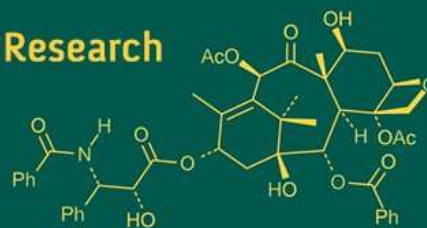
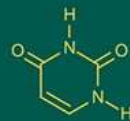
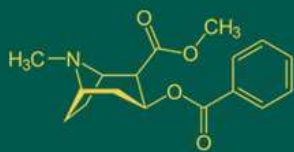


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Effect of seed soaking and growing media on germination and survivability of acid lime (*Citrus aurantifolia* Swingle) under shade net condition

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Abstract

An experiment was conducted at the Horticulture Nursery, Department of Fruit Science, IGKV, Raipur, Chhattisgarh, during the winter season of 2025–26 to study the effect of seed soaking and growing media on germination and survivability of acid lime (*Citrus aurantifolia* Swingle) under shade net condition. The experiment used a Completely Randomized Design (CRD) with fifteen treatments and three replications, testing three seed soaking treatments Water @ 24 hours, Vermiwash @ 25% for 12 hours, and Cow urine @ 25% for 12 hours combined with growing media of sand, soil, FYM, cocopeat and vermicompost. Seed soaking and growing media combinations significantly influenced germination, survival and seedling growth, with T₉ (Vermiwash + Sand + Soil + FYM + Cocopeat + Vermicompost) giving the best results overall. T₉ recorded the fastest germination (19.33 days), the maximum germination percentage (86.02%), the maximum survival percentage (80.11%) and germination index (2.19) along with the maximum average number of seedlings per seed or polyembryony (3.66). It also produced the maximum height of seedlings (20.98 cm), the maximum no. of leaves (22.53) and the maximum diameter (2.96 mm) as well as the maximum Seedling Vigour Index-I (4125.51), Vigour Index-II (299.34) and tap root length (19.98 cm). T₁₄ (Cow urine with the same enriched media) ranked second and was statistically *at par* with T₉ in several parameters, while the control T₀ (Water + Sand + Soil) recorded the minimum values across most parameters. Economically, T₉ gave the maximum net return (₹1068) and benefit-cost ratio (3.80), confirming that vermiwash seed soaking combined with an enriched sand-soil-FYM-cocopeat-vermicompost medium is the most effective treatment for acid lime seedling production.

Keywords: Acid lime, seed soaking, vermiwash, cow urine, growing media, germination, seedling growth, survivability.

Introduction

Acid lime (*Citrus aurantifolia* Swingle) is an important fruit crop belonging to the family Rutaceae and is widely cultivated in tropical and subtropical regions of India. It is valued for its tart flavour, aromatic properties, nutritional importance and high vitamin C content. Acid lime is commercially cultivated in several states of India including Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Bihar, Madhya Pradesh, Assam and Chhattisgarh. Chhattisgarh is also an important acid lime growing region.

Acid lime is mainly propagated through seeds because of its high degree of nucellar embryony, which contributes to the production of true-to-type seedlings. However, acid lime seeds are recalcitrant in nature and are sensitive to drying and chilling. The crop also exhibits relatively slow and irregular germination, which can result in poor seedling establishment and increased mortality under nursery conditions.

Seed germination and subsequent seedling establishment are influenced by several factors including seed quality, pre-sowing seed treatment, growing media, moisture availability, aeration and nutrient supply. Seed soaking treatments can help modify the seed coat, remove inhibitory substances and activate metabolic processes required for germination. Organic substances such as cow urine and vermiwash have also been reported to contain nutrients and growth-promoting substances that may enhance germination and seedling vigour.

Growing media play an important role in providing physical support, moisture, aeration and nutrients to developing seedlings. Sand improves drainage and aeration, cocopeat provides good pore space and moisture retention, while FYM and vermicompost contribute nutrients and improve the physical and biological properties of the growing medium.

Keeping these aspects in view, the present investigation was undertaken to identify a suitable combination of seed soaking treatment and growing media for improving germination, survivability and seedling growth of acid lime under shade net conditions.

