International Journal of Horticulture, Agriculture and Food Science (IJHAF)
ISSN: 2456-8635
[Vol-9, Issue-2, Apr-Jun, 2025]
Issue DOI: https://dx.doi.org/10.22161/ijhaf.9.2
Peer-Reviewed Journal

Effect of Potting Mixture on Growth and Development of Grafted Saplings of Sweet Orange (*Citrus sinensis* L. Osbeck) in Ramechhap, Nepal

Khem Raj Upadhyaya[1*] and Apil Joshi[2]

[1]Faculty of Agriculture, Agriculture and Forestry University, Chitwan, Nepal
Email: updkhem@gmail.com
[2]Department of Plant and Soil Science, University of Massachusetts Amherst (UMASS), USA
apiljoshi75@gmail.com
[*]Corresponding author: updkhem@gmail.com

Received: 02 Mar 2025; Received in revised form: 03 Apr 2025; Accepted: 08 Apr 2025; Available online: 15 Apr 2025

***Abstract*— *The present investigation on "Effect of different potting media on growth characteristics of sweet orange (Citrus sinensis L. Osbeck) saplings" was conducted in Ramechhap, Nepal, in 2023. The experiment aimed to find out the most suitable combination of potting media for optimal growth of sweet orange sapling. The experiment was laid out according to one factor Completely Randomized Design (CRD) with three experimental units. Seven different combinations of potting media treatments: T1 (surface soil: Farm yard manure (FYM)), T2 (surface soil: vermicompost), T3 (forest soil: sand: FYM), T4 (surface soil: sand: vermicompost), T5 (forest soil: vermicompost), T6 (surface soil: sand) and T7 (cocopeat: surface soil) were taken in the ratio of 1:1 by volume. Based on the results obtained from the present investigation, it was observed that the maximum increase in plant height 28.98 centimeters (cm), leaf area (16.83cm^2), number of primary branches (3.14), number of leaves (15.20) and survival percentage (85.25%) was observed in treatment combinations of forest soil with vermicompost. The maximum stem diameter (2.51cm) was recorded in media combination T3 (forest soil: sand: FYM). The study concluded that most effective mixture of potting media for enhanced growth of sweet orange saplings was found to be T5 (Vermicompost: forest soil) (1:1) followed by T2 (surface soil: vermicompost) (1:1) and least growth was seen in T7 (cocopeat: surface soil) (1:1).*

***Keywords*— Completely Randomized Design, Growth characteristics, Potting media, Saplings, Vermicompost**

I. INTRODUCTION

Citrus is one of the most important groups of fruits of tropical and subtropical regions (Bouharmont & Beloualy, 1996). Sweet oranges are a key citrus crop with export potential in the global market (Dahal et al., 2020). Sweet orange (*Citrus sinensis* L. Osbeck), also called Junar in Nepal, is an evergreen flowering tree whose tight-skinned citrus fruit has a longer shelf life than loose-skinned mandarins (Dhakal et al., 2023). Numerous citrus varieties can be grown in Nepal's mid-hills due to the region's distinct terrain and agro-climatic conditions (FAO and MoAC, 2011). Among them, sweet orange (*Citrus sinensis* L. Osbeck) is the second most widely grown citrus in Nepal. It thrives in altitudes of 800-1400 masl in the mid-hill zone, with optimal temperatures ranging from 5 to 35℃ (MoALD, 2017). Sweet oranges are grown in 51 of Nepal's 77 districts; however, Ramechhap and Sindhuli districts contribute remarkably to production (MoALD, 2023). In the surveyed year 2020/21, the total sweet orange area in the Ramechhap district was 1325 ha with the productivity of 13.65 Mt/ha (MoALD, 2023). The introduction of the Zone and Super zone by the Government of Nepal (GoN) under Prime Minister Agriculture Modernization Project (PMAMP), recognizing the importance in Ramechhap and Sindhuli, has made some progress in terms of production and productivity of sweet orange (Acharya & Shrestha, 2021).

