Journal of Innovative Agriculture
Research Article

Young tree performance of grapefruit varieties (*Citrus paradisi* Macf.) under central Indian conditions

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Volume: 11, Issue: 1, Pages: 18-23
DOI: https://doi.org/10.37446/jinagri/rsa/11.1.2024.18-23
Received: 02 November 2023 / Accepted: 21 February 2024 / Published: 31 March 2024

Background: Grapefruit is one of the important citrus species commercially cultivated worldwide. Recently, it is gaining popularity in India. Identification of regional specific suitable varieties is important. Keeping in this view, an experiment was conducted at Research Farm, ICAR-Central Citrus Research Institute, Nagpur to evaluate performance of grapefruit varieties under Central India conditions.

Methods: Seven grapefruit varieties *viz.,* NRCC Grapefruit – 6, Flame, Star Ruby, Red Blush, Marsh Seedless, Foster and Imperial budded on Rough lemon rootstock were planted at a spacing of 5 x 5 m during 2017. The experiment was laid out in Randomized Block Design with three replications. The observations on plant growth, yield, and quality parameters were recorded during 2023.

Results: The analysis of the data suggested that significant differences were found among the grapefruit varieties for the traits studied. The highest plant height was found in Red Blush (1.71 m) followed by Marsh Seedless (1.60 m). However, the highest canopy volume was found Red Blush (4.84 m^3) followed by Marsh Seedless (3.51 m^3), which were at par. Among seven varieties, the highest fruit weight was found in NRCC Grapefruit 6 (470.67 g) followed by Red Blush (370.00 g) and Flame Grapefruit (319.33 g). The highest TSS was found in Foster (8.60 ^{o}Brix) and NRCC Grapefruit-6 (8.60 ^{o}Brix). The highest juice content was in NRCC Grapefruit-6 (37.79 %). There was no significant difference was found for number of fruits tree-1 and the highest yield was recorded in Red Blush (5.87 kg/tree) which was at par with Flame (5.51 kg/tree) and NRCC Grapefruit-6 (5.51 kg/tree).

Conclusion: Based on the findings from first year of fruiting, NRCC grapefruit-6, Red Blush and Flame grapefruit are performing better at the initial stage of bearing.

Keywords: *Citrus paradasi, grapefruit, early stage, growth, yield*

Introduction

Citrus, third most important fruit crops in India, is being cultivated in 1.09 million ha in 2020-21 with 14.26 million tonnes with productivity of 12.66 t/ha according to 3rd advance estimate published by Ministry of Agriculture and Farmers Welfare, Govt. of India. Mandarin, acid lime and lemons, and sweet orange are the three predominant citrus species cultivated in India and shares 42 %, 31 % and 19 % area respectively during 2022. The other citrus species like pummelo, citron, *etc.* occupy 8 % area. Grapefruit (*C. paradisi* Macf.) is the fourth most important species in the world (Sharma et al., 2015). It is the youngest member in citrus family which is originated in Barbados less than 300 year ago

(Scora, 1975). It is believed to be a hybrid of pummelo (*C. maxima*) and sweet orange (*C. sinensis*) (de Moraes et al., 2007). Recent molecular studies proved that grapefruit originated by hybridization from pummelo and sweet orange (Wu et al., 2018).

In India, grapefruit is cultivated in sub-tropical regions of Punjab and in a limited scale at Coorg regions of Karnataka. It is also cultivated by few farmers in Maharashtra. It has wider adaptability (Reuther, 1973) and can be grown in most of the citrus growing regions of India. Due to rich in nutrients and awareness about grapefruit among the people, it is slowly but steadily gaining popularity in India. The fruits are rich in vitamins and minerals, particularly vitamin C and also rich in phytochemicals like polyphenols, pectin, lycopene, flavonoids, limonoids, organic acids, *etc*. (Patil et al., 2009; Uckoo et al., 2011; Xi et al., 2015). It has health promoting properties, hence called as functional food (Zou et al., 2016). It is low in energy, rich in vitamin A and C and moderately rich in potassium. The peel is used for essential oil extraction and this essential oil have characteristic aroma due to presence of terpenes and terpene oxides and have high market demand (Flamini & Cioni, 2010; Esmaeili et al., 2012). Grapefruit has numerous health benefits and it is said to be good for diabetic patients. Several varieties are being cultivated throughout the world. India has vast areas suitable for grapefruit cultivation and several grapefruit varieties have been introduced. However, the information on suitable grapefruit varieties for commercial cultivation in India is lacking. Hence, the present study was undertaken to study the performance of grapefruit varieties to identify the suitable varieties based on growth, yield and quality characters.

