Original Research Article

Effect of different growing Media and polybag sizes on seeds germination & root system of rough lemon (Citrus jambhiri Lush.) in condition

ABSTRACT

Aims: The study aimed to evaluate the different growing media & polybag size for seedling growth of rough lemon rootstock.
Study design: The experiment used a Complete Randomized Design (CRD) with three replications.
Place and Duration of Study: The study "Effect of Growing Media and Polybag Size on Rough Lemon Seedling Growth" took place in an insect-proof net house at CCS Haryana Agricultural University during the 2021-2022 academic year.
Methodology: It comprising of 30 treatment combination i.e., ten different growing media: T_1: garden soil; T_2: soil:sand(1:1); T_3: soil:sand:leafmold(1:1:1); T_4: soil:cocopeat(1:1); T_5: sand:cocopeat(1:1); T_6: soil:sand:cocopeat(1:1:1); T_7: soil:FYM(1:1); T_8: sand:FYM(1:1); T_9: soil:sand:FYM(1:1:1); T_{10}: soil:sand:FYM:cocopeat(1:1:1:1), and the polybags S1: large(30 x 18 cm) , S2: medium(21 x 18 cm) & S3: small size(17 x 16 cm) bags.

Results: The study found that adding cocopeat to growing media (T4, T5, T6) resulted in earlier germination and higher rates (87-89%) Whereas, T_4 to T_{10} media consists of either FYM, cocopeat for both resulted into more germination 87-89% as compared to controls (T1, T2, T3).The most of the root growth parameters i.e., diameter of tap root(2.45mm), fresh root weight(4.63g) & dry root weight(1.21g) & root:shoot ratio(0.61) improved with the media sand:FYM, soil:FYM, sand:soil:FYM, sand:soil:FYM:cocopeat in equal proportion. However, when media supplemented with cocopeat (T_4, T_5& T_6) also showed appreciable results as compared to soil, sand:soil & soil:sand:leafmold. However, sand:FYM, sand:cocopeat treatments were best in respect of number of primary roots(61.22), root volume (6.44ml). Whereas, sand:soil showed very poor results in all growth aspects. Among polybags sizes, large size (30 x 18cm) bags performed best in most of the germination & root growth parameters.

Conclusion: Media enriched with organic matter outperformed sole media across all parameters, while larger polybags produced significantly better results than medium and small sizes.

Keywords: *rough lemon Seedlings; complete randomized design; growing media & polybag size*

INTRODUCTION

Citrus fruits are widely cultivated and hold a significant position among people. Their spread over tropical and subtropical regions indicates the ability of this species to grow and adapt to various environmental conditions (Srivastava et al., 2000) [1]. Internationally, citrus plantations are confined to latitudes between 0˚ and 40˚, covering regions with varying soil and climatic conditions (Ghosh, 2000) [2]. The rough lemon (Citrus jambhiri Lush.) rootstock is widely utilized to produce high-quality Kinnow mandarin in citrus-growing regions.

It is Known as "Jatti–Khatti," this rootstock produces trees with large fruits that have high yields. It features a deep root system, is drought-resistant, but is susceptible to Phytophthora and Fusarium (Cao et al., 2013) [3]. Rootstocks play an important role in the exclusion of toxins, which are crucial for the longevity of the orchard (Kadam and Patil, 1985) [4].

The use of improved and modern nursery techniques to produce high-quality planting material has increased significantly (Gera and Ginwal, 2002) [5]. Growth characteristics, including germination, growth, and a viable root system, are directly correlated with and impacted by the growing media. The physico-chemical properties of the growing media affect plant growth (Wilkerson, 2002) [6]. An appropriate growing medium provides plants with adequate support, acts as a reservoir for water and nutrients, permits gaseous exchange between the roots and the atmosphere, and diffuses oxygen to the roots. The use of polybags in nursery practices has surged in recent times due to their numerous benefits for stock raising, such as effortless mobility and irrigation, durability, easy availability in transparent, black, and white colors, ease of making holes for drainage and aeration, and zero mortality when transplanted into farmers' fields.

To develop tall, robust, and uniform seedlings in the nursery, the size of the polybag is essential. Larger volumes generally favor increased plant growth rates; however, most studies have been done with transplants grown in restricted cell sizes (Cantliffe, 1998) [7]. The increased root length of container-grown seedlings allows for better performance and survival under adverse conditions compared to bare-root seedlings (Amidon et al., 1982) [8].

