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Influence of rootstock vigor on scion growth and fruit yield in citrus under saline conditions

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Abstract

Soil salinity is one of the defining constraints for citrus cultivation in coastal and semi-arid tracts worldwide, and rootstock selection remains the most practical tool available to growers for managing its effects on tree performance. This research evaluated six commercially available rootstocks for their influence on scion growth, fruit yield, and quality of Mosambi sweet orange (*Citrus sinensis* Osbeck cv. Mosambi) under saline irrigation conditions at Kerala Agricultural University, Thrissur, during 2020-2023. Trees budded onto Rough Lemon produced the tallest canopy (284.6 cm), highest canopy volume (8.72 m³), and greatest fruit yield (48.2 kg/tree), while Cleopatra Mandarin gave the lowest yield at 28.3 kg/tree. Leaf sodium concentration was lowest in Rough Lemon (0.31%) and Volkamer Lemon (0.34%), with corresponding K⁺/Na⁺ ratios of 2.84 and 2.67. Juice quality parameters including TSS and vitamin C content followed the same ranking pattern. Vigorous rootstocks that restricted sodium translocation to the scion maintained better photosynthetic efficiency and higher yields under salinity stress of 4.2 dS/m irrigation water.

Keywords: Rootstock vigor, scion growth, citrus, saline conditions, grafted plants, Rough Lemon, sodium exclusion, fruit quality, sweet orange, salt tolerance

Introduction

Rootstock selection is, in practical terms, the single most effective decision a citrus grower can make to buffer against soil and water salinity. Citrus trees are classified as salt-sensitive, with yield reductions beginning at soil electrical conductivity levels as low as 1.7 dS/m ^[1]. In India, approximately 6.73 million hectares of agricultural land are affected by salinity, and citrus orchards in coastal Kerala, Gujarat, and Rajasthan frequently encounter irrigation water with EC values between 2 and 6 dS/m ^[2]. The damage from salinity in citrus occurs mainly through chloride and sodium toxicity to leaves, osmotic stress limiting water uptake, and nutritional imbalances caused by ion antagonism ^[3].

Rootstocks modulate the salt response of grafted trees by regulating the uptake and translocation of toxic ions from roots to the scion ^[4]. Vigorous rootstocks such as Rough Lemon and Volkamer Lemon tend to produce larger root systems with greater absorptive surface area, which may dilute ion concentrations and maintain favourable K⁺/Na⁺ ratios in the canopy ^[5]. But the relationship between rootstock vigor and salt tolerance isn't straightforward, because some dwarfing rootstocks show good sodium exclusion despite their smaller root volume ^[6]. This research aimed to compare six rootstocks for their effects on scion growth, ion partitioning, fruit yield, and quality under saline irrigation to identify the best options for salt-affected citrus orchards in Kerala.

Climatic Conditions During the Trial

The experimental orchard was located at the Instructional Farm of Kerala Agricultural University, Thrissur (10.52° N, 76.21° E, 22 m altitude). The region has a humid tropical climate with mean annual rainfall of 2,900 mm concentrated during the southwest monsoon (June-September). Mean maximum temperature ranged from 30.4°C to 36.1°C and minimum from 22.8°C to 25.6°C during the research period. Saline irrigation water (EC 4.2 dS/m, SAR 6.8) was drawn from a bore well and applied through basin irrigation at fortnightly intervals during non-monsoon months.

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Material and Methods

Material

The trial used an established orchard of Mosambi sweet orange budded onto six rootstocks: Rough Lemon (*C. jambhiri*), Rangpur Lime (*C. limonia*), Troyer Citrange (*C. sinensis* × *Poncirus trifoliata*), Sour Orange (*C. aurantium*), Volkamer Lemon (*C. volkameriana*), and Cleopatra Mandarin (*C. reshni*). Trees were eight years old at the start of observations and spaced at 6 m × 6 m. Saline irrigation had been applied for three consecutive years before data recording began in 2020 [7]. The experiment followed a randomized block design with four replications of three trees each.