Materials and Methods

The current study was carried out at the Research Farm, ICAR-Central Citrus Research Institute, Nagpur, Maharashtra ($21^0 09' 01"$N latitude and $79^0 01' 27"$E longitude). Seven grapefruit varieties Flame, Star Ruby, Red Blush, Imperial, Foster, Marsh Seedless and NRCC Grapefruit – 6 budded on Rangpur lime (*C. limonia* Osbeck) were used for this study. Uniformly sized, disease-free, one-year-old plants were spaced at 5 x 5 meters and planted in 2017. The experiment was laid out in Randomized Block Design with three replications and each replication comprising four trees per variety. Uniform cultural practices were followed for all the varieties and drip irrigation was used for irrigating the plants. Fruiting commenced in 2022, and the data collected in 2023 were used for analysis.

Growth characteristics such as tree height (m) and canopy volume (m^3) (CV = H (r^2) where CV= canopy volume, H= tree height and r^2= tree radius) were recorded. Yield characteristics such as fruit weight (g), fruit length (mm), fruit diameter (mm), rind thickness (mm), no. of segments, juice content (%), and no. of seeds $fruit^{-1}$ were recorded. The TSS (^{0}Brix) was measured using digital refractometer. The titratable acidity (%) was analyzed as per the method suggested by AOAC (1960). These data were collected from 10 randomly selected fruits in each replication and the mean was calculated. The no. of fruits $tree^{-1}$ and yield $tree^{-1}$ were recorded on four trees in each replication and the mean was computed. Data were subjected to statistical analysis as per the methods suggested by Panse & Sukhatme (1967).

Results

The analysis of the data revealed that significant variations were observed (p=0.05) for the different traits among the seven grapefruit varieties studied.

Table 1. Evaluation of promising clones of Grapefruit for growth parameters

Cultivar	Plant height (m)	Scion girth (cm)	Rootstock girth (cm)	Plant spread (m)	Canopy value (m^3)
Flame Grapefruit	1.33^{ABC}	18.38^{AB}	20.75^{ABC}	1.38^{BCD}	1.52^{B}
NRCC Grapefruit-6	1.48^{ABC}	23.75^{A}	26.00^{AB}	1.81^{ABCD}	2.65^{AB}
Star Ruby	1.56^{ABC}	24.25^{A}	27.25^{A}	1.91^{ABC}	3.12^{AB}
Red Blush	1.71^{A}	25.13^{A}	27.75^{A}	2.21^{A}	4.84^{A}
Imperial	1.11^{BC}	12.13^{B}	14.62^{C}	1.09^{CD}	0.92^{B}
Foster	1.00^{C}	15.25^{B}	17.50^{BC}	1.01^{D}	0.75^{B}
Marsh Seedless	1.60^{AB}	24.88^{A}	27.75^{A}	2.01^{AB}	3.51^{AB}
General Mean	1.40	20.54	23.09	1.63	2.47
SE(d)	0.179	2.537	2.803	0.250	0.892
Tukey HSD at 5%	**0.5921**	**8.3838**	**9.2625**	**0.8255**	**2.946**

The morphological data presented in the table 1 revealed that Red Blush recorded the maximum plant height (1.71 m) and Foster recorded the minimum plant height (1.00 m). Red Blush recorded maximum scion girth (25.13 cm) and rootstock girth (27.75 cm) which was at par with Marsh Seedless (scion girth – 24.88 cm and rootstock girth – 27.75

cm). The maximum plant spread and canopy volume was recorded by Red Blush (2.21 m and 4.84 m^3, respectively) and the minimum plant spread and canopy volume was recorded by Foster (1.01 m and 0.75 m^3, respectively).

