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Studies on pre-bearing performance of various rootstocks in sweet orange (*Citrus sinensis*) cv. Sathgudi

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Abstract
The present investigation was undertaken to know the pre-bearing performance of various rootstocks in sweet orange cv. Sathgudi. In this study, different rootstocks namely Rough lemon, Rangpur lime, Alemow NRCC-1, NRCC- 2, NRCC -3, NRCC-4, NRCC-5 and NRCC-6 were budded with scion of Sweet orange cv. Sathgudi. The results revealed that scion budded on NRCC-3 took minimum (17.66 days) for first bud sprouting and (26.22 days) for 50% sprouting contrarily the NRCC-1 root stock took a maximum (22.44 days) for first bud sprouting and (31.44 days) for 50% sprouting. The scion attributes like length of the scion, diameter of the scion, sturdiness quotient, number of leaves, number of nodes, length of internodes, relative water content (RWC), and girth of the rootstock were found to be maximum in the scion budded on NRCC-3 rootstock and the minimum were recorded in scion budded on NRCC-1. The total chlorophyll content (1.11 mg/g) including chlorophyll -a (0.85 mg/g) and chlorophyll -b (0.37mg/g) was found to be maximum in scion budded on Rough lemon rootstock while the lowest was recorded in NRCC-1.

Keywords: Rootstocks, budding, scion attributes, relative water content (RWC) and total chlorophyll content

Introduction
Sweet Orange (*Citrus sinensis*) was considered one of the most important fruit crops of the citrus group. Sweet Orange belonged to the family Rutaceae. It, required a dry climate, arid weather and distinct summer and winter seasons with low rainfall. It was grown on a wide range of soils ranging from clay to light sandy and was sensitive to salt. Sweet orange was well grown on medium black, red, alluvial sandy loamy soil in Andhra Pradesh state. In Andhra Pradesh, Sweet orange was cultivated in an area of 118,210 ha with a production of 2,955,170 MT of fruit and was first placed both in the area and production of sweet orange during the year 2021-22.

Budding had several benefits, including the ability to combine the finest qualities of a scion with those of a rootstock and allowing trees to mature consistently and start bearing fruit sooner than those propagated by seeds (3 to 4 years in contrast with 6 to 7 years). The selection of suitable graft combinations was essential to produce fruits because scion and rootstock relations affected the physiology of each other, including minerals uptake, vigor, and yield performance. Rootstocks significantly affect the capacity of grafted plants to absorb nutrients and water, synthesize hormones and store photosynthates. More than twenty horticultural characteristics were affected by the rootstocks, such as tree vigor, tolerance to temperature, disease resistance, and adaptation to adverse soil conditions. The rootstock made the tree adaptable to soil and climatic conditions as well as resistant to pests and diseases. Therefore, rootstocks affected the rate of growth and had an impact on the quantity and quality of fruit (Lacey and Foord 2006) [3]. In addition to supporting the tree in the soil, the rootstock was also responsible for the absorption of water and nutrients, thus altering the increase of the tree canopy, photosynthesis, providing storage of carbohydrates and tolerance to some diseases. Most citrus plantations in Andhra Pradesh state were on Rangpur lime rootstock. This stock had suitable characteristics like drought tolerance, an extensive root system for high vigour, a large tree, high yield and early production but was susceptible to gummosis and citrus greening. These diseases became the most lethal diseases of citrus in India, which were mainly responsible for citrus decline, particularly sweet oranges, resulting in lowering the productive age of orchards (Reddy *et al.*, 2021) [8].

Given the significant role that the currently utilized rootstocks played in the state, the requirement for new rootstocks emerged as a critical issue. The imperative to prioritize the development of fresh varieties and rootstocks in Andhra Pradesh was evident. Therefore, the evaluation of appropriate citrus rootstocks was crucial because these rootstocks influenced growth characteristics and physiological parameters of scion on 9 rootstocks budded with Sweet orange cv. Sathgudi under the Rayalaseema region of Andhra Pradesh. Keeping in mind the above consequences, the current study was undertaken.

Materials and Methods

A citrus rootstocks trial was conducted in the Fruit Science block of field No.18, College of Horticulture, Anantharajupeta, which fell under the Southern agro-climatic zone of Andhra Pradesh at an elevation of 162 m (531 feet) above mean sea level, and geographically it lay between 13° 59' North latitude and 79° 19' East longitude. The promising seedling rootstocks of 11 months old were brought from CCRI, Nagpur, and they were planted in the open field. The scions of Sathgudi were collected from 7-year-old plants and T-budded on 1-year-old rootstock. The plants were drip irrigated and exposed to conventional practices.

Scion and rootstocks used in this study

Scion species:	*Citrus sinesis*
Scion cultivar:	Sathgudi
Root stocks:	Alemow, Rangapur lime, Rough lemon, NRCC -1, NRCC-2, NRCC-3, NRCC-4, NRCC-5, NRCC-6.