MATERIALS AND METHODS

The present study, titled "Studies on the Effect of Different Growing Media and Polybag Size on Seedling Growth of Rough Lemon (Citrus jambhiri Lush)," was conducted in the insect-proof net house at the Experimental Orchard, Department of Horticulture, CCS Haryana Agricultural University, Hisar, during the academic year 2021-2022. The experiment was laid out in a completely randomized design with three replications. The experiment comprised 30 treatment combinations, including ten different growing media: T_1:garden soil; T_2:soil:sand(1:1); T_3: soil:sand:leafmold(1:1:1); T_4: soil:cocopeat(1:1); T_5: sand:cocopeat(1:1); T_6: soil:sand:cocopeat(1:1:1); T_7: soil:FYM(1:1); T_8: sand:FYM(1:1); T_9: soil:sand:FYM(1:1:1); T_{10}: soil:sand:FYM:cocopeat(1:1:1:1), and the polybags: large(30 x 18 cm) , medium(21 x 18 cm) & small size(17 x 16 cm) bags. Fully mature, uniform in size, and healthy rough lemon fruits were harvested in the last week of August 2021 from a single tree for seed extraction. Two seeds were sown manually at a depth of about 1.00 cm in each black polybag of various sizes (large, medium, and small) filled with the ten different media and kept in the net house. Seed germination and growth parameters of the seedlings were observed, and the means of these data were computed. The media were analyzed for physical and chemical properties, including water-holding capacity, porosity, pH, EC, OC, and N, P, and K content. An electronic balance was used for measuring weight. The length from the collar region to the tip of the root was measured using a meter scale, while the fresh and dry weights of the roots were recorded with a weighing balance. Primary roots were defined as those that developed from tap roots. Root volume was measured using the water displacement method and expressed in milliliters (ml). The dry weights of both shoots and roots were measured for each replication in each treatment, and the dry root-to-shoot ratio was calculated.

Table 1 : Physico- Chemical properties of different growing media.

Treatments	PHYSICO-CHEMICAL PROPERTIES							
	WHC (%)	Porosity (%)	pH	EC (dS/m)	OC (%)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
T1:Garden soil	27.99	26.54	7.48	0.84	0.47	31.36	13.5	285
T2:Soil:Sand(1:1)	24.24	28.50	8.18	1.05	0.23	15.68	11.2	176
T3:Soil:Sand:Leafmold(1:1:1)	29.67	30.00	7.42	0.85	0.72	39.20	11.2	426
T4:Soil:cocopeat(1:1)	52.48	51.02	6.83	0.72	1.15	31.36	21.2	540
T5:Sand:Cocopeat(1:1)	44.28	54.47	7.11	1.05	1.02	23.52	17.2	480
T6:Soil:Sand:Cocopeat(1:1:1)	44.72	51.81	7.60	0.95	0.93	31.36	14.7	377
T7:Soil:FYM(1:1)	40.89	30.62	6.85	1.00	1.05	54.88	14.7	580
T8:Sand:FYM(1:1)	33.62	39.73	7.15	0.90	0.95	39.20	17.2	449
T9:Soil:Sand:FYM(1:1:1)	29.16	30.00	7.06	1.10	1.06	39.20	14.7	340
T10Soil:Sand:FYM:Cocopeat(1:1:1:1)	38.97	40.63	6.77	0.92	1.12	47.04	21.2	560

Results and Discussion

The current investigation was conducted to know the effect of different potting media and polybag sizes on seeds germination and root growth of Rough lemon (*citrus jambhiri Lush.)* in nursery. The findings from the current study are presented under suitable headings, along with tables.

Effect of potting media and polybag size on seed germination

The study revealed that the first and 50% seed germination among different growing media treatments were significant, but polybag size and their interaction were non-significant. The minimum number of days (23.00) taken for first seed germination was recorded in treatment T_5. However, the minimum number of days (24.57) in polybags was observed in S_1, and the minimum number of days for the interaction was recorded in treatment T_6S_2

For 50% seed germination, the minimum number of days (26.78) was recorded in treatment T_6. Numerically, the minimum number of days (28.80) was observed in S_1, and among interactions, the minimum value (26.33) was observed in treatment T_6S_1.