2. Materials and Methods

The present investigation was carried out in a shade net house at the Horticulture Nursery, Department of Fruit Science, College of Agriculture, Indira Gandhi Krishi

Vishwavidyalaya, Raipur, Chhattisgarh, during the winter season of 2025-26. Raipur is situated in the central Chhattisgarh plain at 298.15 m above mean sea level (21.25° N latitude, 81.62° E longitude) and comes under the seventh agro-climatic zone of India (Eastern Plateau and Hills region), characterized by a sub-humid climate with hot summers and cold winters and an average annual rainfall of 1200-1400 mm. The experiment was laid out in a Completely Randomized Design (CRD) comprising fifteen treatment combinations, each replicated thrice, with 20 seedlings per treatment (900 seedlings in total). Three seed soaking treatments Water @ 24 hours, Vermiwash @ 25% for 12 hours and Cow urine @ 25% for 12 hours were combined with growing media prepared from sand, soil, farmyard manure (FYM), cocopeat and vermicompost either singly or in combination, to constitute the fifteen treatments (T₀-T₁₄) as detailed in Table 1.

Table 1: Details of treatments

Notation	Treatment details
T ₀	Water @ 24 hrs + Sand + Soil (Control)
T ₁	Water @ 24 hrs + Sand + Soil + FYM
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost

Data on days taken for initiation of germination, germination percentage, survival percentage, germination index, average number of seedlings per seed (polyembryony), seedling height, seedling diameter, number of leaves, fresh and dry weight of shoot and root, tap root length, seedling vigour indices, success percentage and economics of seedling production were recorded at appropriate intervals up to 120 days after sowing (DAS). The data were statistically analyzed following the analysis of variance (ANOVA) technique for CRD (Fisher and Yates, 1963) and treatment means were compared using the critical difference (CD) at 5% level of significance.

3. Results and discussion

3.1 Germination parameters

Data on days taken for initiation of germination, germination percentage, survival percentage, germination index and average number of seedlings per seed, as influenced by seed soaking and growing media, are presented in Table 2.

Seed soaking and growing media significantly influenced all the germination parameters studied. The minimum number of days required for initiation of germination (19.33) was recorded in T₉ (Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost) which was

statistically *at par* with T₁₄ (20.29) and T₄ (21.19), while the maximum days (31.69) was recorded in the control (T₀). The maximum germination percentage (86.02) was recorded in T₉ *at par* with T₁₄ (83.79) and minimum in T₀ (46.36). Similarly the maximum survival percentage was observed in T₉ (80.11) and minimum in T₀ (38.33). The maximum germination index recorded in T₉ (2.19) and minimum in T₀ (1.02). The maximum average number of seedlings per seed/polyembryony observed in T₉ (3.66) and minimum in T₀ (0.75).

The superior performance of T₉ may be attributed to the presence of plant growth-promoting substances, essential nutrients, enzymes and beneficial microorganisms in vermiwash, which enhance physiological and biochemical activity within the seed, while the enriched medium (FYM, cocopeat and vermicompost) improved aeration, moisture retention and nutrient availability favouring rapid imbibition, embryo development and multiple embryo emergence. These findings are in close agreement with Yadav *et al.* (2012)^[19] and Kiran Sagar *et al.* (2024)^[12] in acid lime, Bhutiya (2017)^[3] in Kagzi lime and with the reports of Panda *et al.* (2018)^[16] and Jadhav *et al.* (2019)^[6], who observed enhanced germination and polyembryony with organic seed treatments and nutrient-rich growing media.

Table 2: Effect of seed soaking and growing media on germination parameters of acid lime.

Notation	Treatment	Days to germination	Germination (%)	Survival (%)	Germination index	Average no. of Seedlings / seed
T ₀	Water @ 24 hrs + Sand + Soil (Control)	31.69	46.36	38.33	1.02	0.75
T ₁	Water @ 24 hrs + Sand + Soil + FYM	29.69	56.12	49.06	1.21	1.00
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost	28.67	67.31	59.12	1.81	2.33
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat	28.53	69.19	65.00	1.41	1.66
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	21.19	79.26	75.04	2.03	2.67
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil	30.54	53.33	46.67	1.13	0.80
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM	29.16	58.02	55.03	1.35	1.70
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost	22.43	76.63	68.31	1.87	2.68
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat	24.33	74.08	63.34	1.74	1.67
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	19.33	86.02	80.11	2.19	3.66
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil	31.41	50.05	48.32	1.09	0.78
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM	29.67	57.01	51.67	1.25	1.34
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost	26.17	74.57	65.01	1.83	2.35
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat	28.23	73.31	62.98	1.69	1.68
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	20.29	83.79	78.13	2.09	3.33
	SE (m) ±	0.47	1.15	1.07	0.03	0.05
	C.D. @ 5%	1.38	3.35	3.21	0.09	0.15