A research trial consisted of nine treatments (rootstocks), with 5 plants per treatment and 3 replications, resulting in 135 plants as experimental material for the study. Data related to budding performance and growth attributes of scion influenced by rootstocks were recorded. The budding performance was evaluated by noting the number of days required for the first bud sprouting and for 50 percent sprouting by regularly observing the scion in the field. The length (in centimeters) of the scion shoot and the diameter of the scion were measured using a scale. The sturdiness quotient was calculated by dividing scion height by scion diameter. The number of leaves, the number of nodes, and the length of internodes were recorded from a newly sprouted scion shoot. The relative water content (RWC) of the leaves was measured using the formula: RWC = (FW-DW/ TW-DW) * 100, where FW = Fresh weight measured with an electronic balance, DW = Dry weight measured by drying turgid weighed leaves in an oven at 60°C for 24 hours, and TW = Turgid weight of leaves, measured with an electronic balance by immersing leaves selected for fresh weight in distilled water for 24 hours. The chlorophyll content of leaves was determined using supernatant extract of leaves with a spectrophotometer. The girth of the rootstock was measured at the broadest point using Vernier calipers. The experiment was set up in a randomized block design with nine treatments replicated thrice. The significance of various treatment effects was assessed using the "F" value at a 5% level of significance.

Results and Discussion

In terms of budding performance, NRCC-3 had the quickest first sprouting, taking just 17.66 days. Rangapur lime, Rough lemon, NRCC-6, Alemow and NRCC-2 had similar sprouting times, with values ranging from 18.22 to 20.33 days, all comparable to NRCC-3. NRCC-4 had a slightly longer time at 20.77 days. NRCC-1, on the other hand, had the slowest first bud sprouting, taking 22.44 days. NRCC-3 also exhibited rapid 50% sprouting, with only 26.22 days required, followed by NRCC-5 at 29.55 days. In contrast, NRCC-1 took the longest time for 50% bud sprouting, with 31.44 days. This variation in sprouting times is likely due to the establishment of a connection between the rootstock and scion, with the adhesion of parenchyma being the first step, followed by the development of vascular elements. The formation of a vascular connection during wound healing is crucial, as grafting can disrupt the plant's vascular system. Similar findings were reported by Rasool *et al.* (2020) [7] and Ona *et al.* (2018) [4] in Sweet orange.

Rootstock pummelo had a quick bud break, occurring in just 21.31 days, while Kalamanchi took the longest at 22.36 days. Kalamanchi also had the maximum number of leaves per graft, with 37.35 leaves, whereas rough lemon had the minimum at 22.49 leaves.

The length of the growing scion shoot was at its maximum when budded on NRCC-3 rootstock, with the highest plant height reaching 28.44 cm, and Rangapur lime closely followed with a height of 28.39 cm, which was on par with NRCC-3. Rough lemon had a slightly shorter height of 26.43 cm. On the other hand, the minimum scion height (16.57 cm) was observed with NRCC-1 rootstock. NRCC-3 rootstock also recorded the maximum scion diameter (1.03 cm), while Rangapur lime had a diameter of 0.58 cm, and NRCC-1 had the smallest scion diameter at 0.38 cm. The increased scion shoot length over rough lemon might be attributed to the quick and strong union formation between the rootstock and the bud (Skene *et al.*, 1983) [11], along with an adequate supply of photosynthates during the early growth stage.

The maximum sturdiness quotient (49.68) was found in the Rangapur lime rootstock, while NRCC-5 had the lowest sturdiness quotient. NRCC-3 showed the highest number of nodes (25.22), and Rangapur lime closely followed with 24.44 nodes, which was on par with NRCC-3, whereas Rough lemon had 20.44 nodes. The minimum number of nodes (13.22) was observed with NRCC-1. Both the number of leaves and the length of internodes were at their maximum when budded on NRCC-3 rootstock, followed by Rough lemon. Conversely, the minimum number of leaves and the shortest internode length were observed with NRCC-1. These variations could be attributed to inherent differences in the rootstocks (Rajamanickam *et al*., 2021) [6] and likely resulted from ongoing developmental processes, including cell division, expansion, and differentiation, which influence the size, shape, and structure of plants (Taiz *et al.*, 2002) [12].

The girth of the rootstock nearly doubled, with NRCC-3 rootstock recording the maximum girth (10.30 mm), followed by NRCC-4 (7.25 mm) and NRCC-1 had the smallest girth at 6.17 mm. The effect of rootstock, period, and their interaction significantly influenced rootstock girth (Jitendra *et al.*, 2012) [1].

Regarding chlorophyll content, Rough lemon exhibited the highest total chlorophyll content (1.11 mg/g), followed closely by Rangapur lime (1.07 mg/g), NRCC-3 (1.05 mg/g), NRCC-6 (1.05 mg/g) and Alemow (1.00 mg/g) which were on par with Rough lemon. NRCC-4 had a lower total chlorophyll content (0.83 mg/g). Conversely, NRCC-1

rootstock exhibited the lowest total chlorophyll content (0.68 mg/g). These differences may be attributed to variations in chlorophyll synthesis and degradation in these rootstocks, with more photo-oxidation of chlorophyll pigment observed in NRCC-1 due to its lower chlorophyll content (Richmond and Lang, 1957) [9]. Similar results were reported by Kumar *et al*. (2017) [2] in Kinnow on different rootstocks.

