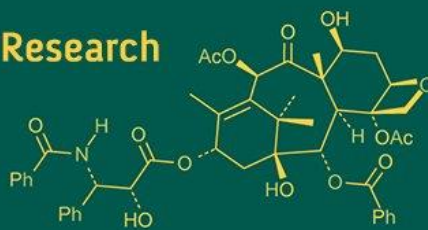
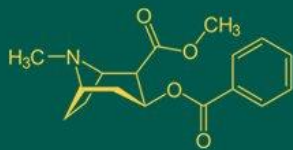


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Comparative study of bud take success and early growth of different sweet orange (*Citrus Sinensis* (L.) Osbeck) cultivars on rough lemon rootstock

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Abstract

A comparative study was undertaken to evaluate the bud take success and early growth characteristics of six sweet orange varieties budded onto rough lemon rootstock. The varieties tested includes T₁-Pera, T₂-Sathgudi, T₃-Mosambi, T₄-Anantapur Local, T₅-Nallimpalli Local and T₆-BARI 1 arranged in a Randomized Block Design (RBD) with three replications. Key parameters assessed were Days taken to bud sprout, budding success percentage (%), Height of the budded plant (cm), Root length (cm), Fresh weight of the root (g), Fresh weight of the shoot (g), Dry weight of the root (g), Dry weight of the shoot (g) reflecting the compatibility and early vigor of the scion-rootstock combinations. Results showed that T₂-Sathgudi demonstrated the highest budding success and rapid bud sprouting coupled with superior early growth traits across all parameters. Conversely, T₁ exhibited the lowest with delayed performance and reduced growth measures. These findings highlighted significant varietal differences affecting budding success and early development, aligning with prior studies emphasizing rootstock-scion compatibility as critical for successful propagation. The superior performance of Sathgudi on Rough lemon rootstock suggests its potential preference for nursery and commercial planting programs aiming for efficient establishment and vigor in early growth phases. This research provides empirical basis for varietal selection prioritizing early bud success and vigor on rough lemon rootstock to optimize citrus nursery production.

Keywords: Rootstock, scion, budding, bud sprout and fresh weight

Introduction

Citrus is among the most widely cultivated fruit crops worldwide, valued both for its pleasant taste and aroma as well as for its nutritional benefits. These fruits are especially recognized for their high vitamin C levels and for containing numerous bioactive compounds, such as carotenoids and flavonoids, that contribute to human health. Taxonomically, citrus belongs to the Rutaceae family under the subfamily Aurantioideae, which also includes genera such as *Fortunella*, *Poncirus*, *Eremocitrus*, and *Microcitrus*. Historical and genomic evidence suggests that the citrus group originated in Southeast Asia, particularly in the Himalayan region, and later spread to other parts of the world. Recent genomic studies have further confirmed this origin, showing that the crop thrived under favorable monsoon climates (Wu *et al.*, 2018) ^[27].

Sweet orange (*Citrus sinensis* L.), considered one of the most important and palatable citrus fruits, was spread globally through historical trade routes, particularly by Portuguese and Italian traders. Today, the major producers of sweet orange include the United States, Brazil, Spain, Italy, India, South Africa, and Egypt, with the United States leading world production (Shravan *et al.*, 2018) ^[22]. In India, citrus occupies about 1.09 million hectares with an annual production of roughly 14.15 million metric tons, of which sweet orange contributes approximately 220 thousand hectares and 3.89 million metric tons (Anonymous, 2021) ^[2]. Its popularity across the country is mainly due to its sweetness, fragrance, and attractive golden-yellow color.

Botanically, sweet orange trees are medium-sized, evergreen, and upright, with spreading crowns and slender, sometimes spiny branches. Budding is the most common method of citrus propagation, as it allows desirable traits of both scion and rootstock to be combined, while also reducing the time required for trees to reach fruit-bearing maturity compared to

seed-propagated plants. Appropriate scion-rootstock combinations are vital for successful orchard establishment, influencing mineral uptake, growth vigor, and fruit yield. The present study was therefore designed to evaluate the performance of different sweet orange cultivars when budded onto rough lemon (*Citrus jambhiri* Lush.) rootstock. The focus was on assessing budding success, establishment rate, and early growth performance of the scions. The results are expected to provide practical guidance to farmers and nursery managers in choosing the most suitable scion cultivars for efficient nursery production and enhanced orchard productivity.