3.2 Seedling growth parameters

The height of seedling, seedling diameter and number of leaves per seedling were recorded at 30, 60, 90 and 120 DAS (Table 3), while fresh and dry weight of shoot, their ratio and success percentage were recorded at 120 DAS (Table 4). At every stage of observation, T₉ recorded significantly superior seedling height, diameter and number of leaves followed by T₁₄ and T₄, while the control (T₀) remained the lowest throughout the observation. At 120 DAS, maximum seedling height was 20.98 cm in T₉ and minimum was 9.44 cm in T₀. Similarly the maximum diameter was 2.96 mm in T₉ and minimum was 1.88 mm in T₀. The maximum number of leaves observed in T₉ (22.53) and minimum in T₀ (11.49). Fresh weight of shoot recorded maximum in T₉ (4.35 g) and minimum in T₀ (1.41 g). Similarly the dry weight of shoot recorded maximum in T₉ (2.02 g) and minimum in T₀ (0.49 g). The fresh-to-dry weight ratio was recorded maximum in the water-soaked

treatments T₁₀ (2.90) and T₀ (2.87), whereas the minimum was recorded in T₃ (1.87) and T₁₃ (1.98). Success percentage was observed maximum in T₉ (83.30%) and minimum in T₀ (41.67%). The consistently superior vegetative growth under T₉ and T₁₄ can be explained by the combined effect of seed-soaking bio-stimulants (vermiwash/cow urine) supplying auxin, cytokinins and beneficial enzymes, together with the enriched growing medium (FYM, cocopeat, vermicompost) that improved nutrient availability, moisture retention, aeration and microbial activity, thereby promoting cell division, elongation and dry-matter accumulation. These results support the findings of Kadam *et al.* (2010) and Nagar *et al.* (2011) in acid lime, Khatana *et al.* (2015), Joshi *et al.* (2015) [7] and Meshram *et al.* (2015) [14] in acid lime/Kagzi lime, and Dhaka and Pal (2009) [4] and Kherdekar (2003) [10], who reported similar improvement in seedling growth and vigour with organic seed treatments and nutrient-enriched media.

Table 3: Effect of seed soaking and growing media on seedling height (cm), seedling diameter (mm) and number of leaves per seedling 30,60,90 and 120 DAS of acid lime.

