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Tree morphology, yield and fruit quality of grapefruit cultivars on different rootstocks in Inceptisol

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ABSTRACT

Influence of seven rootstocks on tree morphology, fruit quality and leaf physiology of 'Marsh Seedless' and 'Redblush' grapefruits was evaluated under subtropical north India. Rootstock effect on shoot relative elongation rate was found to be negligible. Both the cultivars showed higher fruiting density on rough lemon and Troyer citrange. 'Marsh Seedless' fruits did not differ much among rootstocks owing to sphericity. However, most spherical 'Redblush' fruits were recorded on *Jatti Khatti* (98.31%). Sour orange and *Billikichlli* induced very firm fruits in both the cultivars. 'Marsh Seedless' fruits on sour orange and *Billikichlli* developed maximum colour, whereas more bright and coloured 'Redblush' fruits were noticed on rough lemon, sour orange and *Billikichlli*. Moreover, while sour orange imparted the highest total phenol content (TPC) (490.23 mg Catechol/l juice) in 'Marsh Seedless' fruits, *Billikichlli* induced the highest (480.24 mg Catechol/l juice) in 'Redblush' fruits. 'Marsh Seedless' fruits with the highest naringin content (238.27 µg/ml) were recorded on Troyer citrange and those of 'Redblush' (122.17 µg/ml) on rough lemon. *Billikichlli* for 'Marsh Seedless' and *Jatti Khatti* for 'Redblush' were found desirable under moisture stress condition due to their lowest LWL (30.55 and 34.21%, respectively). Furthermore, highest leaf stomatal density in both 'Marsh Seedless' (0.48/mm^2) and 'Redblush' (0.40/mm^2) were reported on rough lemon.

Key words: *Citrus paradisi*, naringine, marsh seedless, redblush, total phenol content.

INTRODUCTION

Among different citrus fruits, grapefruit (*Citrus paradisi* Macf.) is a popular diet fruit due to its high content of vitamin C, minerals, organic acids, phenolics and flavonoids. These phytochemicals have been found to possess outstanding antioxidant potential, which can prevent many chronic diseases in human beings (Tripoli *et al*., 16). Grapefruit is also highly regarded among pharmaceutical industries owing to its high naringin and naringenin content, which exhibit anti-microbial and anti-cancerous properties. Additionally, grapefruit consumption enhances the bioavailability of several drugs. With growing awareness about nutrient-rich foods, Indian consumers are now showing interest in grapefruit as an essential part of a healthy diet.

'Marsh Seedless' and 'Redblush' have been recommended as two potential grapefruit cultivars in Delhi locality, which essentially belongs to subtropical north-India (Dubey *et al*., 7). Though, many rootstock evaluation programs concerning grapefruit have been carried out abroad (Castle *et al*., 5), standardisation of rootstocks in subtropical-India is still not advanced so far. Further, a clear concept about the under-lying mechanism of scion-stock interaction is of utmost importance to attain better performance under a certain edaphoclimatic condition.

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Selection of appropriate scion-rootstock combination is inevitable as it characteristically affects several metabolic processes of the composite plant such as: root hydraulic conductivity, photosynthesis, nutrient uptake, tree growth, fruit setting, yield, productivity, fruit quality, resistance to several biotic and abiotic stresses etc. (Aloni *et al*., 1; Sharma *et al*., 14). Moreover, rootstock performance also varies depending upon variety and location, which necessitates scion as well as region specific research on rootstocks. Hence, the present study aims to evaluate the performance of grapefruit cultivars 'Marsh Seedless' and 'Redblush' on different rootstocks under subtropical conditions of north India in respect of tree growth, fruit quality and leaf physiology.

MATERIALS AND METHODS

The experiment was conducted at the main orchard of Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi; which is situated at 77°12' E longitude, 28°40' N latitude and 228.6 m above msl altitude. Falling under a typical subtropical zone, it received an annual rainfall of 1123.1 and 990.9 mm during 2016 and 2017, respectively. The soil type is alluvial with pH 7.4 and electrical conductivity [EC; 1:2 (w/v) in water]. The observations were taken on 'Marsh Seedless' and 'Redblush' trees grafted on seven different rootstocks (Table 1) during 2016-17

and 2017-18. The plants were grown at a distance of 4 m × 4 m. All the standard methods of cultivation practices were followed. The experimental design was randomized block design (RBD) with five replications.

