. Similarly, other accessions except MS-2 also had higher estimated yield as compared to check cultivars. During 9th year of planting, MS-13, MS-7 MS-3 and MS-17 yielded 277.06, 183.50, 146.97 and 69.78% higher fruit than Valencia; and 380.95, 261.61, 215.01 and 116.56% than Jaffa, respectively. However, if comparisons among accessions is taken into account for the last 5 years of yield, selection MS-13 yielded up to 20 tonnes/ha during 8th and 9th years of planting. During the 9th year of planting, yield in MS-2, MS-3, MS-16 decreased from previous years. Earlier, Saddoud Debbabi *et al.* (9) also reported variation in pomological traits of different sweet orange cultivars.

All the sweet orange accessions had significantly higher fruit weight than check cvs Valencia and Jaffa (Table 5). Nevertheless, MS-3, MS-13 and MS-7

Table 3. Fruit yield of different sweet orange accessions over five years.

Accession	Yield/ tree (kg)				
	2008-09	2009-10	2010-11	2011-12	2012-13
MS-1	2.10^{e}	5.50^{ed}	7.60^{g}	14.71^{d}	7.48^{gf}
MS-2	4.20^{cb}	12.85^{b}	8.40^{f}	10.40^{f}	3.92^{c}
MS-3	4.10^{ed}	4.87^{ed}	15.60^{d}	24.70^{b}	20.35^{cd}
MS-5	11.56^{a}	14.93^{ba}	16.80^{c}	13.10^{e}	17.51^{ed}
MS-7	4.65^{b}	12.97^{bc}	22.40^{b}	18.2^{c}	23.36^{b}
MS-13	2.40^{e}	15.90^{a}	28.60^{a}	33.11^{a}	31.07^{a}
MS-16	3.17^{ed}	6.40^{d}	12.45^{e}	24.40^{b}	13.99^{Cd}
MS-17	2.70^{e}	12.73^{c}	11.56^{e}	10.10^{f}	8.84^{f}
Jaffa*	4.07^{cd}	5.27^{ed}	8.70^{f}	7.42^{g}	8.24^{f}
Valencia*	4.50^{c}	3.87^{e}	7.56^{g}	10.85^{f}	12.60^{e}
LSD (P ≤ 0.05)	1.19	2.20	1.00	1.18	3.64

*Commercial sweet orange cultivars taken as check.

Table 4. Estimated yields of different sweet orange accessions (last five years pooled data).

Accession	Yield/ha (tonne)				
	2008-09	2009-10	2010-11	2011-12	2012-13
MS-1	1.42^{gh}	3.53^{dc}	4.73^{e}	9.53^{d}	4.66^{e}
MS-2	3.13^{c}	8.07^{b}	8.73^{c}	6.61^{f}	2.57^{f}
MS-3	1.86^{fe}	3.05^{de}	4.03^{ef}	15.60^{b}	12.45^{c}
MS-5	6.95^{a}	9.43^{a}	9.37^{c}	8.23^{e}	14.67^{b}
MS-7	3.59^{b}	8.10^{b}	10.50^{ba}	11.43^{c}	14.40^{b}
MS-13	1.62^{fg}	9.97^{a}	10.87^{a}	20.50^{a}	19.70^{a}
MS-16	1.99^{e}	4.03^{c}	7.78^{d}	15.60^{b}	8.19^{d}
MS-17	1.28^{h}	7.90^{b}	10.10^{ba}	6.73^{f}	8.83^{d}
Jaffa*	1.52^{fgh}	3.47^{de}	3.57^{f}	3.86^{g}	4.26^{e}
Valencia*	2.52^{d}	2.40^{e}	3.83^{f}	2.63^{h}	5.20^{e}
LSD ($P \leq 0.05$)	0.34	0.70	0.85	0.86	1.03

*Commercial sweet orange cultivars taken as check.

had higher fruit weight by 117.60, 91.33 and 90.60% as compared to Jaffa respectively and by 140.44, 111.43 and 110.61% respectively as of Valencia. Fruit size (length and diameter) was found highest in MS-3 (80.89 mm × 88.28 mm) followed by MS-13 (82.48 mm × 83.78 mm). Check cultivar Valencia had the minimum fruit size (59.24 mm × 61.86 mm). Juice recovery was found to be the highest in MS-16 (56.25%), which did not differ significantly with MS-2 (52.42%) and MS-17 (51.96%). However, total juice content per fruit was recorded the highest in MS-7 which was statistically at par with MS-3 and MS-13. MS-7, MS-3 and MS-13 (103.14, 102.76 and 76.74%) than standard check cultivar Jaffa and 89.61, 89.26 and 76.74% higher than Valencia. Significantly higher seeds/fruit was recorded in MS-1, which was statistically at par with MS-7, MS-13, and MS-16. Lowest count was found in Valencia which did not differ significantly with Jaffa, MS-2, MS-3 and MS-5. All the sweet orange accessions had thicker rind than both check cultivars. The highest rind thickness was recorded in MS-3 followed by MS-13 and MS-17. In other accessions, rind thickness varied from 3.44 mm in MS-16 to 4.85 mm in MS-2. Variations in physico-chemical quality was also reported in grapefruit cultivars (Dubey *et al.*, 5) and in Baramasi lemon (Jawanda *et al.*, 6).