Notation	Treatment	Seedling height (cm)				Seedling diameter (mm)				Number of leaves per seedling			
		30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T ₀	Water @ 24 hrs + Sand + Soil (Control)	1.03 ^k	3.93 ^h	7.04 ^h	9.44 ^h	0.61 ^j	0.71 ⁱ	1.09 ^j	1.88 ^j	2.76 ^k	3.95 ^j	8.87 ⁱ	11.49 ^k
T ₁	Water @ 24 hrs + Sand + Soil + FYM	1.30 ^j	5.6 ^f	8.64 ^{efg}	13.06 ^f	0.79 ^h	0.90 ^g	1.65 ^h	2.04 ^{hi}	4.48 ^{hi}	7.06 ^{gh}	10.49 ^h	14.45 ^{hi}
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost	2.13 ^e	6.5 ^e	10.12 ^d	13.67 ^{ef}	1.04 ^{cde}	1.41 ^d	2.14 ^{ef}	2.63 ^d	7.53 ^d	11.13 ^d	15.51 ^{de}	19.43 ^d
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat	1.71 ^h	5.44 ^{fg}	7.16 ^h	13.19 ^{ef}	1.01 ^{ef}	1.11 ^{ef}	2.06 ^f	2.19 ^g	4.97 ^g	8.75 ^e	12.41 ^g	17.31 ^f
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	3.11 ^c	8.29 ^c	11.98 ^c	16.02 ^c	1.09 ^{abc}	1.58 ^b	2.43 ^{bc}	2.77 ^{bc}	9.01 ^b	13.41 ^b	17.43 ^b	21.41 ^{ab}
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil	1.21 ^j	5.7 ^f	8.41 ^{fg}	12.12 ^g	0.75 ^h	0.82 ^{gh}	1.32 ⁱ	2.02 ⁱ	4.06 ^{ij}	6.53 ^{gh}	9.71 ^{hi}	13.54 ^{ij}
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM	1.69 ^h	6.21 ^e	10.1 ^d	14.09 ^{de}	0.98 ^f	1.07 ^f	2.01 ^f	2.15 ^{gh}	4.69 ^{gh}	7.61 ^f	12.09 ^g	16.13 ^g
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost	2.90 ^d	8.09 ^{cd}	13.19 ^b	16.29 ^c	1.07 ^{abc}	1.53 ^{bc}	2.32 ^{cd}	2.71 ^{bc}	8.88 ^b	13.28 ^{bc}	17.21 ^{bc}	21.19 ^{bc}
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat	2.00 ^f	5.01 ^g	9.11 ^{ef}	14.80 ^d	1.04 ^{cde}	1.39 ^d	2.11 ^{ef}	2.52 ^e	6.11 ^e	10.51 ^d	15.12 ^{ef}	19.22 ^{de}
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	4.56 ^a	10.16 ^a	15.11 ^a	20.98 ^a	1.11 ^a	1.69 ^a	2.59 ^a	2.96 ^a	10.43 ^a	14.61 ^a	18.59 ^a	22.53 ^a
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil	1.11 ^k	5.59 ^f	7.94 ^g	10.09 ^h	0.69 ⁱ	0.79 ^{hi}	1.21 ^{ij}	1.99 ^{ij}	3.89 ^j	6.39 ^h	9.34 ⁱ	13.11 ^j
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM	1.55 ⁱ	6.4 ^e	9.35 ^e	14.12 ^{de}	0.86 ^g	1.03 ^f	1.83 ^g	2.06 ^{hi}	4.59 ^{gh}	7.18 ^{fg}	11.63 ^g	15.38 ^{gh}
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost	2.17 ^e	7.79 ^d	12.04 ^c	15.04 ^d	1.05 ^{bcd}	1.48 ^{cd}	2.21 ^{de}	2.69 ^{cd}	7.97 ^c	12.69 ^c	16.34 ^{cd}	20.21 ^{cd}
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat	1.89 ^g	4.22 ^h	8.4 ^{fg}	14.1 ^{de}	1.02 ^{def}	1.20 ^e	2.09 ^{ef}	2.34 ^f	5.49 ^f	9.08 ^e	14.33 ^f	18.27 ^{ef}
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	3.38 ^b	9.02 ^b	13.86 ^b	18.29 ^b	1.10 ^{ab}	1.61 ^{ab}	2.51 ^{ab}	2.81 ^b	9.24 ^b	14.39 ^a	18.13 ^{ab}	22.23 ^{ab}
	SE (m) ±	0.03	0.16	0.25	0.31	0.02	0.03	0.04	0.04	0.15	0.23	0.34	0.37
	C.D. @ 5%	0.09	0.45	0.73	0.90	0.05	0.09	0.12	0.11	0.44	0.66	0.97	1.08

Table 4: Effect of seed soaking and growing media on fresh and dry weight of shoot (g), fresh: dry weight ratio and success percentage of acid lime at 120 DAS

Notation	Treatment	Fresh wt. shoot (g)	Dry wt. shoot (g)	Fresh: Dry ratio	Success (%)
T ₀	Water @ 24 hrs + Sand + Soil (Control)	1.41 ^k	0.49 ^k	2.87 ^a	41.67 ⁱ
T ₁	Water @ 24 hrs + Sand + Soil + FYM	1.99 ⁱ	0.92 ^{hi}	2.16 ^{bc}	51.69 ^{fh}
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost	2.87 ^e	1.53 ^d	1.87 ^d	61.12 ^e
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat	2.23 ^h	1.11 ^f	2 ^{bcd}	66.19 ^d
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	3.96 ^b	1.85 ^b	2.15 ^{bc}	78.33 ^b
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil	1.81 ^j	0.88 ⁱ	2.05 ^{bcd}	50.11 ^h
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM	2.10 ^{hi}	1.07 ^{fg}	1.96 ^{cd}	55.03 ^{fg}
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost	3.68 ^c	1.75 ^c	2.1 ^{bc}	71.67 ^c
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat	2.61 ^f	1.25 ^e	2.08 ^{bc}	68.32 ^{cd}
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	4.35 ^a	2.02 ^a	2.15 ^{bc}	83.30 ^a
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil	1.77 ^j	0.61 ^j	2.9 ^a	50.01 ^h
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM	2.00 ⁱ	1.01 ^{gh}	1.98 ^{cd}	55.03 ^f
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost	3.51 ^d	1.60 ^d	2.19 ^b	70.60 ^c
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat	2.42 ^g	1.23 ^e	1.96 ^{cd}	68.32 ^{cd}
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	4.09 ^b	1.93 ^{ab}	2.11 ^{bc}	80.89 ^{ab}
	SE (m) ±	0.06	0.03	0.06	1.12
	C.D. @ 5%	0.17	0.09	0.18	3.25

