

Biomass Partitioning and Root System Development of Acid Lime (*Citrus aurantifolia* Swingle) Seedlings under Contrasting Growing Media and Nutrient Regimes in a Shade-Net Nursery

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Abstract— The quality of citrus nursery stock depends not only on shoot growth but also on the development and proportional allocation of root and shoot biomass. A secondary analysis was undertaken using the root and biomass observations from an acid lime (*Citrus aurantifolia* Swingle) cv. Sai Sharbati nursery experiment conducted during 2025–26 at Sweet Orange Research Station, Badnapur. The original experiment comprised seven media–nutrition treatments in a Completely Randomized Design with three replications. The present manuscript focuses specifically on root biomass, shoot biomass, root volume and biomass partitioning rather than the germination and general growth response reported in the associated publication. The integrated potting mixture + cocopeat medium supplied with 20:10:10 g NPK seedling⁻¹ (T7) produced the highest root fresh weight (3.45 g), root dry weight (0.68 g), shoot fresh weight (16.55 g), shoot dry weight (4.19 g) and root volume (3.89 cm³). Potting mixture + cocopeat with 40:25:25 NPK (T6) and potting mixture with 40:25:25 NPK (T3) were the next strongest treatments for biomass production. Although the sole cocopeat treatment with 60:25:25 NPK (T4) showed the highest root:shoot dry ratio (0.59), its absolute root and shoot biomass were very low, demonstrating that a high ratio alone is not an indicator of superior seedling quality. T7 combined substantial absolute root development with markedly greater shoot biomass and therefore showed the most favourable overall biomass architecture. The findings highlight the importance of evaluating absolute root traits together with biomass allocation when selecting acid lime seedlings for nursery transplanting.

Keywords— acid lime, root biomass, shoot biomass, root volume, biomass partitioning, cocopeat, nursery substrate

I. INTRODUCTION

High-quality nursery plants are essential for successful establishment of perennial citrus orchards. While conventional nursery assessments commonly emphasize height, leaf number and survival, the root system is equally important because it determines anchorage, water acquisition, nutrient absorption and the ability of a seedling

to establish after transplanting. A seedling with a large shoot but weak roots may suffer transplant shock, whereas a seedling with a high root:shoot ratio but very small absolute biomass may simply be under severe growth restriction.

Growing media strongly influence root-zone aeration, water availability, bulk density and nutrient retention. Cocopeat has high porosity and water-holding capacity and

can improve physical conditions when appropriately blended with mineral and organic media. However, the response of seedlings to a substrate cannot be interpreted independently of nutrient supply. Moderate fertilization in a physically favourable substrate may stimulate both root exploration and shoot biomass, whereas an excessive nutrient concentration in a poorly buffered substrate can restrict growth.

The associated acid lime nursery experiment compared conventional potting mixture, cocopeat and a blended medium under different NPK regimes. The published analysis emphasized germination, survival, vegetative growth and overall seedling vigour. The present secondary analysis addresses a different question: how do these media–nutrition combinations modify absolute root and shoot biomass, root volume and the partitioning of dry matter between roots and shoots? Such an analysis is useful for nursery quality assessment because biomass allocation provides information that cannot be obtained from shoot growth measurements alone.

II. OBJECTIVES

- To evaluate the effect of contrasting growing media and NPK regimes on root fresh and dry biomass of acid lime seedlings.
- To quantify treatment effects on shoot fresh and dry biomass and root volume.
- To interpret root:shoot dry biomass allocation together with absolute root and shoot development for nursery seedling quality assessment.

III. MATERIALS AND METHODS

The secondary analysis used observations from the original shade-net nursery experiment conducted at Sweet Orange Research Station, Badnapur during 2025–26 on acid lime cv. Sai Sharbati. The original experiment followed a Completely Randomized Design with seven treatments and three replications, with six seedlings per treatment unit. Seedlings were raised in 40 × 30 × 10 cm trays. The media consisted of conventional potting mixture, cocopeat and a 1:1 blend of potting mixture and cocopeat, with NPK regimes imposed according to the original treatment structure.

Table 1. Treatment structure used in the original experiment.