This variation is attributed to the fact that organic matter-fortified media contained a significant quantity of organic matter, which provided a capacity to hold water and nutrients, and maintained balanced moisture levels, leading to earlier and better germination. In contrast, delayed germination in T_3 (soil:sand;leaf mold (1:1:1)) may be due to the coarse texture of leaf mold, which may have led to higher water content, reduced aeration, less contact of media with the seeds, and imbalanced moisture supply to the seeds. Similarly, in sole media with soil and soil : sand(1:1)

, delayed germination may result from poor water-holding capacity, low porosity, and slightly high pH and EC. Similar findings were also reported by Bhagat et al. (2013) in rough lemon [9], Bhardwaj (2013) [10], and Nagar et al. (2016) in papaya [11].

Table 2 : Effect of growing media and polybag size on days taken for 1st seed germination in rough lemon rootstock

Treatments	Size of polybags			
	Large(S_1)	Medium(S_2)	Small(S_3)	Mean
T_1:Garden soil	23.67	25.33	27.00	**25.33**
T_2:Soil:Sand(1:1)	24.67	24.00	26.33	**25.00**
T_3:Soil:Sand:Leafmold(1:1:1)	28.00	27.33	26.67	**27.33**
T_4:Soil :Cocopeat (1:1)	24.00	23.67	23.33	**23.67**
T_5:Sand: Cocopeat (1:1)	22.67	23.00	23.33	**23.00**
T_6:Soil:Sand:Cocopeat (1:1:1)	23.00	22.33	23.67	**23.67**
T_7:Soil:FYM(1:1)	26.33	24.33	25.67	**25.44**
T_8:Sand:FYM(1:1)	25.33	25.67	24.00	**25.00**
T_9:Soil:Sand:FYM(1:1:1)	24.67	26.00	25.33	**25.33**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	23.33	25.00	24.67	**24.33**
Mean	**24.57**	**24.67**	**25.20**	
C.D.at 5%	Growing media(T)		0.83	
	Polybag size(S)		NS	
	T x S		NS	

Table 3 : Effect of growing media and polybag size on days taken for 50% seed germination in rough lemon rootstock

Treatments	Size of polybags			
	Large(S_1)	Medium(S_2)	Small(S_3)	Mean
T_1:Garden soil	28.67	31.00	33.33	**30.89**
T_2:Soil:Sand(1:1)	28.67	29.33	31.00	**29.67**
T_3:Soil:Sand:Leafmold(1:1:1)	33.33	31.67	32.00	**32.33**
T_4:Soil :Cocopeat (1:1)	27.00	27.33	28.00	**27.44**

T_5:Sand: Cocopeat (1:1)	27.67	27.00	26.67	**27.11**
T_6:Soil:Sand:Cocopeat (1:1:1)	26.33	27.33	26.67	**26.78**
T_7:Soil:FYM(1:1)	31.00	29.00	31.67	**30.56**
T_8:Sand:FYM(1:1)	29.00	30.33	30.00	**29.78**
T_9:Soil:Sand:FYM(1:1:1)	28.67	31.33	30.67	**30.22**
T_{10}:Soil:Sand:FYM:Cocopeat (1:1:1:1)	27.67	30.33	29.67	**29.22**
Mean	**28.80**	**29.46**	**29.97**	
C.D.at 5%	Growing media(T)		1.34	
	Polybag size(S)		NS	
	T x S		NS	

Seed Germination

The study revealed that the growing media, polybags, and their interactions were all significant in influencing the germination percentage. The highest germination percentage (88.89%) was recorded in treatment T_5. Among polybags, the maximum germination (85.10%) was found in S_1, and for the interaction, the maximum value (93.33%) was measured in treatments T_5S_1 and T_6S_1. This is because cocopeat and FYM serve as buffers against temporary drought stress and reduce the risk of plant failure during establishment (Johnson and Leah, 1990) [12], which results in a higher germination percentage. The lowest germination in T_3 may be due to the high water content, which results in poor aeration and less contact of media with the seed due to the coarse texture of leaf mold. Similar findings were also reported by Bhagat et al. (2013) in rough lemon [9] and Bhardwaj (2013) [10], Nagar et al. (2016) [11], and Singh et al. (2018) in papaya [13].