Shoot relative elongation rate (RER) was estimated according to Berman and DeJong (4) with some modifications. Length of five young shoots of July flush per plant was measured twice at one month interval with a measuring scale and RER was calculated. Fruiting density was calculated as number of fruits harvested per tree to the canopy volume. Sphericity (φ) of the fruits was determined according to Mohsenin (11). Fruit firmness was determined in five randomly harvested mature fruits by texture analyzer. Peel colour was assessed by using colour TEC PCM/PSM (CIE Lab system) machine in L*, a* and b* coordinates (McGuire, 10).

Moreover, naringin content (μg ml^{-1}) in grapefruit juice was analysed in a high-performance liquid chromatographic system– HPLC (Ribeiro and Ribeiro, 13). Total phenol content (TPC) in the fruit juice was estimated by Folin-Ciocalteu method (Thimmaiah, 15).

Leaf water loss (LWL) was measured on five fully-developed leaves collected from each selected tree. First, the fresh weight (FW) of each leaf was measured and kept at room temperature for 4 h and then its air dried weight (DW) was recorded. It was calculated using the formula:

$$\text{LWL (\%)} = \frac{(FW - DW)}{FW} \times 100$$

Stomatal density was assessed by counting the number of stomata per field of view (40X magnification) and was expressed in $mm^{2.}$

Statistical analysis was done using SAS software (9.3 SAS Institute, Inc, USA). Tukey's honest significance test was performed and P values ≤ 0.05 were considered as significant.

Table 1. Scions and rootstocks used in the study.

Common name	Scientific name
Scion cultivar	
'Marsh Seedless'	*Citrus paradisi* Macf.
'Redblush'	*Citrus paradisi* Macf.
Rootstock	
Rough lemon	*Citrus jambhiri* Lush
Attani-2	*Citrus rugulosa* Hort. ex Tanaka (Accession No. IC 285452)
Jatti Khatti	*Citrus jambhiri* Lush
Billikichlli	*Citrus reshni* Hort. ex Tanaka
Sour orange	*Citrus aurantium* L.
RLC-4	*Citrus jambhiri* Lush (Accession No. IC 274693)
Troyer citrange	*Citrus sinensis* (L.) Osbeck × *Poncirus trifoliata* (L.) Raf.

RESULTS AND DISCUSSION

Marsh Seedless trees on different rootstocks did not exhibit significant variation with regard to shoot relative elongation rate (RER) (Fig. 1). Similar trend was noticed for 'Redblush' trees, where though significantly higher shoot RER was recorded on RLC-4 (0.020 mm mm^{-1} day^{-1}) and Troyer citrange (0.017 mm mm^{-1} day^{-1}), remaining rootstocks were found to differ non-significantly from each other. In the contrast, rootstock mediated significant variation in RER was previously reported in peach (Basile *et al*., 11). Rootstocks significantly affected fruiting density (FD) of both the scion cultivars (Fig. 2). Highest FD in 'Marsh Seedless' trees was recorded on rough lemon (1.21 no. of fruits/m^3canopy volume), followed by Troyer citrange (1.05 no. of fruits/m^3

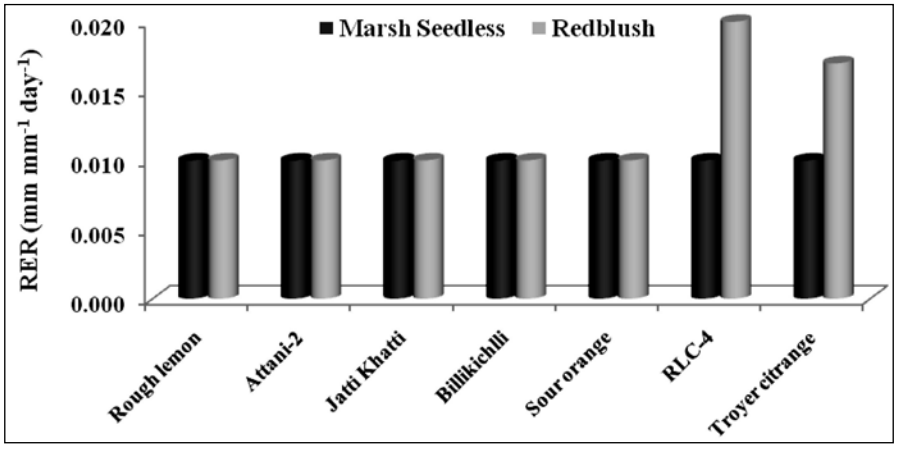

Fig. 1. Effect of rootstocks on shoot relative elongation rate (RER) of grapefruit cvs. 'Marsh Seedless' and 'Redblush'.