Treatment	Media and nutrient regime
T1	Potting mixture 2:1:1 (Sand:Soil:FYM)
T2	Potting mixture + 60:25:25 NPK g seedling ⁻¹
T3	Potting mixture + 40:25:25 NPK g seedling ⁻¹
T4	Cocopeat + 60:25:25 NPK g seedling ⁻¹
T5	Cocopeat + 40:25:25 NPK g seedling ⁻¹
T6	Potting mixture + cocopeat + 40:25:25 NPK g seedling ⁻¹
T7	Potting mixture + cocopeat + 20:10:10 NPK g seedling ⁻¹

Root fresh weight was measured after uprooting and washing the root system. Root dry weight was determined after oven drying at 65 ± 2 °C to constant weight. Shoot fresh weight was measured after separation from the root system, and shoot dry weight was obtained after drying under the same conditions. Root volume was determined by water displacement. Root:shoot ratio was calculated from dry root weight divided by dry shoot weight.

For the present secondary analysis, two descriptive biomass-allocation indicators were additionally calculated from treatment means: root dry matter percentage = root dry weight/(root dry weight + shoot dry weight) × 100; and shoot:root dry biomass ratio = shoot dry weight/root dry weight. These derived indicators are used for interpretation only and do not replace the statistical analyses reported in the original thesis.

IV. RESULTS AND DISCUSSION

4.1 Root biomass response

Marked treatment differences were observed in root biomass. T7 produced the highest root fresh weight (3.45 g) and root dry weight (0.68 g), followed by T3 (3.07 and 0.61 g) and T1/T6 (0.56 g root dry weight each). T4 produced the lowest root fresh weight (0.74 g) and root dry weight (0.15 g). Thus, the treatment with the highest root:shoot ratio was not the treatment with the largest root system. The results demonstrate the importance of considering absolute root biomass when judging nursery quality.

Table 2. Root-system characteristics under different media–nutrition combinations.

Parameter	T1	T2	T3	T4	T5	T6	T7
Root fresh weight (g)	2.82	2.35	3.07	0.74	1.10	2.77	3.45
Root dry weight (g)	0.56	0.48	0.61	0.15	0.23	0.56	0.68
Root volume (cm ³)	3.36	2.61	3.50	0.94	1.42	3.07	3.89

4.2 Shoot biomass response

Shoot biomass showed a strong response to the interaction between growing medium and nutrient regime. T7 produced 16.55 g shoot fresh weight and 4.19 g shoot dry weight, the highest values among all treatments. T3

recorded 14.01 and 3.43 g, while T6 recorded 13.11 and 3.17 g, respectively. In contrast, T4 recorded only 1.29 g shoot fresh weight and 0.27 g shoot dry weight. The large difference indicates that substrate suitability, rather than nutrient dose alone, was critical for converting available nutrients into structural biomass.

Table 3. Shoot biomass under different media–nutrition combinations.

Parameter	T1	T2	T3	T4	T5	T6	T7
Shoot fresh weight (g)	12.55	8.56	14.01	1.29	2.77	13.11	16.55
Shoot dry weight (g)	3.10	1.93	3.43	0.27	0.60	3.17	4.19

4.3 Biomass partitioning and root:shoot relationships

The conventional root:shoot dry ratio provides a relative measure of biomass allocation but can be misleading if interpreted without absolute biomass. T4 had the highest ratio (0.59), followed by T5 (0.40) and T2 (0.25), whereas T7 had the lowest ratio (0.16). However, T4 had only 0.15 g root dry weight and 0.27 g shoot dry weight, while T7 had 0.68 g root dry weight and 4.19 g shoot dry weight. Consequently, the high ratio in T4 reflected severe restriction of shoot growth rather than superior root development.

On a treatment-mean basis, T7 allocated approximately 14.0% of total dry biomass to roots and 86.0% to shoots, whereas T4 allocated approximately 35.7% to roots and 64.3% to shoots. The shoot:root dry biomass ratio was approximately 6.16 under T7 compared with 1.80 under T4. This contrast indicates that T7 produced a much larger and more productive shoot system while retaining substantial absolute root biomass. For nursery purposes, this combination is more meaningful than a high root:shoot ratio produced by severely stunted seedlings.

Table 4. Derived biomass-allocation indicators based on treatment means.

Indicator	T1	T2	T3	T4	T5	T6	T7
Total dry biomass (g)	3.66	2.41	4.04	0.42	0.83	3.73	4.87
Root dry matter (%)	15.30	19.92	15.10	35.71	27.71	15.01	13.96
Shoot dry matter (%)	84.70	80.08	84.90	64.29	72.29	84.99	86.04
Shoot:root dry ratio	5.54	4.02	5.62	1.80	2.61	5.66	6.16

4.4 Root volume as an indicator of transplantable root-zone development

Root volume provides a complementary measure of the three-dimensional extent of the root system. T7 recorded the maximum root volume (3.89 cm³), followed by T3 (3.50 cm³) and T1 (3.36 cm³), while T4 recorded only 0.94 cm³. The simultaneous increase in root dry weight and root volume under T7 suggests that the treatment promoted both root mass accumulation and spatial development. The close performance of T3 indicates that conventional potting mixture supplied with an intermediate nutrient dose can also

produce a substantial root system when cocopeat is unavailable.

