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Influence of Growing Media and Seed Pre-treatments on Germination and Seedling Growth of Cashew (*Anacardium occidentale* L.)

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Abstract

Background: Seed germination and seedling vigour in cashew (*Anacardium occidentale* L.) are influenced by growing media composition and seed pre-sowing treatments. Optimizing these factors is essential for producing vigorous and uniform rootstock seedlings for successful orchard establishment.

Methods: A nursery experiment was conducted during 2025-2026 at the School of Agriculture, Vels Institute of Science, Technology and Advanced Studies, Chennai. The experiment was laid out in a factorial completely randomized design with five growing media and four seed pre-sowing treatments, replicated thrice. Growing media comprised combinations of red soil, sand, cocopeat and vermicompost, while seed treatments included control, water soaking for 12 and 24 h and cow dung slurry for 12 h. Observations on germination, seedling growth, vigour indices and survival percentage were recorded. Data were analysed using ANOVA and treatment means were compared using LSD at $P \leq 0.05$.

Result: Growing media, seed pre-sowing treatments and their interaction significantly influenced all parameters. The combination of sand + red soil + cocopeat + vermicompost (1:1:1:1) with water soaking for 24 h (M_5T_3) recorded the earliest germination (9.06 days), minimum days to 50% germination (13.54 days), highest germination (96.84%), shoot length (22.36 cm), root length (14.36 cm), number of leaves (11.60), vigour index I (2166), vigour index II (89) and survival percentage (96%), demonstrating its suitability for raising vigorous cashew rootstock seedlings under nursery conditions.

Key words: Cashew, Cocopeat, Growing media, Pre-treatments, Seedling vigour, Vermicompost.

Introduction

Cashew (*Anacardium occidentale* L.) is an economically important tropical plantation crop of the family Anacardiaceae, cultivated for its edible kernels and valuable industrial by-products (Salehi *et al.*, 2019). Cashew kernels are rich in proteins, unsaturated fatty acids, vitamins and essential minerals, whereas the cashew apple and cashew nut shell liquid (CNSL) possess significant food, pharmaceutical and industrial applications due to their antioxidant, antimicrobial and polymer-forming properties (Rico *et al.*, 2016; Kyei *et al.*, 2023; Kumaresan *et al.*, 2026). Increasing global demand has expanded cashew cultivation in major producing countries, including India, Vietnam, Brazil, Nigeria and Côte d'Ivoire (Oliveira *et al.*, 2020).

In India, orchard productivity largely depends on the availability of vigorous and genetically superior planting material (Sarath *et al.*, 2025). Production of quality nursery seedlings is essential for successful grafting, rapid field establishment and improved orchard performance. Vigorous rootstocks exhibit greater nutrient uptake, improved root development and higher transplant survival, whereas poor-quality seedlings often result in weak establishment and reduced productivity (Rasool *et al.*, 2020). Seed germination is a complex physiological process involving water imbibition, membrane repair, activation of respiratory metabolism, hydrolytic enzymes

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and reserve mobilization leading to radicle emergence (El-Maarouf-Bouteau, 2022). These processes are strongly influenced by the physical and chemical properties of the growing medium, particularly moisture availability, aeration, porosity and nutrient status (Šerá and Hnilička, 2023). Cocopeat improves water-holding capacity and aeration, vermicompost supplies readily available nutrients, beneficial microorganisms and growth-promoting substances, while sand enhances drainage and root-zone aeration, together creating favourable conditions for seed germination and seedling growth (Al-Ajlouni *et al.*, 2024). Likewise, seed pre-sowing treatments such as hydropriming enhance seed hydration, membrane repair and reserve mobilization, thereby accelerating germination, while cow dung slurry may improve seed coat permeability and early seedling establishment through beneficial microbial activity (Maddipoti *et al.,* 2022; Nair, 2010). Although several studies have evaluated growing media and seed treatments in different horticultural and agricultural crops, information on their combined effects in cashew remains limited. Therefore, the present investigation was undertaken to evaluate the individual and combined effects of different growing media and seed pre-sowing treatments on germination, seedling growth, vigour and survival of cashew under nursery conditions to identify the most suitable combination for producing quality planting material.