However, several aspects seem to be lacking in sweet orange production. The lack of quality and disease-free saplings for establishing the orchard is one of the primary elements that affects overall orchard performance for higher fruit yield (FAO and MoAC, 2011). The selection of the growing media is one of the most essential factors for growing seedlings and saplings (NCRP, 2018).

Growing media are soilless materials necessary for the growth of plants (Khan et al., 2006). Compost, peat, coconut (*Cocos nucifera L.*), tree bark, coir and poultry feathers are examples of non-inert or organic materials, whereas inert or inorganic materials include perlite, clay, mineral wool, and vermiculite (Khan et al., 2006). The benefits of transplant production include early and consistent crop maturity, effective use of land, energy, time, and seed supplies, the creation of pest-free transplants, a decrease in the use of pesticides and herbicides, and above all-healthy and uniform seedlings (Ünal, 2013; Chrysargyris et al., 2013; Marinou et al., 2013). While raising nursery, farmers must deal with soil-related challenges in open field settings such as root rot, nematode infestation, and crust development in the root zone due to higher amount of silt and rock in the soil layer, which causes the improper root growth of the young sapling (Joshi, 2022). Therefore, the purpose of the research is to make the farmers produce quality saplings with a potting media alongside a good ratio of organic fertilizer. According to Khan et al., (2006) good potting media management is critical for the development of quality fruit tree seedlings, as strong growth is required to withstand the seasonal threats experienced in the field. The concentrations of macro and microelements in the leaves of grafted cultivars were significantly impacted by rootstocks (Rameeh et al., 2020). Therefore, this experiment will provide proper knowledge and ideas to the farmers of Ramechhap about the use of the best potting media for the growth of young saplings of sweet orange. It has been demonstrated that applying organic fertilizers to potted medium improves soil fertility and increases the availability of vital nutrients, which in turn promotes root growth (Chatzistathis et al., 2021; Zhang et al., 2020).

II. MATERIALS AND METHODS

The research was conducted at the private semi-high-tech nursery of sweet orange, located in Manthali municipality-4, Saalu, Ramechhap. The scion of local variety was utilized (Kaini, 2013), and trifoliate rootstock was selected for grafting. Approximately one-year-old rootstock and 6-8 month-old scion were used for grafting purpose and were chosen as planting material. Seven different potting mixtures were prepared separately and covered with plastic. Heaps of different potting media was left overnight. Thus, prepared potting media were filled in a polybag of size 20*10 cm and of capacity 1 kg. Thus, grafted Saplings were transplanted singly in each polybag and placed inside small structured polyhouse for bud initiation up to 15 days. Watering was done immediately after transplanting and at regular intervals throughout research period. Qualitative analysis of seven different potting media was conducted in the laboratory by taking the samples from each mixture, as shown in Table 1. The data collected for the observation included soil P^{H}, nitrogen, phosphorus and potassium content in each of the potting mixtures.

Table 1: Qualitative analysis of the potting media

Treatments		**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
Soil P^{H}		7.0	7.0	7.0	8.0	5.5	8.0	8.0
	Low							
Nitrogen	Medium		✓				✓	
	High	✓		✓	✓	✓		✓
	Low					✓	✓	✓
Phosphorus	Medium				✓			
	High	✓	✓	✓				
	Low		✓				✓	
Potassium	Medium			✓		✓		✓
	High	✓			✓			

Source: Ramechhap polytechnic lab

1.1. Experimental Design

The experiment was laid out in single factorial Completely Randomized Design (CRD) inside a screen house with 7 treatments. Each treatment represents the potting mixture. Each experimental unit consists of 21 potted saplings of sweet orange, having 3 saplings for each treatment. The experiment began on February 27 and ended on June 30, 2023.