Relative water content (RWC) among rootstocks showed significant differences, with NRCC-3 rootstock having the highest RWC (76.38%), followed by Rangapur lime (75.08%), Rough lemon (74.60%), and NRCC-6 (72.04%) which were on par with NRCC-3, followed by Alemow (70.64%). The lowest RWC was found in NRCC-1 (67.72%) rootstock. NRCC-3's high RWC may be attributed to its inherent characteristics, as it is vigorous in terms of water and nutrient absorption (Singh *et al.,* 2019) [10], making it better suited for water-scarce areas. Higher RWC values in leaves could be considered selection criteria for breeding plants that tolerate drought conditions (Rahman *et al.,* 2000) [5].

In conclusion, rootstock had good compatibility between both, scion and rootstock and have major effect on morphological and physical parameters like budding performance length of scion shoot, scion diameter, number of nodes, leaves and sturdiness quotient etc. The judicious selection of rootstock leads to success of citrus plantations whereas wrong selection leads to decline. Our findings suggested that the overall performance of NRCC-3 rootstock was better in budding performance and various physical growth attributes of the scion.

Table 1: Number of days required for first sprouting and days required by 50% sprouting influenced by various root stocks

Root stocks	Days required for first sprouting	Days required for 50% sprouting
NRCC-1	22.44	31.44
NRCC-5	21.77	29.55
NRCC-4	20.77	29.00
Alemow	19.22	27.44
Rangapur lime	18.22	26.77
NRCC-6	18.78	27.44
NRCC-2	20.33	28.77
NRCC-3	17.66	26.22
Rough lemon	18.77	26.89
SE (m)	1.00	0.97
CD@5%	3.02	2.96

Table 2: Stem parameters and sturdiness quotient influenced by various root stocks

Root stocks	Stem parameters				Sturdiness quotient H/D	
	Scion Height(cm) (H)		Scion Diameter(cm) (D)			
	60 Days	90 Days	60 Days	90 Days	60 Days	90 Days
NRCC-1	8.74	16.57	0.19	0.38	45.77	43.17
NRCC-5	8.86	17.30	0.22	0.40	39.23	43.25
NRCC-4	10.00	17.96	0.23	0.41	43.11	42.86
Alemow	15.53	21.39	0.34	0.54	45.15	39.62
Rangapur lime	19.87	28.39	0.40	0.58	49.68	48.69
NRCC-6	16.46	25.70	0.39	0.57	42.20	44.69
NRCC-2	13.01	19.72	0.28	0.43	45.98	44.93
NRCC-3	23.11	28.44	0.47	1.03	48.44	27.54
Rough lemon	18.88	26.43	0.39	0.60	48.28	43.76
SE (m)	0.86	0.50	0.05	0.02	0.78	0.59
CD @ 5%	2.62	1.52	0.17	0.08	2.38	1.80

Table 3: Number of leaves, girth of root stock, chlorophyll content and RWC of leaves influenced by various root stocks.

Root stocks	Number of leaves on scion		Girth of rootstock (mm)		Chlorophyll content (mg/g)			RWC of leaves (%)
	60 Days	90 Days	Before budding	After budding	Chlorophyll a	Chlorophyll b	Total Chlorophyll	
NRCC-1	7.66	12.39	3.13	6.17	0.57	0.15	0.68	67.72
NRCC-5	8.55	12.44	3.86	6.52	0.57	0.23	0.81	67.91
NRCC-4	9.29	14.55	3.90	7.25	0.61	0.24	0.83	69.93
Alemow	14.22	14.11	4.25	8.60	0.74	0.27	1.00	70.64
Rangapur lime	16.11	21.11	4.98	9.59	0.81	0.34	1.07	75.08
NRCC-6	14.33	18.33	4.37	8.63	0.77	0.28	1.05	72.04
NRCC-2	11.55	13.89	4.18	7.25	0.73	0.25	0.94	70.07
NRCC-3	18.67	22.44	5.20	10.30	0.81	0.33	1.05	76.38
Rough lemon	15.22	18.55	4.44	9.29	0.85	0.37	1.11	74.60
SE (m)	2.11	0.84	0.24	0.71	0.03	0.03	0.08	1.25
CD @ 5%	6.38	2.55	0.72	2.15	0.10	0.11	0.26	3.78

Conclusion

In conclusion rootstock had good compatibility between both, scion and rootstock and have major effect on morphological and physical parameters like budding performance length of scion shoot, scion diameter, number of nodes, leaves and sturdiness quotient etc. The judicious selection of rootstock leads to success of citrus plantations whereas wrong selection leads to decline. Our findings suggested that the overall performance of NRCC-3 rootstock was better in budding performance and various physical growth attributes of the scion.

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