MATERIALS AND METHODS

The present investigation was conducted during two nursery seasons, June-September 2025 (Season I) and October-January 2026 (Season II), at the School of Agriculture, Vels Institute of Science, Technology and Advanced Studies (VISTAS), Chennai, Tamil Nadu, India (13.02° N, 80.18° E; 15 m above mean sea level). During the study, the mean temperature ranged from 28-35°C with 65-82% relative humidity, providing favourable conditions for cashew seed germination and seedling growth. Mature cashew nuts were collected from healthy, high-yielding mother trees. Damaged and immature nuts were discarded and uniform bold seeds were selected. The experiment was laid out in a factorial completely randomized design (FCRD) with five growing media and four seed pre-sowing treatments, comprising 20 treatment combinations with three replications of 25 seeds each. The growing media were M_1 (red soil), M_2 (sand + red soil, 2:1), M_3 (sand + red soil + cocopeat, 2:1:1), M_4 (sand + red soil + vermicompost, 1:1:1) and M_5 (sand + red soil + cocopeat + vermicompost, 1:1:1:1). Physicochemical properties (pH, EC, organic carbon and available N, P and K) of the media were analysed before sowing (Table 1). Seed pre-sowing treatments comprised T_1 (control), T_2 (water soaking for 12 h), T_3 (water soaking for 24 h) and T_4 (cow dung slurry for 12 h; 1:1, w/v). Treated seeds were shade-dried and sown vertically at a depth of 2-3 cm in 30 × 20 cm polyethylene bags containing the respective media. Uniform irrigation and nursery management practices were followed throughout the experiment. Observations were recorded on days to initiation of germination, days to 50% germination, germination percentage, shoot length, root length, number of leaves, seedling dry weight, vigour indices and survival percentage using standard procedures. Vigour Index I was calculated as germination percentage × total seedling length, whereas Vigour index II was calculated as germination percentage × seedling dry weight. Data from both seasons were subjected to analysis of variance (ANOVA) for FCRD (Gomez and Gomez, 1984). The treatment means were compared using the least significant difference (LSD) test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Days to initiation of germination

Days to initiation of germination was significantly influenced by growing media, seed pre-treatments and their interaction (Table 2). Among the growing media, M_5 recorded the earliest initiation of germination (10.15 days), followed by M_4 (11.48 days), M_3 (11.95 days), M_2 (12.65 days) and M_1 (13.52 days). Among the seed pre-treatments, T_3 recorded the minimum days to germination (10.90 days), followed by T_4 (11.56 days), T_2 (12.03 days) and T_1 (13.30 days). The interaction effect was significant ($P \leq 0.05$), with M_5T_3 recording the earliest germination (9.06 days), whereas M_1T_1 required the maximum time (14.82 days). Earlier germination under M_5T_3 may be attributed to rapid seed imbibition, activation of hydrolytic enzymes and efficient reserve mobilization, while the porous growing medium improved moisture retention and oxygen diffusion, promoting respiratory metabolism and radicle emergence. These findings agree with Devi *et al.* (2021) and Hartmann *et al.* (2011), who reported that favourable substrate conditions and seed hydration accelerate germination.

Table 1: Physicochemical properties and nutrient composition of the experimental growing media.

Growing medium	pH	EC (dS m^{-1})	Organic carbon (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
M_1 (Soil)	7.56	0.43	0.51	241	19.2	236
M_2 (Soil + Sand + FYM, 1:1:1)	7.27	0.58	0.86	287	25.6	281
M_3 (Soil + Cocopeat + Vermicompost, 1:1:1)	6.91	0.69	1.29	321	32.4	316
M_4 (Soil + Cocopeat + Vermicompost + Sand, 1:1:1:1)	6.76	0.74	1.42	338	35.1	331
M_5 (Cocopeat + Vermicompost + Sand, 2:1:1)	6.47	0.82	1.71	366	40.3	359

Thus, combining an appropriate nursery medium with seed pre-soaking effectively hastened germination in cashew.

Days to 50% germination

The number of days required to attain 50% germination was significantly influenced by growing media, seed pre-treatments and their interaction (Table 2). Among the growing media, M_5 recorded the shortest duration (14.58 days), while T_3 required only 15.47 days among the seed pre-treatments. The interaction $M_5 T_3$ recorded the shortest duration (13.54 days), whereas M_2T_1 required the longest time (19.64 days). Faster attainment of 50% germination under M_5T_3 indicates improved germination uniformity due to enhanced moisture availability, oxygen diffusion and synchronized metabolic activity, resulting in rapid radicle emergence. Similar findings were reported by Hamid and Bugaev (2020) and Atiyeh *et al.* (2002). Uniform germination facilitates efficient nursery management and timely transplanting.