Table 2: Treatment details

Treatments	Potting mixtures
T1	Surface soil: FYM
T2	Surface soil: Vermicompost
T3	Forest soil: Sand: FYM
T4	Surface soil: Sand: Vermicompost
T5	Forest soil: Vermicompost
T6	Surface soil: Sand
T7	Cocopeat: Surface soil

Note: Each potting media was taken in a ratio of 1:1 by volume.

1.2. Parameters taken for Observation

The parameters that were investigated about the impact of combining various potting media on the growth characteristics of sweet orange saplings were mentioned. Depending on the needs, information was gathered from each plant at various points of time.

Plant height (cm): Height records were taken from all saplings from each experimental unit for each treatment. The height of sapling was measured from the top surface of potting media, which is marked at that point by a marker, to the tip of the growing point with scale. Average height was calculated in cm. Plant height data were collected at 30-day intervals after transplanting.

Stem diameter (cm): Stem diameter of selected saplings from each experimental unit was recorded by measuring diameter at 5 cm above the surface of potting media with the help of Vernier caliper, and the average was calculated in cm. The data for the stem diameter was taken at 60DAG and subsequently at monthly intervals.

Number of leaves: The data for the number of leaves were taken at 60DAG and subsequently at monthly intervals. Leaves were counted from every grafted sapling from each experimental unit, and average data were taken.

Leaf area (cm^2): Leaf area was calculated by the graph paper method. The data for leaf area was taken at the end of the experiment, i.e., 120DAG. Fully expanded seven leaves were taken from each experimental unit. The boundaries of leaves were drawn on graph paper, and the squares inside the boundary were counted. One full square was counted as 1 cm^2.

Number of primary branches: The data for the number of branches were taken at the end of the experiment, i.e., 120DAG. Branches were counted from every grafted sapling from each experimental unit, and average data were taken.

Survival percentage: Survival percentage data were taken at the end of the experiment and calculated as:

$$\text{Graft success} = \frac{\text{Total no. of sprouted scion} - \text{Dead grafts after sprouting}}{\text{Total no. of sprouted scion}} \times 100$$

1.3. Data Analysis

The collected data were systematically arranged and entered in MS Excel. Then, the arranged data were analyzed using the software, RStudio. The means were compared by using the LSD test at a 5% level of significance. MS Excel and MS Word were used for tabulation, graphs, and figures. Effectiveness of treatments was studied based on above-mentioned parameter.

III. RESULTS

Plant height

The effect of potting mixture on sapling height was found significant at 60 Days after grafting (DAG) (Table 3). The statistical analysis indicated that plant height showed non-significant variation with potting media at 30DAG, and at 60 DAG, 90 DAG and 120 DAG, plant height showed significant variation with potting media. Forest soil: vermicompost (1:1) showed a significantly higher value (19.64 cm), and cocopeat: surface soil (1:1) showed significantly lower value (13.31 cm), which is statistically at par with surface soil: sand (1:1), forest soil: sand: FYM (1:1:1), and surface soil: sand: FYM (1:1:1) at 60DAG. The maximum sapling height at 90DAG was observed in forest soil: vermicompost (1:1) (25.98 cm), and the minimum height was observed in cocopeat: surface soil (1:1) (13.87cm). Similarly, the same results were obtained at 120DAG.

Table 3: Height of sweet orange saplings observed at different days after grafting as influenced by potting media at Ramechhap district, Nepal, 2023

Treatment	Plant height (cm)			
	30DAG	60DAG	90DAG	120DAG
Surface Soil: FYM	11.48	15.25[bcd]	17.60[c]	20.01[c]
Surface Soil: Vermicompost	11.34	17.20[b]	22.14[b]	25.14[b]
Forest Soil: FYM	11.46	14.73[cd]	17.01[c]	19.34[c]
Surface Soil: Sand: Vermicompost	10.49	15.89[bc]	20.82[b]	23.71[b]
Forest Soil: Vermicompost	12.04	19.64[a]	25.98[a]	28.98[a]
Surface Soil: Sand	11.77	14.63[cd]	16.97[c]	19.41[c]
Cocopeat: Surface soil	11.60	13.31[d]	13.87[d]	19.26[c]
LSD (0.05)	NS	2.10	2.21	2.22
SE_m (±)		0.28	0.29	0.29
F probability		***	***	***
CV%		14.12	12.23	10.56
Grand mean		15.78	19.20	22.26