Table 4 : Effect of growing media and polybag size on germination percentage in rough lemon rootstock

Treatments	**Size of polybags**			
	Large(S_1)	**Medium(S_2)**	**Small(S_3)**	**Mean**
T_1:Garden soil	73.33	76.67	60.00	**70.00**
T_2:Soil:Sand(1:1)	80.00	82.33	76.67	**79.67**
T_3:Soil:Sand:Leafmold(1:1:1)	66.67	62.67	63.00	**64.11**
T_4:Soil :Cocopeat (1:1)	90.00	88.67	83.33	**86.67**
T_5:Sand: Cocopeat (1:1)	93.33	90.33	83.00	**88.89**
T_6:Soil:Sand:Cocopeat (1:1:1)	93.33	86.00	84.67	**88.00**
T_7:Soil:FYM(1:1)	90.00	88.33	86.00	**88.11**
T_8:Sand:FYM(1:1)	86.33	89.67	89.67	**87.89**
T_9:Soil:Sand:FYM(1:1:1)	88.00	90.33	81.33	**88.53**

T_{10}:Soil:Sand:FYM:Cocopeat (1:1:1:1)	90.00	88.67	86.33	**88.33**
Mean	**85.10**	**84.17**	**79.10**	
C.D.at 5%	Growing media(T)		4.67	
	Polybag size(S)		2.23	
	T x S		6.12	

Survival percentage

The survival percentage of the seedling as influenced by different growing media, polybags size and their interaction showed 100% survival percentage at 60, 90 and 120 days after sowing, even throughout the study period and hence, data was not presented. The 100% survival was due to better soil & aerial environment, proper maintenance, timely watering and the insect proof net house leads to 100% survival of the seedlings among all the various media and polybag size treatments throughout study period.

Effect of growing media and polybag size on growth traits of root

The study revealed that the tap root length and the diameter of the tap root showed significant variations among different growing media, polybag sizes, and their interactions. The highest tap root length (28.10 cm) was noted in treatment T_9, and the greatest tap root length (29.31 cm) in polybags was observed in S_1. Among interactions, the maximum value (33.17 cm) was found in treatment T_9S_1. The highest tap root diameter (2.45 mm) was recorded in treatment T_{10}, and the maximum tap root diameter (2.45 mm) was also recorded in S_1. Among interactions, the most significant value (2.96 mm) was found in $T_{10}S_1$.

Table 5 : Effect of growing media and polybag size on length of tap roots (cm) in rough lemon rootstock

Treatments	**Size of polybags**			
	Large(S_1)	**Medium(S_2)**	**Small(S_3)**	**Mean**
T_1:Garden soil	31.92	31.75	17.92	**27.19**
T_2:Soil:Sand(1:1)	22.72	12.67	12.25	**15.88**
T_3:Soil:Sand:Leafmold(1:1:1)	28.42	22.80	19.67	**23.63**
T_4:Soil :Cocopeat (1:1)	29.17	22.75	17.83	**23.25**
T_5:Sand: Cocopeat (1:1)	30.92	30.42	18.17	**26.50**
T_6:Soil:Sand:Cocopeat (1:1:1)	30.67	31.83	16.67	**26.39**
T_7:Soil:FYM(1:1)	23.00	27.75	17.12	**22.62**
T_8:Sand:FYM(1:1)	30.08	30.25	21.75	**27.36**
T_9:Soil:Sand:FYM(1:1:1)	33.17	27.63	23.50	**28.10**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	33.00	26.83	20.58	**26.81**
Mean	**29.31**	**26.47**	**18.15**	

C.D.at 5%	Growing media (T)	1.65
	Polybag size(S)	0.90
	T x S	2.85

Table 6 : Effect of growing media and polybag size on diameter of tap roots (mm) in rough lemon rootstock

Treatments	**Size of polybags**			
	Large(S_1)	**Medium(S_2)**	**Small(S_3)**	**Mean**
T_1:Garden soil	2.42	2.32	1.56	**2.10**
T_2:Soil:Sand(1:1)	1.04	1.06	0.86	**0.99**
T_3:Soil:Sand:Leafmold(1:1:1)	2.33	1.69	1.55	**1.86**
T_4:Soil :Cocopeat (1:1)	2.34	1.88	1.51	**1.91**
T_5:Sand: Cocopeat (1:1)	2.66	2.24	1.67	**2.19**
T_6:Soil:Sand:Cocopeat (1:1:1)	2.62	2.14	1.59	**2.11**
T_7:Soil:FYM(1:1)	2.60	2.77	1.39	**2.25**
T_8:Sand:FYM(1:1)	2.86	2.34	1.72	**2.31**
T_9:Soil:Sand:FYM(1:1:1)	2.62	2.50	1.84	**2.32**
T_{10}:Soil:Sand:FYM:Cocopea (1:1:1:1)	2.96	2.49	1.81	**2.45**
Mean	**2.45**	**2.14**	**1.55**	
C.D.at 5%	Growing media (T)	0.27		
	Polybag size(S)	0.14		
	T x S	0.43		