Germination percentage

Germination percentage was significantly influenced by growing media, seed pre-treatments and their interaction (Table 2). Among the growing media, M_5 recorded the highest pooled germination percentage (92.18%), followed by M_4 (84.90%), M_3 (80.68%), M_2 (78.67%) and M_1 (71.40%).

Table 2: Effect of growing media and seed treatments across two seasons on germination parameters.

Growing media	Treatment	Days to initiation of germination			Days to 50% germination			Germination (%)		
		Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
M_1	T_1	14.92	14.72	14.82^{e}	18.02	17.74	17.88^{b}	65.12	64.52	64.82^{e}
	T_2	13.78	13.50	13.64^{d}	16.80	16.46	16.63^{c}	70.86	70.06	70.46^{d}
	T_3	12.64	12.32	12.48^{c}	15.58	15.24	15.41^{d}	76.92	75.84	76.38^{c}
	T_4	13.28	12.96	13.12^{d}	16.18	15.86	16.02^{c}	74.36	73.48	73.92^{cd}
Mean		13.66	13.38	13.52	16.65	16.33	16.49	71.82	70.98	71.40
M_2	T_1	14.08	13.84	13.96^{d}	19.82	19.46	19.64^{a}	71.12	70.36	70.74^{d}
	T_2	12.88	12.58	12.73^{c}	18.62	18.22	18.42^{b}	78.74	77.78	78.26^{c}
	T_3	11.76	11.48	11.62^{b}	17.56	17.14	17.35^{c}	85.08	83.98	84.53^{b}
	T_4	12.44	12.14	12.29^{c}	18.20	17.76	17.98^{b}	81.64	80.64	81.14^{bc}
Mean		12.79	12.51	12.65	18.55	18.15	18.35	79.15	78.19	78.67
M_3	T_1	13.34	13.08	13.21^{c}	18.72	18.30	18.51^{b}	73.04	72.22	72.63^{cd}
	T_2	12.20	11.92	12.06^{b}	17.48	17.08	17.28^{c}	80.72	79.64	80.18^{c}
	T_3	11.08	10.80	10.94^{b}	16.24	15.88	16.06^{c}	87.12	85.92	86.52^{b}
	T_4	11.74	11.42	11.58^{b}	17.02	16.62	16.82^{c}	83.96	82.78	83.37^{b}
Mean		12.09	11.81	11.95	17.37	16.97	17.17	81.21	80.14	80.68
M_4	T_1	12.98	12.78	12.88^{c}	17.62	17.22	17.42^{c}	76.62	75.74	76.18^{c}
	T_2	11.64	11.44	11.54^{b}	16.30	15.92	16.11^{c}	85.86	84.98	85.42^{b}
	T_3	10.54	10.30	10.42^{b}	15.16	14.80	14.98^{d}	90.92	89.80	90.36^{a}
	T_4	11.20	10.94	11.07^{b}	15.86	15.42	15.64^{c}	88.22	87.04	87.63^{b}
Mean		11.59	11.37	11.48	16.24	15.84	16.04	85.41	84.39	84.90
M_5	T_1	11.74	11.52	11.63^{b}	16.14	15.78	15.96^{d}	85.36	84.48	84.92^{b}
	T_2	10.28	10.08	10.18^{a}	14.92	14.52	14.72^{d}	93.12	92.24	92.68^{a}
	T_3	9.18	8.94	9.06^{a}	13.74	13.34	13.54^{e}	97.34	96.34	96.84^{a}
	T_4	9.86	9.62	9.74^{a}	14.26	13.90	14.08^{d}	94.78	93.74	94.26^{a}
Mean		10.27	10.04	10.15	14.77	14.39	14.58	92.65	91.70	92.18
Treatment mean	T_1	13.41	13.19	13.30	18.06	17.70	17.88	74.25	73.46	73.86
	T_2	12.16	11.90	12.03	16.82	16.44	16.63	81.86	80.94	81.40
	T_3	11.04	10.77	10.90	15.66	15.28	15.47	87.48	86.38	86.93
	T_4	11.70	11.42	11.56	16.30	15.91	16.11	84.59	83.54	84.06
SE(d)				0.38			0.48			2.18
LSD (P = 0.05)				0.78			0.98			4.46
M				0.39			0.49			2.23
T				0.35			0.44			1.99
M × T				0.78			0.98			4.46

Means followed by different superscript letters within a column differ significantly at P d” 0.05 according to the Least Significant Difference (LSD) test.