3.3 Root parameters

Data on length of tap root, fresh and dry weight of root and dry shoot: root ratios at 120 DAS are presented in Table 5. The maximum tap root length (19.98 cm) was recorded in T₉ and minimum in (8.76 cm). The maximum fresh root weight (2.54 g) and dry root weight (1.46 g) were recorded in T₉, followed by T₁₄ and T₄, while the minimum fresh root weight (0.63 g) and dry root weight (0.17 g) were recorded in T₀. The dry shoot: root ratio was minimum in T₉ (1.38) and maximum in T₁₁ (3.15), indicating that T₉ produced a

proportionately larger and more efficient root system relative to shoot growth. The enhanced root growth under T₉ and T₁₄ may be ascribed to improved nutrient availability, microbial activity and moisture retention in the enriched growing medium together with the growth-promoting effect of vermiwash/cow urine. The similar findings with Vishwakarma and Sharma (2020) ^[18] in acid lime, Sindhe *et al.* (2008) ^[17] in Rangpur lime, and Lunagariya *et al.* (2022) ^[13] and Kiran Sagar *et al.* (2024) ^[12] in acid lime.

Table 5: Effect of seed soaking and growing media on root parameters of acid lime at 120 DAS.

Notation	Treatment	Tap root length (cm)	Fresh wt. root (g)	Dry wt. root (g)	Dry shoot: root ratio
T ₀	Water @ 24 hrs + Sand + Soil (Control)	8.76 ^h	0.63 ^k	0.17 ⁱ	2.88 ^b
T ₁	Water @ 24 hrs + Sand + Soil + FYM	12.5 ^{de}	1.01 ^{hij}	0.31 ^h	2.96 ^b
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost	12.02 ^{ef}	1.77 ^e	0.82 ^e	1.86 ^f
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat	12.42 ^{de}	1.19 ^{fg}	0.58 ^f	1.91 ^f
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	15.42 ^b	2.25 ^c	1.27 ^b	1.45 ^g
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil	11.39 ^f	0.98 ^{ij}	0.33 ^h	2.66 ^c
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM	13.79 ^c	1.12 ^{gh}	0.46 ^g	2.32 ^{de}
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost	14.02 ^c	2.19 ^{cd}	0.98 ^c	1.78 ^f
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat	13.86 ^c	1.29 ^f	0.51 ^g	2.45 ^d
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	19.98 ^a	2.54 ^a	1.46 ^a	1.38 ^g
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil	10.43 ^g	0.93 ^j	0.28 ^h	2.17 ^e
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM	13.18 ^{cd}	1.08 ^{ghi}	0.32 ^h	3.15 ^a
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost	13.09 ^{cd}	2.08 ^d	0.91 ^d	1.75 ^f
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat	12.43 ^{de}	1.27 ^f	0.47 ^g	2.61 ^c
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	16.18 ^b	2.38 ^b	1.31 ^b	1.47 ^g
	SE (m) ±	0.29	0.04	0.02	0.06
	C.D. @ 5%	0.85	0.12	0.06	0.16

3.4 Seedling vigour index

Seedling vigour index-I and vigour index-II at 120 DAS, computed from germination percentage and total seedling length are presented in Table 6. The maximum vigour index-I (4125.51) and vigour index-II (299.34) were recorded in T₉, followed by T₁₄, while the minimum vigour index-I (843.76) and vigour index-II (30.59) were recorded

in T₀. The maximum vigour indices in T₉ reflect the cumulative benefit of rapid, uniform germination combined with vigorous shoot and root growth, consistent with the reports of Atiyeh *et al.* (2000) ^[2] and Arancon *et al.* (2004) ^[1] on vermicompost-based media, and Kiran Sagar *et al.* (2024) ^[12] in acid lime.