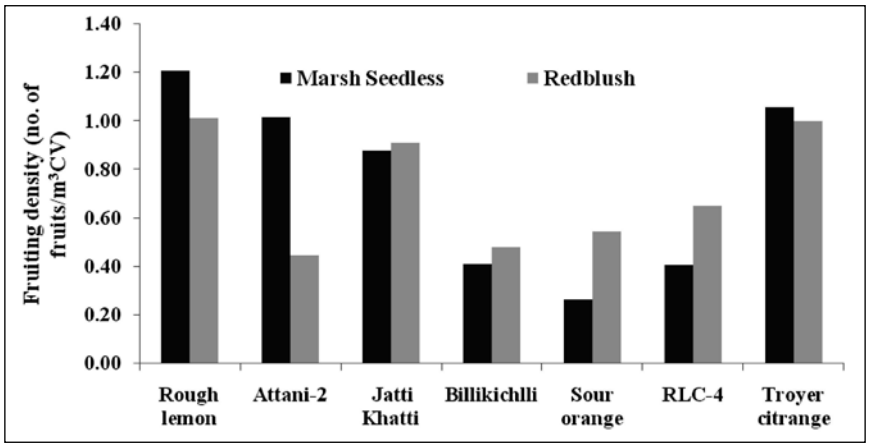

Fig. 2. Effect of rootstocks on fruiting density of grapefruit cvs. 'Marsh Seedless' and 'Redblush'.

canopy volume). Contrarily, sour orange induced the lowest FD (0.27 no. of fruits/m^3 canopy volume) in 'Marsh Seedless' trees. Further, 'Redblush' trees too, showed the highest FD (1.01 no. of fruits/m^3CV, respectively) when grown on rough lemon which did not vary significantly from those on Troyer citrange. However, 'Redblush' trees had the lowest value on Attani-2 (0.45 no. of fruits/m^3CV, respectively), which had parity with the trees on *Billikichlli* (0.48 no. of fruits/m^3CV). Rootstock triggered variation in fruiting density may be due to their differential influence on scion tree water status, nutrient uptake and photosynthetic capacity (Aloni *et al*., 1; Dubey and Sharma, 6).

Significant effect of rootstocks was noticed on different fruit physical parameters (Table 2). 'Marsh Seedless' fruits were found to be 94-95% spherical and did not differ significantly on different rootstocks. However, 'Redblush' fruits showed significant variation regarding sphericity. 'Redblush' fruits were most spherical on *Jatti Khatti* (98.31%) which was non significant with the rest of the rootstocks, except Troyer citrange and RLC-4, which induced the least spherical fruits (94.23, 94.69 %, respectively). Effect of rootstocks on fruit sphericity was alos reported earlier by Gjamovski *et al*. (9) in sweet cherry. Moreover, 'Marsh Seedless' fruits were most firm on Troyer citrange (1075.15 g), followed by those on sour orange (1058.78 g) and *Billikichlli* (979.51 g). The least firm fruits of 'Marsh Seedless' was exhibited on RLC-4 rootstock (738.03 g). 'Redblush' trees had the most firm fruits on Attani-2 (847.65 g), followed by those on *Billikichlli* (768.12 g) and sour orange (676.86 g). However, rough lemon rootstock induced the least firm fruits (503.15 g) on 'Redblush' trees. Similar findings were reported by Bassal *et al*. (3), who noticed most firm 'Marisol' clementine fruits on sour orange rootstock.