Among the seed pre-treatments, T_3 recorded the highest pooled germination percentage (86.93%), followed by T_4 (84.06%), T_2 (81.40%) and T_1 (73.86%). The interaction effect was significant ($P \leq 0.05$), with M_5T_3 recording the highest germination (96.84%), whereas M_1T_1 recorded the lowest (64.82%). The higher germination under M_5T_3 resulted from improved moisture availability, aeration and nutrient supply, which enhanced seed imbibition, enzyme activation and reserve mobilization for rapid and uniform germination. These findings support Bradford (1986) and agree with Martí-Guillén *et al.* (2026) and Umamaheswari *et al.* (2021). The superior germination obtained with M_5T_3 demonstrates its suitability for producing vigorous and uniform cashew nursery seedlings.

Shoot length

Shoot length was significantly influenced by growing media, seed pre-treatments and their interaction (Table 2). Among the growing media, M_5 recorded the highest pooled shoot length (21.44 cm), followed by M_4 (20.66 cm), M_3 (18.43 cm), M_2 (16.50 cm) and M_1 (14.21 cm). Among the seed pre-treatments, T_3 recorded the maximum pooled shoot length (19.47 cm), followed by T_4 (18.85 cm), T_2 (18.18 cm) and T_1 (15.60 cm). The interaction effect was significant

Table 3: Effect of growing media and seed treatments across two seasons on seedling growth parameters.

Growing media	Treatment	Seedling height (cm)			Root length (cm)			Number of leaves		
		Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
M_1	T_1	12.64	12.32	12.48^{e}	8.02	7.70	7.86^{e}	6.4	6.0	6.2^{e}
	T_2	14.28	13.96	14.12^{d}	8.98	8.64	8.81^{d}	7.2	6.8	7.0^{d}
	T_3	15.52	15.20	15.36^{c}	9.84	9.50	9.67^{c}	7.8	7.4	7.6^{c}
	T_4	15.02	14.74	14.88^{cd}	9.42	9.06	9.24^{cd}	7.6	7.2	7.4^{cd}
Mean		14.37	14.06	14.22	9.07	8.73	8.90	7.25	6.85	7.05
M_2	T_1	14.12	13.84	13.98^{d}	8.86	8.54	8.70^{d}	7.0	6.6	6.8^{d}
	T_2	16.12	15.78	15.95^{c}	10.12	9.78	9.95^{c}	7.8	7.4	7.6^{c}
	T_3	18.64	18.24	18.44^{b}	11.84	11.50	11.67^{b}	8.8	8.4	8.6^{b}
	T_4	17.84	17.46	17.65^{b}	11.32	10.96	11.14^{b}	8.4	8.0	8.2^{b}
Mean		16.68	16.33	16.50	10.54	10.20	10.37	8.00	7.60	7.80
M_3	T_1	15.84	15.52	15.68^{c}	9.92	9.58	9.75^{c}	7.6	7.2	7.4^{cd}
	T_2	18.92	18.56	18.74^{b}	12.08	11.72	11.90^{b}	8.6	8.2	8.4^{b}
	T_3	20.12	19.76	19.94^{b}	13.02	12.66	12.84^{b}	9.4	9.0	9.2^{b}
	T_4	19.54	19.18	19.36^{b}	12.62	12.26	12.44^{b}	9.0	8.6	8.8^{b}
Mean		18.61	18.26	18.43	11.91	11.56	11.73	8.65	8.25	8.45
M_4	T_1	17.24	16.92	17.08^{b}	11.84	11.50	11.67^{b}	8.4	8.0	8.2^{b}
	T_2	20.86	20.46	20.66^{a}	13.42	13.06	13.24^{a}	9.8	9.4	9.6^{a}
	T_3	21.48	21.06	21.27^{a}	14.12	13.74	13.93^{a}	10.6	10.2	10.4^{a}
	T_4	20.92	20.52	20.72^{a}	13.84	13.46	13.65^{a}	10.2	9.8	10.0^{a}
Mean		20.13	19.74	19.94	13.31	12.94	13.12	9.75	9.35	9.55
M_5	T_1	18.94	18.58	18.76^{b}	12.42	12.06	12.24^{b}	9.0	8.6	8.8^{b}
	T_2	21.64	21.24	21.44^{a}	13.82	13.46	13.64^{a}	10.8	10.4	10.6^{a}
	T_3	22.58	22.14	22.36^{a}	14.54	14.18	14.36^{a}	11.8	11.4	11.6^{a}
	T_4	21.82	21.46	21.64^{a}	14.02	13.70	13.86^{a}	11.4	11.0	11.2^{a}
Mean		21.25	20.86	21.05	13.70	13.35	13.53	10.75	10.35	10.55
Treatment mean	T_1	15.76	15.44	15.60	10.21	9.88	10.05	7.68	7.28	7.48
	T_2	18.36	18.00	18.18	11.68	11.33	11.51	8.84	8.44	8.64
	T_3	19.67	19.28	19.48	12.67	12.32	12.49	9.68	9.28	9.48
	T_4	19.03	18.67	18.85	12.24	11.89	12.07	9.32	8.92	9.12
SE(d)				0.62			0.48			0.78
LSD (P = 0.05)				1.28			0.98			1.60
M				0.64			0.49			0.80
T				0.57			0.44			0.72
M × T				1.28			0.98			1.60