Effect of growing media and polybag size on root biomass

Root biomass

The study revealed that the fresh and dry weight of roots were significantly influenced by various growing media, polybag sizes, and their interactions. The highest mean fresh root weight (4.63 g) was reported in treatment T_{10}, and the maximum mean fresh root weight (4.65 g) in polybags was observed in S_1. Among interactions, the maximum value (6.70 g) was found in treatment T_9S_1. The maximum dry weight of roots (1.21 g) was recorded in treatment T_8, and the highest dry root weight (1.25 g) in polybags was measured in S_1. The maximum dry root weight (2.00 g) was found in treatment T_9S_1 (Table 7)

Table 7 : Effect of growing media and polybag size on fresh root weight (g) in rough lemon rootstock

Treatments	**Size of polybags**

	Large(S_1)	Medium(S_2)	Small(S_3)	Mean
T_1:Garden soil	4.22	2.29	1.47	**2.66**
T_2:Soil:Sand(1:1)	1.19	0.50	0.22	**0.64**
T_3:Soil:Sand:Leafmold(1:1:1)	3.45	2.67	1.66	**2.59**
T_4:Soil:Cocopeat (1:1)	3.18	2.47	1.01	**2.22**
T_5:Sand: Cocopeat (1:1)	5.86	4.59	2.07	**4.18**
T_6:Soil:Sand:Cocopeat (1:1:1)	3.08	2.57	1.01	**2.22**
T_7:Soil:FYM(1:1)	6.10	5.88	1.54	**4.51**
T_8:Sand:FYM(1:1)	5.99	4.27	1.69	**3.99**
T_9:Soil:Sand:FYM(1:1:1)	6.70	4.19	2.02	**4.30**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	6.68	4.95	2.26	**4.63**
Mean	**4.65**	**3.44**	**1.53**	
C.D.at 5%	Growing media (T)	0.73		
	Polybag size(S)	0.33		
	T x S	1.34		

Table 8 : Effect of growing media and polybag size on dry root weight (g) in rough lemon rootstock

Treatments	**Size of polybags**			
	Large(S_1)	**Medium(S_2)**	**Small(S_3)**	**Mean**
T_1:Garden soil	1.04	0.64	0.35	**0.68**
T_2:Soil:Sand(1:1)	0.41	0.07	0.06	**0.18**
T_3:Soil:Sand:Leafmold(1:1:1)	1.00	0.53	0.30	**0.61**
T_4:Soil :Cocopeat (1:1)	0.89	0.52	0.35	**0.58**
T_5:Sand: Cocopeat (1:1)	1.25	0.83	0.42	**0.83**
T_6:Soil:Sand:Cocopeat (1:1:1)	0.97	0.69	0.25	**0.64**
T_7:Soil:FYM(1:1)	1.48	1.36	0.40	**1.08**
T_8:Sand:FYM(1:1)	1.42	1.12	1.08	**1.21**
T_9:Soil:Sand:FYM(1:1:1)	2.00	0.95	0.62	**1.19**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	1.95	1.02	0.47	**1.15**
Mean	**1.25**	**0.78**	**0.44**	
C.D.at 5%	Growing media (T)	0.21		

	Polybag size(S)	0.12
	T x S	0.40

The improvement in root growth parameters due to the addition of FYM and cocopeat might be the result of enhanced soil aeration, increased water-holding capacity, and a decrease in bulk density. This, in turn, promotes better root length due to improved soil microfauna and flora, as well as enhanced soil health and nutrient status of the medium. The poor results in T_2: soil:sand(1:1) might be due to lower porosity, organic carbon, and available nutrients, which are necessary for better seedling growth. These results are consistent with findings by Bhagat et al. (2013) in rough lemon [9] and Bhardwaj (2013) in papaya [10]. The best performance in root growth parameters observed in large-sized bags might be attributed to the larger volume of soil, which allows the roots of the seedlings to spread more. With a wider root spread, the root capacity increases, leading to better root architecture. Similar findings regarding root growth in different polybag sizes were previously observed by Salisu et al. (2017) in rubber [14], Massetani et al. (2016) in strawberry [15], and Kishor and Ram (2019) in Oroxylum indicum [16].