Table 6: Effect of seed soaking and growing media on seedling vigour index-I and vigour index-II of acid lime at 120 DAS.

Notation	Treatment	Seedling vigour index-I	Seedling vigour index-II
T ₀	Water @ 24 hrs + Sand + Soil (Control)	843.76 ^l	30.59 ^m
T ₁	Water @ 24 hrs + Sand + Soil + FYM	1553.96 ^j	69.02 ^{jk}
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost	2536.91 ^f	158.17 ^f
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat	2316.48 ^g	116.93 ^h
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	3522.31 ^c	247.29 ^c
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil	1307.11 ^k	64.53 ^k
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM	1907.69 ^h	88.77 ⁱ
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost	3318.84 ^d	209.2 ^d
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat	2715.77 ^e	130.38 ^g
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	4125.51 ^a	299.34 ^a
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil	976.98 ^l	44.54 ^l
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM	1727.4 ⁱ	75.82 ^j
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost	2768.78 ^e	187.17 ^e
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat	2531.39 ^f	124.62 ^{gh}
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	3893.72 ^b	271.47 ^b
	SE (m) ±	30.93	2.95
	C.D. @ 5%	90.25	8.55

3.5 Economic efficiency

The economics of acid lime seedling production under different treatments, computed on the basis of total cost, gross returns, net returns and benefit: cost (B:C) ratio, are presented in Table 7. Treatment T₉ recorded the maximum B:C ratio (3.80), followed by T₁₄ (3.60) and T₄ (3.39). The

minimum B:C ratio was recorded in control T₀ (2.01). The higher profitability recorded under T₉ was mainly due to better germination, survival and seedling growth resulting from vermiwash seed soaking along with the nutrient-enriched growing medium.

Table 7: Effect of seed soaking and growing media on economic efficiency of acid lime seedling production.

Notation	Treatment	Total cost (₹)	Gross return (₹)	Net return (₹)	B:C ratio
T ₀	Water @ 24 hrs + Sand + Soil (Control)	312	625	313	2.01
T ₁	Water @ 24 hrs + Sand + Soil + FYM	372	800	428	2.15
T ₂	Water @ 24 hrs + Sand + Soil + Vermicompost	412	1050	638	2.55
T ₃	Water @ 24 hrs + Sand + Soil + Cocopeat	327	1000	673	3.06
T ₄	Water @ 24 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	383	1300	917	3.39
T ₅	Vermiwash @ 25% for 12 hrs + Sand + Soil	310	750	440	2.42
T ₆	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM	370	950	580	2.56
T ₇	Vermiwash @ 25% for 12 hrs + Sand + Soil + Vermicompost	410	1225	815	2.98
T ₈	Vermiwash @ 25% for 12 hrs + Sand + Soil + Cocopeat	325	1075	750	3.30
T ₉	Vermiwash @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	382	1450	1068	3.80
T ₁₀	Cow urine @ 25% for 12 hrs + Sand + Soil	310	775	465	2.50
T ₁₁	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM	370	875	505	2.36
T ₁₂	Cow urine @ 25% for 12 hrs + Sand + Soil + Vermicompost	410	1150	740	2.80
T ₁₃	Cow urine @ 25% for 12 hrs + Sand + Soil + Cocopeat	325	1075	750	3.30
T ₁₄	Cow urine @ 25% for 12 hrs + Sand + Soil + FYM + Cocopeat + Vermicompost	382	1375	993	3.60

4. Conclusion

The present investigation revealed that acid lime seeds treated with vermiwash at 25% concentration for 12 hours and sown in a growing medium enriched with Sand + Soil + FYM + Cocopeat + Vermicompost (T₉) consistently outperformed all other treatments with respect to germination parameters, shoot and root growth, seedling vigour, survival, polyembryony and economic returns, recording the highest net return (₹1068) and B:C ratio (3.80). Cow urine at 25% for 12 hours combined with the same enriched medium (T₁₄) proved to be the second-best treatment and a viable alternative to vermiwash. The control treatment (Water @ 24 hours + Sand + Soil), lacking both a bio-stimulant seed soaking treatment and organic media amendments, recorded the poorest performance across all parameters studied. Seed soaking with vermiwash @ 25% for 12 hours combined with an enriched sand-soil-FYM-cocopeat-vermicompost medium can therefore be

recommended for improving germination, survivability, seedling vigour and overall nursery performance of acid lime under shade net conditions.

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