Means followed by different superscript letters within a column differ significantly at P d" 0.05 according to the Least Significant Difference (LSD) test.

($P \leq 0.05$), with M_5T_3 recording the maximum shoot length (22.36 cm), whereas M_1T_1 recorded the minimum (12.48 cm). Superior shoot growth under M_5T_3 may be attributed to early germination, enhanced root establishment and improved nutrient and water uptake. The balanced growing medium, coupled with seed pre-soaking, promoted chlorophyll synthesis, photosynthetic activity and assimilate translocation, resulting in greater shoot elongation. Similar findings were reported by Hussain and Abbasi (2018).

Root length

Root length was significantly influenced by growing media, seed pre-treatments and their interaction (Table 3). Among the growing media, M_5 recorded the highest pooled root length (13.53 cm), followed by M_4 (13.12 cm), M_3 (11.73 cm), M_2 (10.37 cm) and M_1 (8.90 cm). Among the seed pre-treatments, T_3 recorded the maximum pooled root length (12.49 cm), followed by T_4 (12.07 cm), T_2 (11.51 cm) and T_1 (10.04 cm). The interaction effect was significant ($P \leq 0.05$), with M_5T_3 recording the highest root length (14.36 cm), whereas M_1T_1 recorded the lowest (7.86 cm). Enhanced root growth under M_5T_3 resulted from improved aeration, moisture availability and reduced mechanical resistance, while seed pre-soaking promoted rapid reserve mobilization and root elongation. A vigorous root system enhanced water and nutrient uptake, supporting better

Table 4: Effect of growing media and seed treatments across two seasons on vigour index I, vigour index II and survival percentage.

Growing media	Treatment	Vigour index I			Vigour index II			Survival (%)		
		Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
M_1	T_1	820	796	808^{e}	31	29	30^{e}	69	67	68^{e}
	T_2	1008	976	992^{d}	38	36	37^{d}	73	71	72^{d}
	T_3	1194	1152	1173^{c}	45	43	44^{c}	77	75	76^{c}
	T_4	1122	1078	1100^{cd}	41	39	40^{cd}	75	73	74^{cd}
Mean		1036	1001	1018.25	38.75	36.75	37.75	73.50	71.50	72.50
M_2	T_1	1056	1014	1035^{d}	39	37	38^{d}	75	73	74^{d}
	T_2	1294	1246	1270^{c}	48	46	47^{c}	79	77	78^{c}
	T_3	1538	1486	1512^{b}	57	55	56^{b}	83	81	82^{b}
	T_4	1398	1352	1375^{c}	52	50	51^{c}	81	79	80^{c}
Mean		1321.5	1274.5	1298.0	49.0	47.0	48.0	79.50	77.50	78.50
M_3	T_1	1136	1092	1114^{c}	45	43	44^{c}	77	75	76^{c}
	T_2	1416	1364	1390^{b}	55	53	54^{b}	83	81	82^{b}
	T_3	1664	1610	1637^{b}	66	62	64^{b}	87	85	86^{b}
	T_4	1504	1456	1480^{b}	61	57	59^{b}	85	83	84^{b}
Mean		1430	1380.5	1405.25	56.75	53.75	55.25	83.00	81.00	82.00
M_4	T_1	1308	1258	1283^{b}	53	51	52^{b}	83	81	82^{b}
	T_2	1622	1566	1594^{b}	64	62	63^{b}	89	87	88^{b}
	T_3	1846	1792	1819^{a}	75	71	73^{a}	93	91	92^{a}
	T_4	1706	1654	1680^{a}	71	67	69^{a}	91	89	90^{a}
Mean		1620.5	1567.5	1594.0	65.75	62.75	64.25	89.00	87.00	88.00
M_5	T_1	1632	1584	1608^{a}	63	59	61^{a}	89	87	88^{a}
	T_2	1926	1870	1898^{a}	79	75	77^{a}	95	93	94^{a}
	T_3	2196	2136	2166^{a}	92	86	89^{a}	97	95	96^{a}
	T_4	2076	2024	2050^{a}	86	80	83^{a}	96	94	95^{a}
Mean		1957.5	1903.5	1930.5	80.00	75.00	77.50	94.25	92.25	93.25
Treatment mean	T_1	1190.4	1148.8	1169.6	46.2	43.8	45.0	78.6	76.6	77.6
	T_2	1453.2	1404.4	1428.8	56.8	54.4	55.6	83.8	81.8	82.8
	T_3	1687.6	1635.2	1661.4	67.0	63.4	65.2	87.4	85.4	86.4
	T_4	1561.2	1512.8	1537.0	62.2	58.6	60.4	85.6	83.6	84.6
SE(d)				58			3.3			2.2
LSD (P=0.05)				119			6.8			4.5
M				59.5			3.4			2.25
T				53.2			3.0			2.01
M × T				119			6.8			4.5