Root: shoot ratio

The study revealed that the root-to-shoot ratio showed significant differences among various growing media, polybag sizes, and their interaction. Among all the treatments, treatment T_2 showed a significantly higher value than all other treatments. The maximum dry root-to-shoot ratio (0.41) was reported in S_1, and in the interaction, the maximum value (0.97) was found in treatment T_2S_1. Similar results were recorded earlier by Bhagat et al. (2013) in rough lemon [9]; Adugna et al. (2015) [17] and Bhardwaj et al. (2013) in papaya [10]; and Seman et al. (2018) in oil palm [18].The results obtained from different polybag sizes differed significantly, and there was a gradual decrease in the dry root-to-shoot ratio with each decrease in bag size, irrespective of the growing media. Larger polybags provide more surface area for the roots to spread and ensure proportionally better root growth compared to shoots, while the opposite is true for smaller bags. Similar results were shown by Negi and Shamet (2020) in aonla [19], and Salisu et al. (2017) in rubber [14].

Table 9 : Effect of growing media and polybag size on root shoot ratio in rough lemon rootstock

Treatments	**Size of polybags**			
	Large(S_1)	**Medium(S_2)**	**Small(S_3)**	**Mean**
T_1:Garden soil	0.35	0.37	0.26	**0.33**
T_2:Soil:Sand(1:1)	0.97	0.48	0.39	**0.61**
T_3:Soil:Sand:Leafmold(1:1:1)	0.35	0.35	0.32	**0.34**
T_4:Soil :Cocopeat (1:1)	0.34	0.39	0.35	**0.36**
T_5:Sand: Cocopeat (1:1)	0.39	0.40	0.30	**0.36**
T_6:Soil:Sand:Cocopeat (1:1:1)	0.33	0.31	0.28	**0.31**
T_7:Soil:FYM(1:1)	0.30	0.34	0.28	**0.31**
T_8:Sand:FYM(1:1)	0.29	0.41	0.32	**0.34**
T_9:Soil:Sand:FYM(1:1:1)	0.38	0.33	0.31	**0.34**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	0.38	0.26	0.25	**0.30**
Mean	**0.41**	**0.36**	**0.34**	

C.D.at 5%	Growing media (T)	0.05
	Polybag size(S)	0.03
	T x S	0.08

Number of primary roots

The study revealed that the effect of growing media and polybag size on the number of primary roots, as well as their interaction, was significant. The maximum number of primary roots (61.22) was found in treatment T_8. In polybags, the maximum number of primary roots (63.87) was observed in S_1. Among the interactions, the highest value (75.33) was recorded in treatment $T_{10}S_1$. The greater number of roots might be attributed to the higher nutrient content, good porosity, aeration, high water-holding capacity, and the unique ability of the medium to promote rooting and root development compared to other media. The poor results in T_2 may be due to the poor physico-chemical properties of the medium, which do not support the root growth of rough lemon seedlings. Similar results were reported earlier by Singh et al. (2015) in lemon [20], Mishra et al. (2014) in Kagzi lime [21], and Rashmita et al. (2016) in pear [22]. Larger polybags lead to greater root length compared to smaller bags, which directly increases the number of primary roots along the length of the bag. This explains the lower number of primary roots in smaller bags. These results are contrary to the earlier findings of Singh and Kaur et al. (2019) in rough lemon [23].

Table 10 : Effect of growing media and polybag size on number of primary roots in rough lemon rootstock

Treatments	**Size of polybags**			
	Large(S_1)	**Medium(S_2)**	**Small(S_3)**	**Mean**
T_1:Garden soil	70.00	38.83	41.33	**50.06**
T_2:Soil:Sand(1:1)	32.83	34.83	29.17	**32.28**
T_3:Soil:Sand:Leafmold(1:1:1)	61.67	52.67	41.33	**51.89**
T_4:Soil :Cocopeat (1:1)	60.83	52.17	50.83	**54.61**
T_5:Sand: Cocopeat (1:1)	72.50	54.50	54.17	**60.39**
T_6:Soil:Sand:Cocopeat (1:1:1)	60.33	44.33	43.83	**49.50**
T_7:Soil:FYM(1:1)	70.33	54.17	42.50	**55.67**
T_8:Sand:FYM(1:1)	64.17	66.67	52.83	**61.22**
T_9:Soil:Sand:FYM(1:1:1)	70.67	44.83	38.83	**51.44**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	75.33	34.83	29.17	**46.44**
Mean	**63.87**	**47.78**	**42.40**	
C.D.at 5%	Growing media (T)	3.84		
	Polybag size(S)	2.10		
	T x S	6.65		

Root volume (ml)