Methods

Scion height, trunk girth, canopy spread, and canopy volume were measured annually. Fruit yield was recorded per tree at each harvest. Leaf samples from the fourth and fifth position on non-fruiting spring flush shoots were collected for mineral analysis. Sodium and potassium were determined by flame photometry; chloride by silver nitrate titration [8]. Juice percentage, TSS (digital refractometer), titratable acidity (NaOH titration), and ascorbic acid (DCPIP method) were measured on ten randomly selected fruits per tree per harvest [9]. Leaf chlorophyll was estimated by DMSO extraction and spectrophotometry. Data were pooled over three years (2020-2023) and analyzed by ANOVA at $P = 0.05$.

Results

Table 1: Scion growth, yield, and leaf ion status of Mosambi sweet orange on six rootstocks under saline irrigation (pooled, 2020-2023)

Rootstock	Scion Height (cm)	Canopy Vol. (m ³)	Fruit Yield (kg/tree)	Leaf Na ⁺ (%)	K ⁺ /Na ⁺ Ratio
Rough Lemon	284.6	8.72	48.2	0.31	2.84
Rangpur Lime	261.3	7.84	42.7	0.38	2.41
Troyer Citrange	228.4	6.13	35.4	0.43	2.12
Sour Orange	214.7	5.68	31.8	0.52	1.78
Volkamer Lemon	272.8	8.21	44.6	0.34	2.67
Cleopatra Mandarin	198.3	4.92	28.3	0.58	1.54
SEm(±)	8.42	0.37	2.16	0.03	0.14
CD (P=0.05)	25.26	1.11	6.48	0.09	0.42

Rough Lemon supported the tallest scion, largest canopy volume, and highest fruit yield (Table 1). Leaf Na⁺ was lowest in Rough Lemon (0.31%) and Volkamer Lemon

(0.34%). Cleopatra Mandarin accumulated the most sodium (0.58%) and had the poorest K⁺/Na⁺ ratio (1.54).

Table 2: Fruit quality parameters of Mosambi sweet orange on six rootstocks under saline irrigation

Rootstock	Juice (%)	TSS (°Brix)	Acidity (%)	Vit. C (mg/100ml)
Rough Lemon	46.8	10.4	0.82	42.3
Rangpur Lime	44.2	10.1	0.91	39.8
Troyer Citrange	41.7	9.6	0.97	36.4
Sour Orange	40.3	9.2	1.04	34.1
Volkamer Lemon	45.6	10.3	0.86	41.2
Cleopatra Mandarin	38.4	8.8	1.12	31.6
SEm(±)	1.23	0.28	0.04	1.47
CD (P=0.05)	3.69	0.84	0.12	4.41

Fruit quality mirrored the yield rankings (Table 2). Rough Lemon and Volkamer Lemon produced fruits with higher juice percentage, TSS, and vitamin C. Acidity was lowest in

Rough Lemon fruits (0.82%) and highest in Cleopatra Mandarin (1.12%).

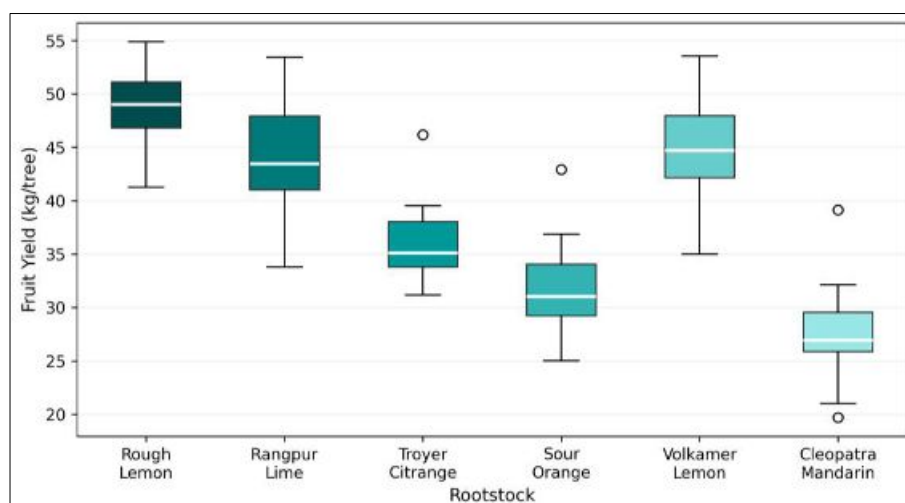


Fig 1: Fruit yield distribution of Mosambi sweet orange on six rootstocks under saline conditions over three years