The contrast between T7 and T4 is particularly relevant to nursery management. Both treatments contained NPK, but their substrate environments differed substantially. The blended substrate in T7 likely provided a more favourable balance between water retention and aeration, while the sole-cocopeat treatment with the higher nutrient dose was associated with restricted root and shoot development. Therefore, nutrient concentration should be optimized in

relation to substrate physical properties rather than considered independently.

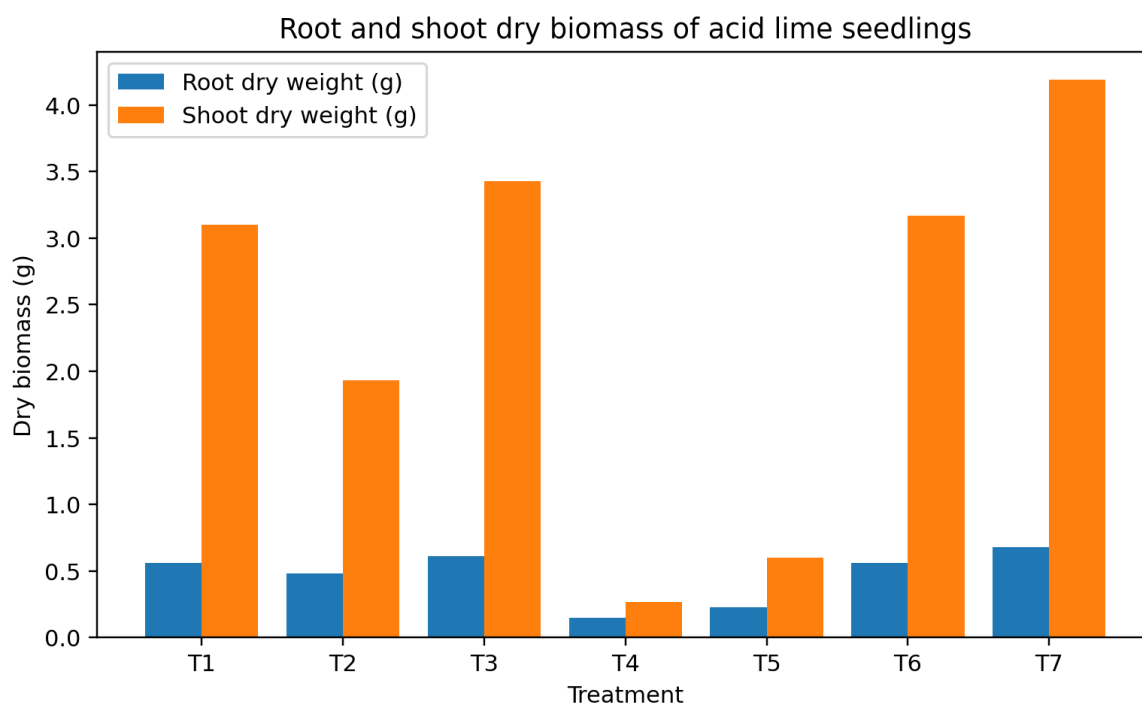


Fig.1. Comparative root and shoot dry biomass under the seven media–nutrition treatments.

V. CONCLUSION

The secondary analysis demonstrates that the best nursery treatment should not be identified from root:shoot ratio alone. Potting mixture + cocopeat supplemented with 20:10:10 g NPK seedling⁻¹ (T7) produced the greatest absolute root fresh and dry biomass, shoot biomass and root volume, while maintaining a comparatively low root:shoot ratio because of strong canopy development. The poor-performing sole-cocopeat treatment T4 showed the highest root:shoot ratio but had extremely low absolute root and shoot biomass, confirming that the ratio represented growth restriction rather than superior seedling quality.

From a nursery-quality perspective, T7 provided the most favourable combination of root-system size, shoot biomass and overall biomass accumulation. T3 was the strongest alternative among the conventional potting-mixture treatments. Future work should validate whether these biomass and root traits translate into faster transplant establishment, greater field survival and improved early growth after planting in the orchard.

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