The data on fruit traits (Table 2) revealed that NRCC grapefruit – 6 recorded the maximum fruit weight (470.67 g), fruit length (94.69 mm), fruit diameter (99.57 mm). Red Blush and Flame Grapefruit had the next maximum mean fruit weight averaging 370.00 and 319.33 g, respectively. Star Ruby recorded the minimum fruit weight (208.00 g), fruit length (66.25 mm) and fruit diameter (76.36 mm). In the first year of fruiting, the number of fruits per tree did not differ significantly. The maximum number of fruits per tree was recorded in Flame grapefruit (17.33 fruits/tree) and the lowest number of fruits per tree was recorded in NRCC grapefruit – 6 (11.67 fruits/tree). Red Blush recorded the highest yield (5.87 kg/tree) which was at par with Flame grapefruit (5.51 kg/tree) and NRCC grapefruit – 6 (5.51 kg/tree). The lowest yield was recorded in Star Ruby (3.19 kg/tree) which is closely followed by Foster (3.83 kg/tree).

Table 2. Fruit traits in different varieties of Grapefruit

Cultivar	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	No. of fruits per tree	Yield (kg/tree)
Flame Grapefruit	319.33^{BC}	77.30^{B}	88.62^{BC}	17.33	5.51^{A}
NRCC Grapefruit-6	470.67^{A}	94.69^{A}	99.57^{A}	11.67	5.51^{A}
Star Ruby	208.00^{D}	66.25^{C}	76.36^{D}	15.33	3.19^{B}
Red Blush	370.00^{B}	83.97^{B}	93.82^{AB}	16.00	5.87^{A}
Imperial	306.67^{BC}	78.07^{B}	86.56^{BC}	14.33	4.33^{AB}
Foster	285.67^{C}	74.85^{BC}	84.50^{C}	13.33	3.83^{AB}
Marsh Seedless	284.00^{CD}	77.04^{B}	85.92^{C}	15.00	4.24^{AB}
General Mean	320.62	78.88	87.91	14.71	4.64
SE(d)	22.006	2.831	2.196	1.963	0.583
Tukey HSD at 5%	**77.018**	**9.909**	**7.6842**	**NS**	**2.0405**

Significant differences were found among the quality traits and the data were presented in (Table 3). Flame grapefruit and NRCC grapefruit-6 had the highest juice content with 38.12 and 37.79% juice, respectively. On the other hand, Star Ruby, Imperial and Foster produced fruits with the lowest juice content in this group with 25.24, 23.39 and 23.25% juice, respectively. The lowest rind thickness was recorded in Flame grapefruit (3.45 mm) and the highest rind thickness was recorded in Marsh Seedless. The lowest rind thickness increased the pulp content; thereby it increased the juice content in Flame grapefruit. It was observed that there were significant differences in the number of seeds among cultivars. Red Blush recorded the maximum number of segments per fruit (13.83) which was at par with Imperial (13.33), Foster (13.33), Star Ruby (13.17) and Marsh Seedless (13.67).

Table 3. Fruit quality traits in different varieties of Grapefruit

Cultivar	Rind thickness (mm)	No. of segments / fruit	Juice content (%)	No. of seeds per fruit	TSS (^{0}Brix)	Acidity (%)
Flame Grapefruit	3.45^{D}	11.67^{B}	38.12^{A}	2.00^{BC}	8.13^{AB}	0.90^{D}
NRCC Grapefruit-6	7.97^{BC}	12.67^{AB}	37.79^{A}	50.00^{A}	8.60^{A}	1.15^{C}
Star Ruby	6.81^{C}	13.17^{A}	25.24^{BCD}	0.50^{C}	7.37^{B}	1.57^{B}
Red Blush	9.00^{AB}	13.83^{A}	29.43^{BC}	51.27^{A}	8.03^{AB}	1.66^{AB}
Imperial	8.63^{AB}	13.33^{A}	23.39^{CD}	52.00^{A}	8.03^{AB}	1.84^{A}
Foster	7.78^{BC}	13.33^{A}	23.25^{D}	50.00^{A}	8.60^{A}	1.59^{B}
Marsh Seedless	9.38^{A}	13.67^{A}	30.18^{B}	8.00^{B}	7.52^{B}	1.63^{AB}
General Mean	7.57	13.10	29.63	30.54	8.04	1.48
SE(d)	0.399	0.427	1.728	1.952	0.272	0.069
Tukey HSD at 5%	**1.395**	**1.4953**	**6.0483**	**6.8303**	**0.9532**	**0.242**