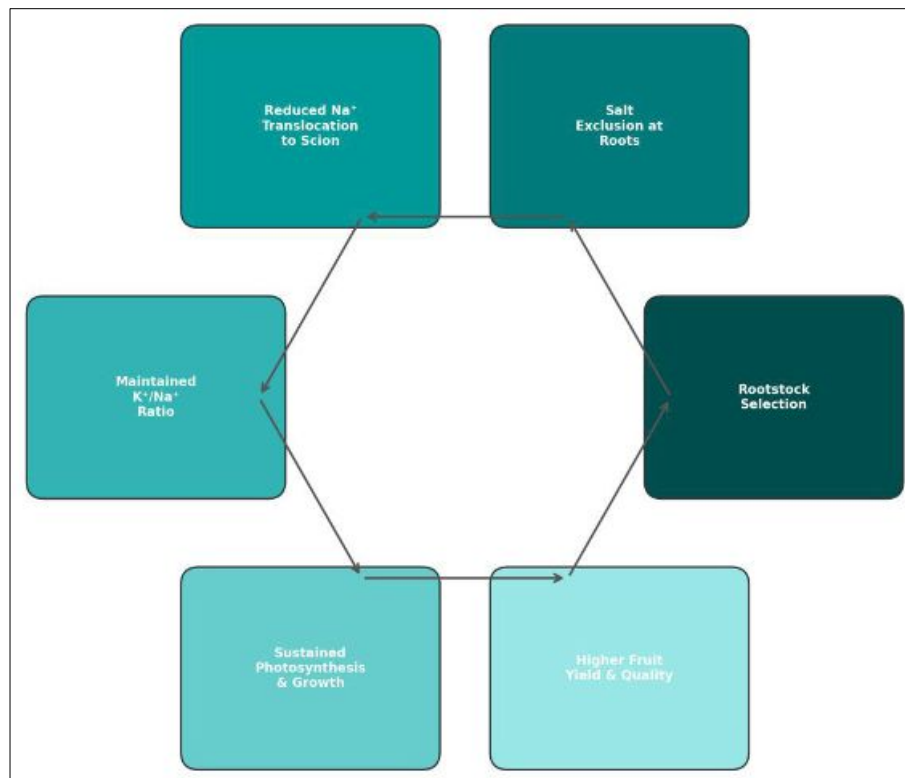


Fig 2: Cycle of rootstock-mediated salt tolerance mechanisms in grafted citrus under saline irrigation

Comprehensive Interpretation

A strong negative correlation was observed between leaf Na^+ concentration and fruit yield ($r = -0.93$, $P < 0.01$). Leaf chlorophyll content followed the same pattern, with Rough Lemon maintaining 2.18 mg/g compared to 1.42 mg/g in Cleopatra Mandarin. This confirms that rootstocks restricting sodium translocation preserve photosynthetic capacity and support higher carbon assimilation for fruit development.

Discussion

The superior performance of Rough Lemon and Volkamer Lemon under saline conditions aligns with earlier reports from semi-arid regions of India and the Mediterranean basin [4, 5]. Both rootstocks are known for vigorous root systems that maintain a larger soil exploration volume, which appears to aid in sodium dilution within the xylem sap. The poor showing of Cleopatra Mandarin is notable because this rootstock is sometimes recommended for salt tolerance based on greenhouse screening data, yet under prolonged field salinity its small root system may not sustain the exclusion mechanism effectively [6].

The clear association between K^+/Na^+ ratio and yield ($r = 0.91$) underscores potassium's role in maintaining stomatal function, enzyme activation, and osmotic balance under salt stress [3]. Growers in salt-affected areas should therefore pair rootstock selection with adequate potassium

Conclusion

Rough Lemon and Volkamer Lemon emerged as the best rootstocks for Mosambi sweet orange under irrigation salinity of 4.2 dS/m, combining vigorous scion growth with effective sodium exclusion and high fruit yield and quality. Cleopatra Mandarin and Sour Orange performed poorly. The K^+/Na^+ ratio in leaves can serve as a reliable screening index for rootstock evaluation under saline conditions.

Growers establishing new citrus orchards in salt-prone areas of Kerala should prefer Rough Lemon or Volkamer Lemon as rootstock.

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