Materials and Methods

The study was conducted during 2023-2024 in Madharpakkam, Vaniyamallee village, Tamil Nadu. Seeds of rough lemon (*Citrus jambhiri* Lush.) rootstock were procured from Arasampatti, Vellore District. These seeds were sown in nursery beds and the seedlings were transplanted to the main field after four months. The plants received regular irrigation and standard nursery management practices. After 11 months, seedlings with a uniform stem girth of 0.8-1.0 cm were selected for budding, as rootstocks of this age and diameter (0.7-0.9 cm) are considered ideal for the operation. Scion budwood for the six sweet orange (*Citrus sinensis* L. Osbeck) cultivars—T₁: Pera, T₂: Sathgudi, T₃: Mosambi, T₄: Anantapur Local, T₅: Nallimpalli Local, and T₆: BARI 1—was collected from certified, healthy, and high-yielding mother plants. The budwood consisted of mature, dormant shoots from the previous season's growth. Following recommended practices, the basal one or two buds were discarded. The budding operation was carried out during the favourable period of June to September. A few days prior to budding, leaves, thorns, and suckers were removed from the rootstock stem up to the intended budding height. The T-budding method was used, where a T-shaped cut was made on the rootstock bark and a single scion bud was inserted into the opening. Bud union formation occurs in stages: first, callus tissue develops, then the cambial layers join, and later vascular tissues grow to connect the scion and rootstock. A Randomized Block Design (RBD) was adopted, consisting of six scion cultivars as treatments, each replicated three times. Different growth parameters were monitored, with early data collected on bud sprouting time and success percentage. Plant height and other growth traits were measured 180 days after bud emergence. Additional data included root length, fresh and dry weights of roots and shoots. Statistical analysis followed the procedures outlined for RBD by Panse and Sukhatme (1985).

Results and Discussion

The present investigation aimed to evaluate the influence of different sweet orange (*Citrus sinensis* L. Osbeck) scion cultivars on the success and subsequent growth of bud on rough lemon (*Citrus jambhiri* Lush.) rootstock. The results revealed significant differences among the six scion cultivars for all parameters studied, with 'Sathgudi' (T₂) consistently demonstrating superior performance and 'Pera' (T₁) exhibiting the least desirable outcomes.

Number of days taken to sprout

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus*

sinensis) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in number of days taken to sprout. Among the treatments, T₂-Sathgudi (34.42) took minimum number of days followed by T₄-Anantapur local (35.45). The maximum number of days (42.73) taken for bud sprout was recorded on T₁ (Pera). Faster sprouting in compatible grafts such as 'Sathgudi' is likely due to quicker healing and earlier re-establishment of vascular flow, allowing nutrients and water to reach the bud sooner (Goldschmidt, 2014) [10]. The delayed sprouting in 'Pera' suggests poor compatibility, where slower callus formation or structural misalignment reduces the efficiency of vascular development, a concept supported in graft studies of other crops (Warschefsky *et al.*, 2016) [26].

Budding success percentage (%)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in budding success percentage. Among the treatments, T₂ (Sathgudi) recorded the highest budding success at 96.81%, followed by T₄ (Anantapur local) with 92.49%. The lowest budding success was observed in T₁ (Pera), which recorded 67.75%.

High success rates in compatible pairs reflect strong union formation and the establishment of functional vascular bridges (Goldschmidt, 2014) [10]. Conversely, lower percentages in cultivars such as 'Pera' may result from weak adhesion, interrupted vascular differentiation, or physiological barriers that prevent proper graft union development (Warschefsky *et al.*, 2016) [26].

Height of the budded plant (cm)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in height of the budded plant. Among the treatments, T₂ (Sathgudi) attained the maximum budded plant height of 52.31 cm, followed by T₄ (Anantapur local) at 51.34 cm. The minimum height of 47.26 cm was recorded in T₁ (Pera).

The taller growth of 'Sathgudi' can be attributed to its vigorous scion characteristics and effective resource transfer across the graft union, enabling continuous supply of nutrients and hormones to the shoot apex. Such compatibility-driven growth advantages have been observed in mango (Yeshitela *et al.*, 2017) [29] and tomato (Djidonou *et al.*, 2019) [7]. By contrast, the restricted height of 'Pera' likely reflects incomplete vascular development, which limits the flow of essential resources to the scion (Warschefsky *et al.*, 2016) [26].

Root length (cm)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in root length. Among the treatments, T₂ (Sathgudi) exhibited the longest root length of 35.22 cm, followed by T₄ (Anantapur

local) at 31.19 cm. The shortest root length of 14.28 cm was recorded in T₁ (Pera).

Scion-rootstock compatibility directly affects root growth, as compatible scions enhance the downward flow of auxins and carbohydrates that stimulate root elongation (Zarrouk *et al.*, 2010; Bowman *et al.*, 2021) [30, 5]. Shorter roots in incompatible grafts such as 'Pera' indicate reduced efficiency of hormonal and carbohydrate transport, a symptom of poor graft union function (Moya *et al.*, 2022) [19].

Fresh weight of the root (g)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in fresh weight of the root. Among the treatments, T₂ (Sathgudi) recorded the highest fresh root weight of 28.52 g, followed by T₄ (Anantapur local) at 26.15 g. The lowest fresh root weight of 12.61 g was observed in T₁ (Pera)."