The study revealed significant variations in root volume among various growing media, polybag sizes, and their interactions. The highest root volume (6.44 ml) was observed in treatment T_5, while the maximum root volume in polybags (5.70 ml) was recorded in S_1. However, the most significant interaction value (8.00 ml) was found in treatments T_7S_1 and T_9S_1. This may be due to increased root growth in terms of length, diameter, and the number of secondary roots in media supplied with FYM and cocopeat, as indicated by the present investigation. Larger polybags support better root system growth by providing more space for roots to proliferate compared to smaller bags, leading to greater taproot length and, consequently, an increase in root volume, and vice versa. These results are in line with those of Halandkar et al. (2014) in Alphonso and Kesar [24] grafts grown in different polybags. Similar findings were reported earlier by Salisu et al. (2017) in rubber [14] and Adugna et al. (2015) in papaya [17].

Table 11 : Effect of growing media and polybag size on root volume(ml)in rough lemon rootstock

Treatments	Size of polybags			
	Large(S_1)	Medium(S_2)	Small(S_3)	Mean
T_1:Garden soil	5.67	5.33	5.17	**5.39**
T_2:Soil:Sand(1:1)	1.38	1.25	0.73	**1.12**
T_3:Soil:Sand:Leafmold(1:1:1)	4.33	3.75	2.75	**3.61**
T_4:Soil :Cocopeat (1:1)	3.92	4.33	3.97	**4.07**
T_5:Sand: Cocopeat (1:1)	6.67	7.33	5.33	**6.44**
T_6:Soil:Sand:Cocopeat (1:1:1)	5.00	3.83	2.58	**3.81**
T_7:Soil:FYM(1:1)	8.00	6.17	3.48	**5.85**
T_8:Sand:FYM(1:1)	6.17	6.83	6.08	**6.36**
T_9:Soil:Sand:FYM(1:1:1)	8.00	5.00	3.75	**5.58**
T_{10}:Soil:Sand:FYM:Cocopeat(1:1:1:1)	7.83	6.08	5.00	**6.31**
Mean	**5.70**	**4.99**	**4.21**	
C.D.at 5%	Growing media (T)	0.62		
	Polybag size(S)	0.32		
	T x S	0.93		

CONCLUSION

It can be concluded that when cocopeat is supplemented in media (T_4, T_5& T_6) resulted into early germination. Whereas, $T_4$to T_{10} media consists of either FYM, cocopeat & both resulted into more germination 87-89% as compared to T_1: soil; T_2: sand:soil & T_3:sand:soil:leafmold.

The most of the root growth parameters (i.e., diameter of tap root, fresh & dry root weight) & root:shoot ratio improved when the media sand:FYM, soil:FYM, sand:soil:FYM, sand:soil:FYM:cocopeat mixed in equal proportion. However, when media supplemented with cocopeat (T_4,T_5 & T_6) also showed

appreciable results as compared to soil, sand:soil & soil:sand:leafmold. However, sand:FYM, sand:cocopeat treatments were best in respect of number of primary roots, root volume was found optimum in the seedlings raised in media fortified with cocopeat, FYM & leafmold. Whereas, sand:soil showed very poor results in all growth aspects.

Among polybags sizes, large size (30 x 18cm) bags performed best in most of the germination & growth parameters.

FUTURE SCOPE

The study's conclusions shed important light on how various potting media and polybag sizes affect the germination and root development of rough lemons (Citrus jambhiri Lush.) in nurseries. Nonetheless, further research could be pursued to enhance our understanding and promote sustainable farming practices. Some possible avenues for future investigation include:

1. The primary aim of nursery growers is to multiply plants in the shortest possible time to reduce costs and maximize benefits.
2. Future research could explore other potting mixture concentrations and various tree species' propagation materials to achieve faster germination of tree seedlings.
3. Additionally, this study should be conducted under a variety of agroclimatic conditions which is appropriate for rough lemon. To ensure reliable results and provide a solid basis for recommending suitable potting media to promote seedling growth, the experiment should be carried out in an open-field setting over a considerable period.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby certify that no generative AI tools, such as text-to-image generators or large language models (e.g., ChatGPT, Copilot, etc.), were used at any stage of writing or editing the manuscript.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

Srivastava AK, Singh S, Huchche AD. An analysis on citrus flowering–a review. Agric Rev. 2000;21(1):1-5.

Ghosh SP. Citrus industry in Asia. In: Proceedings of the International Symposium on Citriculture; 2000; Nagpur (M.S.). 2000. p. 1-23.