Stem diameter

The effect of potting mixture on stem diameter was found significant at 60DAG (Table 4). The maximum stem diameter at 60DAG was observed in forest soil: sand: FYM (1:1:1) (1.32cm), which is statistically at par with surface soil: sand: vermicompost (1:1:1) and surface soil: sand: FYM (1:1:1), and the minimum stem diameter was observed in forest soil: vermicompost (1:1) (1.15cm). Similarly, the same results were obtained at 90DAG and 120DAG.

Table 4: Stem diameter of sweet orange saplings observed at different days after grafting as influenced by potting media at Ramechhap district, Nepal, 2023

Treatment	Average diameter of stem (cm)		
	60DAG	90DAG	120DAG
Surface Soil: FYM	1.23[a]	1.86[a]	2.42[a]
Surface Soil: Vermicompost	1.17[b]	1.78[b]	2.32[b]
Forest Soil: FYM	1.32[a]	2.0[a]	2.51[a]
Surface Soil: Sand: Vermicompost	1.28[a]	1.95[a]	2.46[a]
Forest Soil: Vermicompost	1.15[c]	1.75[c]	2.25[c]
Surface Soil: Sand	1.19[b]	1.8[b]	2.31[b]
Cocopeat: Surface soil	1.25[d]	1.89[d]	2.40[d]
LSD (0.05)	1.85	0.95	0.89
SE_m (±)	0.44	0.16	0.15
F probability	**	***	***
CV%	4.69	3.33	2.53
Grand mean	1.06	1.86	2.38

Number of leaves

The effect of potting mixture on the number of leaves was found significant at 60DAG (Table 5). The maximum number of leaves at 60DAG was observed in surface soil: sand (1:1) (8.0), which is statistically at par with surface soil: sand: vermicompost (1:1:1) and surface soil: vermicompost (1:1), and the minimum number of leaves was observed in cocopeat: surface soil (1:1) (3.0), which is statistically at par with surface soil: sand: FYM (1:1:1), forest soil: sand: FYM (1:1:1), and forest soil: vermicompost (1:1). Similarly, the maximum number of leaves at 90DAG was observed in forest soil: vermicompost (1:1) (12.80), which is statistically at par with surface soil: vermicompost (1:1), and the minimum number of leaves was observed in cocopeat: surface soil (1:1) (4.33). Similar results were obtained at 120DAG as well.

Table 5: Number of leaves of sweet orange saplings observed at different days after grafting as influenced by potting media at Ramechhap district, Nepal, 2023

Treatment	Number of leaves		
	60DAG	90DAG	120DAG
Surface Soil: FYM	3.75^{b}	8.80^{c}	11.80^{b}
Surface Soil: Vermicompost	7.67^{a}	11.75^{ab}	14.25^{a}
Forest Soil: FYM	4.0^{b}	10.60^{b}	13.67^{a}
Surface Soil: Sand: Vermicompost	6.5^{a}	7.83^{c}	10.33^{b}
Forest Soil: Vermicompost	3.0^{b}	12.80^{a}	15.20^{a}
Surface Soil: Sand	8.0^{a}	8.33^{c}	11.33^{b}
Cocopeat: Surface soil	3.0^{b}	4.33^{d}	7.33^{c}
LSD (0.05)	1.45	1.99	2.28
SE_m (±)	0.19	0.21	0.22
F probability	***	***	***
CV%	15.13	12.54	8.94
Grand mean	5.29	9.45	12.30

Leaf area

The data for the leaf area was taken at the end of the experiment, i.e., 120DAG (Table 6). The maximum leaf area was observed in forest soil: vermicompost (1:1) (16.83 cm^2), which is statistically at par with surface soil: sand: FYM (1:1:1), surface soil: vermicompost (1:1), and forest soil: sand: FYM (1:1:1), and minimum leaf area was observed in surface soil: sand (1:1) (8.99 cm^2).