'Marsh Seedless' fruits on different rootstocks did not differ significantly with respect to peel luminosity (L*) and hue angle (h°) but varied considerably for peel chroma (C*) (Table 2). However, 'Redblush' fruits showed significant difference in respect of all the three colorimetric traits. Highest peel L* (42.01) for 'Redblush' fruits were recorded on rough lemon which was statistically at par with those on Troyer citrange. Contrarily, the lowest peel L* (30.33) was reported on RLC-4, showing no significant difference with the fruits on *Jatti Khatti*. 'Marsh Seedless' fruits having the highest peel C* were observed on sour orange (40.24), which were at par with the fruits on *Billikichlli* and Troyer citrange. Lowest C* was recorded on *Jatti Khatti* (34.85), not differing significantly from those on Attani 2 and RLC 4. Further, 'Redblush' fruits exhibited the highest peel C* on sour orange (35.92), which was statistically at par with those on the remaining rootstocks, except RLC-4 and Attani 2. Attani 2 induced the lowest peel C* (29.70). Additionally, the highest *h*° in 'Redblush' fruits was reported on Attani 2 (87.72), showing non significant variation from those on Troyer citrange. However, *Billikichlli* induced the lowest value (76.14) being statistically at par with those on sour orange. Our findings were supported by Perez-Perez *et al*. (12) in lemon.

Fruit biochemical parameters were found to be significantly influenced by different rootstocks (Table 3). Total phenol content (TPC) in 'Marsh Seedless' fruits was highest on sour orange rootstocks (490.23 mg Catechol/l juice), which was statistically *at par* with trees on Troyer citrange. Nevertheless, lowest amount of TPC in the juice was obtained on *Jatti Khatti* (305.29 mg Catechol/l juice). 'Redblush' fruits had highest total phenolic content on *Billikichlli* (480.24 mg Catechol/l juice), whereas lowest TPC was obtained on Attani 2 (333.41 mg Catechol/l juice). Furthermore, 'Marsh Seedless' fruits showed

Table 2. Effect of rootstocks on fruit sphericity, firmness and peel colour of grapefruit cvs. 'Marsh Seedless' and 'Redblush' (two years mean).

Variety/ Rootstock	Sphericity (%)	fruit firmness (g)	Peel colour		
			Luminoscity (L*)	Chroma (C*)	Hue angle (h°)
Marsh Seedless					
Rough lemon'	95.63^{cde}	893.65^{d}	41.84^{ab}	37.27^{bcd}	89.95^{a}
Attani-2	95.60^{cde}	845.61^{e}	42.49^{ab}	35.00^{def}	88.78^{ab}
Jatti Khatti	94.79^{cde}	814.47^{f}	42.09^{ab}	34.85^{ef}	87.64^{ab}
Billikichlli	95.56^{cde}	979.51^{c}	42.54^{ab}	39.62^{ab}	89.96^{a}
Sour orange	95.96^{bcde}	1058.78^{b}	45.17^{a}	40.24^{a}	87.75^{ab}
RLC-4	94.98^{cde}	738.03^{h}	41.80^{ab}	35.88^{cde}	89.96^{a}
Troyer citrange	95.44^{cde}	1075.15^{a}	43.17^{ab}	38.13^{abc}	89.90^{a}
Redblush					
Rough lemon	96.59^{abcd}	503.15^{m}	42.01^{ab}	35.41^{def}	83.17^{c}
Attani-2	97.05^{abc}	847.65^{e}	34.45^{cd}	29.70^{g}	87.72^{ab}
Jatti Khatti	98.31^{a}	647.52^{k}	32.01^{de}	33.65^{ef}	84.20^{c}
Billikichlli	97.98^{ab}	768.12^{g}	36.14^{c}	34.46^{ef}	76.14^{d}
Sour orange	96.39^{abcde}	676.86^{i}	37.12^{c}	35.92^{cde}	76.24^{d}
RLC-4	94.69^{de}	570.86^{l}	30.33^{e}	33.32^{f}	84.23^{c}
Troyer citrange	94.23^{e}	657.15^{j}	41.11^{b}	33.64^{ef}	86.00^{bc}
LSD ($P \leq 0.05$)	2.27	5.90	3.46	2.39	3.42

Table 3. Effect of rootstocks on fruit biochemical and leaf physiological parameters of grapefruit cvs. 'Marsh Seedless' and 'Redblush' (two years mean).