Among the varieties, Star Ruby, Flame grapefruit and Marsh Seedless produced lowest number of seeds, averaging 0.50, 2.00 and 8.00 seeds per fruit, respectively. The grapefruit varieties *viz.* 'Imperial', 'Red Blush', 'Foster' and 'NRCC Grapefruit-6' have produced more number of seeds, averaging 52.0, 51.27, 50.00 and 50.00 seeds per fruit, respectively. The highest TSS was recorded in NRCC grapefruit -6 and Foster (8.60 ^{0}Brix) and the lowest TSS was recorded by Star Ruby (7.37 ^{0}Brix). The lowest acidity was recorded in Flame grapefruit (0.90 %) and the highest acidity was recorded in Imperial (1.84 %)

Discussion

In grapefruit, till date, there are no recommended varieties specifically for cultivation in Central India. Identification of suitable varieties for commercial cultivation requires evaluation of different varieties for their growth and yield performance. In this study, we have evaluated seven different grapefruit varieties for their performance. Each variety exhibited unique growth characteristics. Growth characters like plant height and canopy volume are important which decides the yield of the plant. Significant differences were observed among the varieties for growth characters. In our study, Red Blush, Star Ruby and NRCC grapefruit – 6 are vigorous under Central India conditions which are essential for attaining higher production. The difference in growth of grapefruit varieties might be due to genetics, soil and climatic factors. The variation in growth patterns among different grapefruit varieties in diverse locations was earlier reported by Chaudhary et al. (1991), Ishfaq et al. (2007), and Siddique & Sharif (2020). The fruit traits are also varied significantly among the varieties except number of fruits per tree which did not differ significantly. Inherent genetics, soil and climatic conditions prevailing the growing regions affects the fruit growth and yield of the grapefruit genotype. In this study also, under uniform cultural practices, different grapefruit varieties performed differently at the initial year of fruiting. Similar findings were also reported in different grapefruit varieties by Ozeker (2000) in Turkey, Farid et al. (2015) in Morocco, Baswal et al. (2016) in India and Usman et al. (2020) in Pakistan.

Fruit quality is a key trait which determines the consumer preference and purchasing decisions. Grapefruit is mainly used for fresh juice consumption and higher juice content is highly preferable. In our study, Flame and NRCC grapefruit-6 recorded higher juice content. In India, Sharma et al., (2015) reported variation in juice content of different grapefruit varieties at New Delhi. They have recorded higher juice content (> 45 % juice content) among the varieties when compared to Nagpur conditions (<40 % juice content). Sandy loam soil with high fertility in Delhi might have been influence the juice content when compared to Central India which has black cotton soil. It clearly indicates that soil and climatic conditions influence the fruit quality traits. Seedless character is preferable in citrus as consumer usually do not prefer seeded varieties. Flame, Marsh Seedless and Star Ruby produced fruits with very few seeds at Nagpur. Similar pattern of seeds per fruits were recorded in Delhi conditions (Sharma et al., 2015) except Red Blush which recorded lower seed number per fruit in Delhi. TSS and acidity are the two important factors in citrus which decides the quality. The fruit quality traits are also highly influenced by genetics of the plant, soil and climatic conditions of the growing regions. Variation among the grapefruit varieties grown at different places for fruit quality traits were also reported earlier (Sharma et al., 2015; Farid et al., 2015; Baswal et al., 2016, Siddique & Sharif, 2020; Usman et al., 2020).

Conclusion

Seven grapefruit varieties exhibited significant variations in growth, yield, and quality traits. NRCC Grapefruit-6, Flame Grapefruit, and Red Blush showed vigorous growth, recorded high yields, and produced excellent quality fruits at the initial stage of fruit bearing. This study is also revealed that the Central India is suitable for grapefruit cultivation. Further, it is also suggested that at least five more years of yield and quality data are required to recommend the most suitable grapefruit varieties for commercial cultivation in Central India.

Acknowledgment

The authors are highly grateful to the ICAR- All India Coordinated Research Project for funding and the authors are highly thankful to Director, ICAR-Central Citrus Research Institute, Nagpur for technical and logistical support

Author contributions

Thirugnanavel Anbhazagan: Conducted experiment, data collection, analysis and manuscript writing. Ashutosh Murkute: Conducted experiment and data collection. Indrapal Singh: Designed and conducted experiment. R.K. Sonkar: Manuscript editing. Prasanth Tejkumar: Manuscript editing. Prafulla Jalamkar: Data collection.

Funding

No funding.

Conflict of interest

The author declares no conflict of interest. The manuscript has not been submitted for publication in any other journal.

Ethics approval

Not applicable.

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