Table 6: Leaf area of sweet orange saplings observed at 120 days after grafting as influenced by potting media at Ramechhap district, Nepal, 2023

Treatment	Leaf area (cm^2)
	120DAG
Surface Soil: FYM	13.21^{abc}
Surface Soil: Vermicompost	14.31^{ab}
Forest Soil: FYM	14.15^{ab}
Surface Soil: Sand: Vermicompost	11.62^{c}
Forest Soil: Vermicompost	16.83^{a}
Surface Soil: Sand	8.99^{d}
Cocopeat: Surface soil	12.66^{bc}
LSD (0.05)	2.78
SE_m (±)	1.07
F probability	*
CV%	40.57
Grand mean	12.91

Number of Primary branches

The data for the primary branches were taken at the end of the experiment, i.e., 120DAG (Table 7). The maximum number of primary branches was observed in forest soil: vermicompost (1:1) (3.14), and the minimum number of primary branches was observed in surface soil: sand (1:1) (1.20), which is statistically at par with cocopeat: surface soil (1:1), surface soil: sand: vermicompost (1:1:1), and forest soil: sand: FYM (1:1:1).

Table 7: Number of primary branches of sweet orange saplings observed at 120 days after grafting as influenced by potting media at Ramechhap district, Nepal, 2023

Treatment	Primary branches
	120DAG
Surface Soil: FYM	2.07[b]
Surface Soil: Vermicompost	2.10[b]
Forest Soil: FYM	1.36[c]
Surface Soil: Sand: Vermicompost	1.30[c]
Forest Soil: Vermicompost	3.14[a]
Surface Soil: Sand	1.20[c]
Cocopeat: Surface soil	1.25[c]
LSD (0.05)	1.19
SE_m (±)	0.08
F probability	***
CV%	36.14
Grand mean	1.79

Survival percentage

Survival percentage at the end of the experiment was recorded (Table 8), which showed that the minimum survival percentage (35.15) was recorded in the treatment combination of cocopeat: surface soil (1:1), and the maximum (85.25) was noted in the treatment combination of forest soil: vermicompost (1:1). Treatments consisting of forest soil: vermicompost (1:1) and forest soil: sand: FYM (1:1:1) show a high percentage of survival, while all other treatment combinations show low a percentage of survival.

Table 8: Survival percentage of sweet orange saplings observed at 120 days after grafting as influenced by potting media at Ramechhap district, Nepal, 2023

Treatment	Survival percentage
	120DAG
Surface Soil: FYM	70.43[a]
Surface Soil: Vermicompost	55.40[a]
Forest Soil: FYM	76.35[b]
Surface Soil: Sand: Vermicompost	63.16[a]
Forest Soil: Vermicompost	85.25[b]
Surface Soil: Sand	51.26[a]
Cocopeat: Surface soil	35.15[a]
LSD (0.05)	3.64
SE_m (±)	6.37
F probability	***
CV%	26.97
Grand mean	62.42

IV. DISCUSSION

Plant height

Various growth characteristics, such as the number of leaves per sapling, leaf area, and the number of primary and secondary branches, have a significant impact on sapling height (Bhandari & Regmi, 2021).The effectiveness of photosynthetic and metabolite fluxes across the graft junction is closely related to the growth of the graft partners (Adhikari et al., 2022). For example, studies on the effects of fertigation with nitrogen and phosphorus showed that certain treatments greatly increased the number of leaves, which was positively connected with the length of the shoots and the height of the plants as a whole (Kaur et al., 2024). Thus, the treatment consisting of forest soil: vermicompost (1:1) shows maximum plant height.