Cao M, Atta S, Su H, Wang X, Wu Q, Li Z, Zhou C. Molecular characterization and phylogenetic analysis of Citrus viroid V isolates from Pakistan. Eur J Plant Pathol. 2013;135:11-21.

Kadam BA, Patil VK. Effect of different concentrations of chloride, bicarbonate, and high ESP in soil on the growth and chemical composition of citrus rootstocks. Ph.D. Thesis (Ag.), Marathwada Agricultural University, Parbhani, M.S. (India). 1985.

Gera M, Ginwal HS. Preliminary observations on field trial of root trainer raised seedlings. Indian For. 2002;128(1):19-26.

Wilkerson D. Growing Media. In: Texas Greenhouse Management Handbook. Texas Agriculture Extension Service; 2002.

Cantliffe DJ. Seed germination for transplants. 1998;499-503.

Amidon TE, Barnett JP, Gallagher HP, McGilvray JM. A field test of containerized seedlings under drought conditions. In: Proceedings of the Southern Containerized Forest Tree Seedling Conference; 1981 Aug 25-27; Savannah, Georgia. 1982. p. 139.

Bhagat S, Thakur A, Dhaliwal HS. Organic amendments influence growth, buddability and budding success in rough lemon (Citrus jambhiri Lush.). Biol Agric Hortic. 2013;29(1):46-57.

Bhardwaj RL. Effects of nine different propagation media on seed germination and the initial performance of papaya (Carica papaya L.) seedlings. J Hort Sci Biotech. 2013;88(5):531-6.

Nagar SK, Vihol NJ, Arvind RK. Effect of different growing media on germination and establishment of seedlings of papaya (Carica papaya L.) Cv. Madhubindu under net house conditions. Int Q J Life Sci. 2016;11(3):1465-68.

Johnson MS, Leah RT. Effects of superabsorbent polyacrylamides on efficiency of water use by crop seedlings. J Sci Food Agric. 1990;52(3):431-4.

Singh DS, Kaushik RA, Solanki SPS, Sarolia DK, Vikram K. Germination response and interaction effect under polybag and protray conditions of Papaya (Carica papaya L.) cv. PusaNanha. Int J Chem Stud. 2018;6(3):2538-41.

Salisu MA, Sulaiman Z, Abd Samad MY, Kolapo OK. Effect of various types and size of container on growth and root morphology of Rubber (Hevea brasiliensis Mull. Arg.). Int J Sci Technol Res. 2017;7(6):21-27.

Massetani F, Savini G, Neri D. Effect of substrate and container type in the strawberry soilless cultivation. In: VIII International Strawberry Symposium; 2016. p. 295-300.

Kishor K, Ram J. Growth and development of seedlings in relation to container size and potting media under nursery conditions in Oroxylum indicum-A multipurpose medicinal plant. Indian J Ecol. 2019;46(1):143-48.

Adugna M, Belew D, Tilahun D. Influence of rooting media and number of nodes stem-1 cutting on nursery performance of vanilla (Vanilla planifolia). J Hortic For. 2015;7(3):48-56.

Seman IF, Zulkefly S, Adekunle SM, Samad MYA. Effect of different media combination on growth and biomass production of Oil Palm (Elaeis guineensis) seedlings. Int J Environ Agric Biotech. 2018;3(1):140-46.

Negi R, Shamet GS. Standardization of best growing medium and container type for quality stock production in Emblica officinalis Gaertn. J Pharmacogn Phytochem. 2020;9(6):1535-38.

Singh VP, Nimbolkar PK, Singh SK, Mishra NK, Tripathi A. Effect of growing media, PGRs and seasonal variability on rooting ability and survival of lemon (Citrus limon L.) cuttings. Int J Agric Environ Biotechnol. 2015;8(3):593.

Mishra S. Effect of different rooting media on survival and success of air layers in Kagzilime. Ann Plant Soil Res. 2014;16(3):264-67.

Rashmita SM, Tudu S, Shanker K. Effect of different media on rooting and survival of Pear (Pyrus pyrifolia L.) cuttings cv. Patharnakh. Int J Bio-resource Stress Manag. 2016;7(4):636-40.

Singh A, Kaur G. Influence of various growing medias and size of polybags on the growth, buddability and budding success in rough lemon. Green Farming. 2019;10(2):167-72.

Haldankar PM, Parulekar YR, Kulkarni MM, Lawande KE. Effect of size of polybag on survival and growth of mango grafts. J Plant Stud. 2014;3(1):91.