Total soluble solids (11.31%) of MS-2 was highest which was statistically at par with MS-16 (Table 6). Moreover, all the accessions had higher TSS than commercial check cvs Jaffa and Valencia under same set of environmental and soil conditions. Pooled data over five years indicates that all accessions had TSS more than 9%. Nevertheless all accessions also

Table 5. Fruit size, juice content, seeds and rind thickness of different sweet orange accessions (5 years pooled data)

Accession	Fruit wt. (g)	Fruit length (mm)	Fruit dia. (mm)	Juice (%)	Juice (ml)/ fruit	Seeds/ fruit	Rind thickness (mm)
MS-1	202.81^{c}	73.60^{c}	76.12^{c}	50.71^{bac}	102.88^{cb}	23.92^{a}	3.49^{ed}
MS-2	165.75^{d}	64.19^{ed}	71.33^{d}	52.42^{ba}	86.86^{d}	14.52^{c}	4.85^{bcd}
MS-3	313.23^{a}	80.89^{ba}	88.28^{a}	41.69^{d}	127.03^{a}	11.60^{c}	6.48^{a}
MS-5	228.77^{c}	76.15^{bc}	81.31^{b}	41.69^{d}	94.56^{cbd}	10.68^{c}	4.17^{c}
MS-7	274.36^{b}	79.76^{ba}	83.50^{b}	46.61^{bdc}	127.27^{a}	18.40^{ba}	4.56^{cd}
MS-13	275.43^{b}	82.48^{a}	83.78^{b}	43.63^{dc}	118.63^{a}	18.80^{ba}	5.04^{abc}
MS-16	167.66^{d}	67.17^{d}	71.45^{d}	56.25^{a}	92.44^{cd}	17.33^{ba}	4.44^{bcd}
MS-17	202.64^{c}	73.91^{c}	75.69^{dc}	51.96^{ba}	105.18^{b}	17.88^{b}	5.01^{bc}
Jaffa*	143.95^{ed}	63.12^{ed}	59.34^{e}	43.86^{dc}	62.65^{e}	11.36^{c}	2.79^{e}
Valencia*	130.27^{e}	59.24^{e}	61.86^{e}	47.79^{bdc}	67.12^{e}	11.20^{c}	2.78^{e}
LSD ($P \leq 0.05$)	28.03	5.63	4.36	7.40	11.62	6.01	1.46

*Commercial sweet orange cultivars taken as check.

Table 6. Total soluble solids, acidity and ascorbic acid content in fruits of different sweet orange accessions (5 years pooled data)

Accession	TSS (%)	Acidity (%)	Ascorbic acid (mg/100 ml juice)
MS-1	9.66^{bc}	1.14^{a}	32.84^{d}
MS-2	11.31^{a}	0.92^{bc}	36.16^{cb}
MS-3	9.70^{bc}	0.82^{dc}	37.13^{b}
MS-5	9.23^{c}	0.72^{d}	36.20^{cb}
MS-7	9.04^{c}	0.79^{dc}	39.95^{a}
MS-13	10.40^{b}	0.92^{bc}	35.17^{c}
MS-16	10.46^{ba}	0.98^{b}	31.70^{d}
MS-17	9.87^{bc}	1.03^{ba}	36.47^{cb}
Jaffa*	7.54^{d}	0.75^{d}	41.73^{a}
Valencia*	8.06^{d}	0.72^{d}	36.05^{cb}
LSD ($P \leq 0.05$)	0.88	0.14	1.81

*Commercial cultivars of sweet orange taken as check.

had higher acidity than check cultivars. However, MS-5 and MS-7 had at par values of acidity with Jaffa and Valencia. Only two collections, *viz*., MS-1 and MS-17 had acidity more than 1.0%. Ascorbic acid content was also varied significantly among the accessions. The highest ascorbic acid was recorded in check cultivar Jaffa which was at par with MS-7. However, MS-17, MS-5, MS-3 and MS-2 had almost equal ascorbic acid content to another check cultivar Valencia. Accessions MS-13, MS-16 and MS-2 had higher average TSS during five years of fruiting. However, except MS-1 and MS-17, all the accessions had acidity lower than 1.0% but higher than check cultivars. For ascorbic acid content, MS-17 had higher ascorbic acid content than Valencia but similar to Jaffa. Many accessions, *viz*., MS-2, MS-3, MS-5 and MS-13 had almost equal ascorbic acid content compared to Valencia. Diversity in several phenotypic and quality traits of Mexican lime (Robles-González *et al*., 8) has also been reported. Similarly, Dubey *et al*. (5) also reported variations in different grapefruit cultivars under Delhi conditions.

Among the eight accessions and two check sweet orange cultivars, differences were observed in tree growth, fruit yield, and quality. MS-7 produced the highest tree and canopy volume values. Other accessions had moderate height and canopy volume but more than check cultivars. Since MS-13 accessions showed a lower height and canopy volume and higher yield with comparable fruit quality, it can be appropriate for planting at moderate densities for getting high returns. Hence, MS-13, MS-17, MS-5 and MS-7 may be promising for commercialization.

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