Stem diameter and Leaf area

An increase in stem diameter was seen in media containing farm yard manure, vermicompost and forest soil. Plants with larger root systems tend to have larger stem diameters (Jaenicke, 1999). Additionally, organic manures-particularly vermicompost and farmyard manure-may have enhanced the rhizosphere, which would have increased the plants' access to nutrients (Naidu, 2021). Cocopeat containing potting media boosted sapling root length, possibly related to greater moisture content, aeration, and drainage (Khayyat et al., 2007) and optimal biological and physical conditions in cocopeat (Treder, 2008). Also, cocopeat itself has the highest K content (Treder, 2008). Higher leaf area resulted from superior root development, which was also found by (Khayyat et al., 2007). Higher leaf area was obtained in potting media containing cocopeat (Naik et al., 2018).

Number of leaves and Primary branches

The unaltered oak forest was used to gather the forest soil. Unaltered oak forest types, such as Banj oak forests, typically exhibit greater levels of soil microbial biomass nitrogen (SMBN) and phosphorus (SMBP) than chir pine forests, suggesting a more nutrient-rich soil environment (Manral et al., 2020), which is the primary requirement for the growth of sweet orange saplings. A more varied and active microbial population is supported by oak forests generally having greater levels of soil organic carbon (SOC) and total nitrogen (TN), two elements that are essential for microbial growth and function (Kelly et al., 2021). The above results show that the media containing the forest soils show significant growth in height, number of leaves, and branches.

Survival percentage

The survival rate is a significant element for standardizing the potting material (Rehman et al., 2020). The highest increase in survival percentage was observed in the medium combination including vermicompost. Siddagangaiah et al., (1996) also revealed that the sprout vigor of rooted vanilla cuttings produced on vermicompost media in terms of number of sprouts, sprout lengths, number of leaves/vine, leaf area/vine, number of roots, and root length was the best. Improved rooting was connected with a greater survival rate in *Prunus cerasus* (Prizhmontas, 1991) and in peach cultivar Fertilia (Bartolini, 1994). The logical conclusion appears to be that high numbers of roots are connected with proper nutritional absorption that leads to final survival. Plant survival is strongly correlated with the quantity of roots (Kurd et al., 2010).

V. CONCLUSION

The study concluded some of the information about the effect of different potting media on growth characteristics of sweet orange saplings. Among the treatments, the most effective mixture of potting media for enhanced growth of sweet orange saplings was found to be vermicompost: forest soil (1:1), followed by surface soil: vermicompost (1:1), and the least growth was seen in cocopeat: surface soil (1:1). Results obtained from the experiment under naturally field conditions of Ramechhap, forest soil: vermicompost could be the environmentally friendly option for enhanced growth of citrus saplings. The effectiveness of such organic potting media as well as bio inoculant may be increased in coming years because of its multiplication in the soil and soil health maintenance.

ACKNOWLEDGEMENT

The authors express sincere gratitude to the Prime Minister Agriculture Modernization Project (PMAMP) and Agriculture and Forestry University (AFU), Nepal, for their generous funding and providing support and opportunity to be involved in this enriching project.

REFERENCES

[1] Acharya, U. K., & Shrestha, H. K. (2021). Opportunity and Challenges of Sweet Orange (Citrus sinensis L. Osbeck) Production in Sindhuli and Ramechhap Districts. *Nepalese Horticulture*,*15*,89–96. https://doi.org/10.3126/nh.v15i0.36685

[2] Adhikari, P. B., Xu, Q., & Notaguchi, M. (2022). Compatible graft establishment in fruit trees and its potential markers. *Agronomy*, *12*(8), 1981. https://doi.org/10.3390/agronomy12081981

[3] Bartolini, G. (1994). Interrelation of carbohydrates, rooting and survival of hardwood peach cuttings. *Advances in Horticultural Science*, *8*(3), 131–133.