Heavier root biomass in compatible combinations suggests effective carbohydrate allocation from shoots to roots, a pattern also reported in apple and citrus graft studies (Tworkoski & Fazio, 2015; Mesejo *et al.*, 2020) [25, 18]. In contrast, reduced root weight in 'Pera' indicates inefficient resource transfer across the union, similar to problems observed in incompatible mango and avocado grafts (Rajan & Kumar, 2018; Gonzalez *et al.*, 2018) [21, 11].

Dry weight of the root (g)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in dry weight of the root. Among the treatments, T₂ (Sathgudi) recorded the highest dry root weight of 8.45 g, followed by T₄ (Anantapur local) at 7.83 g. The lowest dry root weight of 5.69 g was observed in T₁ (Pera)."

Strong compatibility enables steady supply of sugars and sustained root biomass accumulation. Comparable results were reported in grafted watermelon and apple, where compatible combinations showed higher root dry matter (López-Elías *et al.*, 2021; Wu *et al.*, 2019) [16, 28]. Lower root

dry weight in 'Pera' indicates impaired carbohydrate allocation across the graft interface, a common issue in incompatible grafts (Pérez-Romero *et al.*, 2020; Forner-Giner *et al.*, 2018) [20, 9].

Fresh weight of the shoot (g)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in fresh weight of the shoot. Among the treatments, T₂ (Sathgudi) recorded the highest fresh shoot weight of 33.95 g, followed by T₄ (Anantapur local) at 28.15 g. The lowest fresh shoot weight of 15.45 g was observed in T₁ (Pera).

Greater shoot biomass reflects better water and nutrient transport through a well-functioning graft union. Similar findings were reported in grafted tomato and walnut, where compatible scions maintained higher shoot weights due to efficient hydraulic and photosynthetic processes (Albacete *et al.*, 2014; Tombesi *et al.*, 2018) [1, 24]. Reduced shoot biomass in 'Pera' may be linked to limited xylem functionality and disrupted hormone balance, a problem also noted in peach-almond grafts (Lo Bianco *et al.*, 2020; Denney *et al.*, 2021) [15, 6].

Dry weight of the shoot (g)

The data pertaining to the comparative study of bud take success and early growth of different sweet orange (*Citrus sinensis*) varieties on rough lemon rootstock are presented in table 1. Significant difference was observed among the six scion cultivars which has given the positive results in dry weight of the shoot. Among the treatments, T₂ (Sathgudi) recorded the highest dry shoot weight of 12.38 g, followed by T₄ (Anantapur local) at 11.63 g. The lowest dry shoot weight of 9.04 g was observed in T₁ (Pera).

Enhanced shoot dry matter in 'Sathgudi' reflects efficient photosynthesis and assimilate translocation across the graft, supporting greater biomass accumulation. Comparable improvements have been reported in avocado and mango (Biel *et al.*, 2021; Singh *et al.*, 2019) [4, 23]. The reduced dry weight in 'Pera' suggests poor phloem connectivity, which restricts sugar flow and limits shoot development, consistent with reports in citrus and apple grafting (Gonzalez *et al.*, 2020; Fazio & Robinson, 2018) [12, 8].

Table 1: Budding Success and Early Growth Characteristics of Sweet Orange Cultivars budded on Rough Lemon Rootstock

Treatments	Days taken to bud sprout (days)	Budding success percentage (%)	Height of the budded plant (cm)	Root length (cm)	Fresh weight of the root (g)	Fresh weight of the shoot (g)	Dry weight of the root (g)	Dry weight of the shoot (g)
T ₁	42.73	74.38	18.80	14.28	12.61	15.45	5.69	9.04
T ₂	34.42	96.81	26.40	35.22	28.51	33.95	8.45	12.38
T ₃	38.30	67.75	21.70	27.37	24.18	22.13	7.25	10.93
T ₄	35.45	92.49	24.75	31.19	26.15	28.15	7.83	11.63
T ₅	39.57	88.48	20.30	22.02	18.55	19.55	6.70	10.27
T ₆	37.20	80.52	23.25	18.24	15.98	17.98	6.18	9.64
S.Ed	0.42	1.70	0.51	1.63	0.28	0.29	0.15	0.18
C.D @ 5%	0.94	3.98	1.47	3.63	0.61	0.63	0.44	0.53

Conclusion

The results of this study clearly show that 'Sathgudi' performed best when budded onto rough lemon rootstock, producing higher bud take success, faster sprouting, and more vigorous early growth compared to the other cultivars

tested. These advantages are likely due to strong genetic compatibility between the scion and rootstock, which promotes rapid union formation and efficient transport of water, nutrients, and hormones. On the other hand, cultivars like 'Pera' showed weaker performance, probably because

of poor graft compatibility that limited vascular development and resource flow. Such limitations result in slower establishment and reduced growth. Therefore, using compatible combinations such as 'Sathgudi' on rough lemon is recommended for nursery production and large-scale propagation of sweet orange. Adoption of these combinations will improve plant establishment, orchard productivity, and ultimately economic returns for citrus growers.

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