Cultivar/ Rootstock	Juice total phenol content (mg catechol/l)	Juice naringin content (µg/ml)	Leaf Water Loss (%)	Leaf stomatal density (mm^{-2})
Marsh Seedless				
Rough lemon'	325.77^{g}	80.76^{f}	37.63^{de}	0.48^{a}
Attani-2	367.65^{f}	111.70^{c}	43.31^{a}	0.44^{ab}
Jatti Khatti	305.29^{h}	105.48^{d}	35.82^{fg}	0.40^{abc}
Billikichlli	423.65^{b}	57.48^{h}	30.55^{i}	0.39^{abc}
Sour orange	490.23^{a}	90.09^{e}	37.32^{de}	0.33^{bcd}
RLC-4	389.65^{d}	113.99^{c}	36.00^{fg}	0.38^{abcd}
Troyer citrange	476.82^{a}	238.27^{a}	34.26^{h}	0.40^{abc}
Redblush				
Rough lemon	428.47^{b}	122.17^{b}	36.90^{ef}	0.40^{abc}
Attani-2	333.41^{g}	78.67^{f}	39.74^{bc}	0.25^{d}
Jatti Khatti	386.24^{de}	68.10^{g}	34.21^{h}	0.27^{cd}
Billikichlli	480.24^{a}	104.53^{d}	38.54^{cd}	0.38^{abcd}
Sour orange	373.18^{ef}	54.72^{h}	34.80^{gh}	0.39^{abc}
RLC-4	407.18^{c}	54.63^{h}	40.05^{b}	0.39^{abc}
Troyer citrange	422.59^{b}	82.03^{f}	39.46^{bc}	0.36^{abcd}
LSD ($P \leq 0.05$)	13.67	4.33	1.23	0.14

the highest naringin content (238.27 µg/ml) on Troyer citrange, followed by those on RLC-4 (113.99 µg/ml). The lowest naringin concentration in juice was noticed on *Billikichlli* (57.48 µg/ml). However, in 'Redblush' fruits, maximum naringin content (122.17 µg/ml) was reported on rough lemon followed by those on *Billikichlli* (104.53 µg/ml). Lowest amount of juice naringin was noticed on RLC-4 (54.63 µg/ml), which was similar statistical with those on sour orange rootstock. Influence of rootstocks on several fruit biochemical parameters was also documented in lemon by Dubey and Sharma (6).

Significant effect of rootstocks on leaf physiological traits was noticed in our experiment (Table 3). 'Marsh Seedless' trees with the highest leaf water loss (LWL) was recorded on Attani 2 (43.31 %), followed by those on rough lemon (37.63 %); while the lowest LWL (30.55%) was recorded on *Billikichlli*. However, for 'Redblush' trees, maximum LWL (40.05%) was induced by RLC 4 rootstock, which was statistically at par with those on Attani 2 and Troyer citrange. The lowest value (34.21%) was found on *Jatti Khatti* not varying significantly from those on sour orange. Our results are in accordance with those reported in grapefruits by Sharma *et al*. (14). Leaf stomatal density in 'Marsh Seedless' was found highest on rough lemon (0.48/mm^2), showing non significant variation from those on the remaining rootstocks except sour orange, which induced the lowest value (0.33/ mm^2). However, for 'Redblush' trees, the highest leaf stomatal density (0.40/mm^2) was recorded on rough lemon whiles the lowest on Attani 2 (0.25/mm^2). Other rootstocks were statistically at par with each other. Plants showing higher stomatal density may be suitable for moderate drought conditions (Galmes *et al*., 8).

It was concluded that rough lemon was found superior in terms of fruiting density and stomatal density for both the scion cultivars whereas it proved better for fruit colour and juice naringin content in 'Redblush' only. Troyer citrange too accounted for maximum fruiting density in both the scions, while for juice naringin content in 'Marsh Seedless' only. Further, sour orange and *Billikichlli* not only produced very firm fruits but also enhanced fruit colour in both the cultivars. However, while sour orange improved juice total phenolics in 'Marsh Seedless', it was *Billikichlli*, which maximised in 'Redblush'. 'Marsh Seedless' trees on *Billikichlli* and 'Redblush' trees on *Jatti Khatti* appeared to be suitable under mild drought stress.

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