[4] Bhandari, N., & Regmi, C. (2021). Effect of Grafting Dates on Success and Growth of Kumquat (Fortunella japonica

Swingle) Sapling. *Nepalese Horticulture*,*15*,97–105. https://doi.org/10.3126/nh.v15i0.36686

[5] Bouharmont, J., & Beloualy, N. (1996). In Vitro Selection for Salt Tolerance in Citrus Rootstocks. In Y. P. S. Bajaj (Ed.), *Somaclonal Variation in Crop Improvement II* (pp. 210–222). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-61081-3_14

[6] Chatzistathis, T., Kavvadias, V., Sotiropoulos, T., & Papadakis, I. E. (2021). Organic fertilization and tree orchards. *Agriculture*, *11*(8), 692. https://doi.org/10.3390/agriculture11080692

[7] Chrysargyris, A., Saridakis, C., & Tzortzakis, N. (2013). Use of municipal solid waste compost as growing medium component for melon seedlings production. *Journal of Plant Biology & Soil Health*, *1*(2), 1–5. https://doi.org/10.13188/2331-8996.1000005

[8] Dahal, S., Shrestha, B., Bista, B., & Bhandari, D. (2020). Production and trade scenario of citrus fruits in Nepal. *Food and Agribusiness Management*,*1*(1),47–53. https://doi.org/10.26480/fabm.01.2020.47.53

[9] Dhakal, N., Kunwar, B., Subedi, K., & Adhikari, D. (2023). Financial Feasibility Analysis of Sweet Orange Production in Sindhuli, Nepal. *Food & Agribusiness Management (FABM)*, *4*(2),100–103. https://doi.org/10.26480/fabm.02.2023.100.103

[10] FAO and MoAC. (2011). *Training Manual For Combating Citrus Decline Problem in Nepal*. https://openknowledge.fao.org/items/36f3c1d2-b25f-4d5e-a3d0-daa9a6381db2

[11] Jaenicke, H. (1999). Seedling Quality. In *In Good Tree Nursery Practices: Practical Guidelines for Community Nurseries* (pp. 7–20). International Centre for Research in Agroforestry (ICRAF).

[12] Joshi, P. (2022). Hi-Tech Nursery Production and Management of Citrus. *Krishi Udyan Darpan*,*2(1)*,128–131. https://saahasindia.org/pdf/English_Vol2_Issue1/32.%20Hi-Tech%20Nursery%20Production%20and%20Management%20of%20Citrus.pdf

[13] Kaini, B. R. (2013). *Sweet orange production and post-harvest management*. Central Junar Cooperative Federation, Tinkune, Kathmandu.

[14] Kaur, N., Thakur, A., Sharma, V., Sharda, R., & Rattanpal, H. (2024). Fertigation with Nitrogen and Phosphorus Improve Plant Growth, Root Growth, and Buddability of Containerized Citrus Nursery Plants. *Communications in Soil Science and Plant Analysis*,*55*,3330–3348. https://doi.org/10.1080/00103624.2024.2392289

[15] Kelly, C., Schwaner, G., Cumming, J., & Driscoll, T. (2021). Metagenomic reconstruction of nitrogen and carbon cycling pathways in forest soil: Influence of different hardwood tree species. *Soil Biology and Biochemistry*, *156*, 108226. https://doi.org/10.1016/j.soilbio.2021.108226

[16] Khan, M. M., Khan, M. A., Abbas, M., Jaskani, M. J., Ali, M. A., & Abbas, H. (2006). Evaluation of potting media for the production of rough lemon nursery stock. *Pakistan Journal of Botany*, *38*(3), 623–629. https://www.pakbs.org/pjbot/PDFs/38(3)/PJB38(3)623.pdf

[17] Khayyat, M., Nazari, F., & Salehi, H. (2007). Effects of different pot mixtures on pothos (Epipremnum aureum Lindl. and Andre 'Golden Pothos') growth and development. *American-Eurasian Journal of Agricultural and Environmental Science*, *2*(4), 341–348.

[18] Kurd, A. A., Khan, S., Shah, B. H., & Khetran, M. A. (2010). Effect of indole butyric acid (IBA) on rooting of olive stem cuttings. *Pakistan Journal of Agricultural Research*, *23*(3–4). https://www.cabdirect.org/cabdirect/abstract/20133374593

[19] Manral, V., Bargali, K., Bargali, S. S., & Shahi, C. (2020). Changes in soil biochemical properties following replacement of Banj oak forest with Chir pine in Central Himalaya, India. *Ecological Processes*,*9*, 1–9. https://doi.org/10.1186/s13717-020-00235-8

[20] Marinou, E., Chrysargyris, A., & Tzortzakis, N. (2013). Use of sawdust, coco soil and pumice in hydroponically grown strawberry. *Plant, Soil and Environment*,*59*(10),452–459. https://doi.org/10.17221/297/2013-PSE

[21] MoALD. (2017). *Statistical Information on Nepalese Agriculture 2015/16*. Ministry of Agriculture and Livestock Development, Kathmandu, Nepal.

[22] MoALD. (2023). *Statistical Information on Nepalese Agriculture 2021/22*. Ministry of Agriculture and Livestock Development, Kathmandu, Nepal.

[23] Naidu, M. M. (2021). Effect of different organic sources of nutrients on growth, yield and quality of sweet orange (Citrus sinensis). *Chemical Science Review and Letters*, *10*(39), 372–376. https://doi.org/10.37273/chesci.cs20511034

[24] Naik, S. M. R., Nandini, M. L. N., Venkataramana, K. T., & Mukundalakshmi, L. (2018). Effect of organic amendments and bio-agents on growth of acid lime (Citrus aurantifolia Swingle) cv. Balaji seedlings in the nursery. *Journal of Pharmacognosy and Phytochemistry*, *7*(6), 1611–1616.

[25] NCRP. (2018). *Annual Report 2074/75 (2017/18)*. National Citrus Research Program, Nepal Agricultural Research Council, Paripatle, Dhankuta.

[26] Prizhmontas, T. (1991). Action of auxins on rooting of sour cherry softwood cuttings. *Sadovodstvo i Vinogradarstvo*, *4*, 18–20.

[27] Rameeh, V., Ramzanpour, M., & MATANI, R. (2020). Effects of Citrus Rootstocks on some Plant Nutrient Elements Absorption of Grafted Cultivars. *Cercetari Agronomice in Moldova*,*52*(4),379–387. https://doi.org/10.46909/cerce-2019-0036

[28] Rehman, M. A., Ehsan, H. M., Ashraf, T., Gurmani, Z. A., Khan, S., & Ali, M. (2020). Effect of growing media on plant growth of rough lemon (Citrus jambhiri Lush.) and Poncirus (Citrus trifoliata). *Journal of Innovative Sciences*, *6*(2), 2–10.

[29] Siddagangaiah, B. A., Vadiraj, M. R., Sudharshan, M. R., & Krishnakumar, V. (1996). Standardization of rooting media for propagation of vanilla (Vanilla planifolia Andr.). *Journal of Spices and Aromatic Crops*, *5*(2), 131–133.

[30] Treder, J. (2008). The effects of cocopeat and fertilization on the growth and flowering of oriental lily 'star gazer.' *Journal of Fruit and Ornamental Plant Research*, *16*, 361–370.

[31] Ünal, M. (2013). Effect of Organic Media on Growth of Vegetable Seedlings. *Pakistan Journal of Agricultural Research*, *50(3)*, 517–522. https://www.researchgate.net/publication/279220515_EFFECT_OF_ORGANIC_MEDIA_ON_GROWTH_OF_VEGETABLE_SEEDLINGS

[32] Zhang, J., Li, B., Zhang, J., Christie, P., & Li, X. (2020). Organic fertilizer application and Mg fertilizer promote banana yield and quality in an Udic Ferralsol. *PLoS One*, *15*(3), e0230593. https://doi.org/10.1371/journal.pone.0230593