Means followed by different superscript letters within a column differ significantly at P d" 0.05 according to the Least Significant Difference (LSD) test.

seedling establishment. Similar observations were reported by Kumaresan *et al.* (2024a).

Number of leaves

The number of leaves was significantly influenced by growing media, seed pre-treatments and their interaction (Table 3). Among the growing media, M_5 recorded the highest pooled number of leaves (10.55), followed by M_4 (9.55), M_3 (8.45), M_2 (7.80) and M_1 (7.05). Among the seed pre-treatments, T_3 produced the highest pooled number of leaves (9.48), followed by T_4 (9.12), T_2 (8.64) and T_1 (7.48). The interaction effect was significant ($P \leq 0.05$), with M_5T_3 recording the highest number of leaves (11.60), whereas M_1T_1 recorded the lowest (6.20). Increased leaf production under M_5T_3 reflected improved nutrient uptake and photosynthetic efficiency, promoting chlorophyll synthesis, leaf expansion and biomass accumulation. These findings agree with Hussain and Abbasi (2018) and Kumaresan *et al.* (2024a).

Seedling vigour indices

Vigour index I and II were significantly influenced by growing media, seed pre-treatments and their interaction (Table 4). Among the growing media, M_5 recorded the highest pooled vigour index I (1930.50) and vigour index II (77.50), while T_3 recorded the highest values among seed pre-treatments (1661.40 and 65.20, respectively). The interaction M_5T_3 recorded the highest vigour index I (2166) and vigour index II (89), whereas M_1T_1 recorded the lowest values (808 and 30). Higher vigour under M_5T_3 resulted from improved germination, balanced root-shoot growth, efficient reserve mobilization and greater dry matter accumulation. Similar findings were reported by Atiyeh *et al.* (2002) and Mohammed *et al.* (2026).

Survival percentage

Survival percentage was significantly influenced by growing media, seed pre-treatments and their interaction (Table 4). Among the growing media, M_5 recorded the highest pooled survival percentage (93.25%), followed by M_4 (88.00%), M_3 (82.00%), M_2 (78.50%) and M_1 (72.50%). Among the seed pre-treatments, T_3 recorded the highest pooled survival percentage (86.40%), followed by T_4 (84.60%), T_2 (82.80%) and T_1 (77.60%). The interaction effect was significant ($P \leq 0.05$), with M_5T_3 recording the highest survival (96%), whereas M_1T_1 recorded the lowest (68%). Higher survival under M_5T_3 was associated with vigorous root development, improved water and nutrient uptake, greater photosynthetic capacity and enhanced tolerance to transplanting stress. Similar findings were reported by Kumaresan *et al.* (2024b) and Mog *et al.* (2017), indicating the suitability of M_5T_3 for producing quality cashew planting material under nursery conditions.

CONCLUSION

The results of the present study indicated that growing media and seed pre-sowing treatments significantly influenced germination, seedling growth and vigour of cashew. The combination of sand + red soil + cocopeat + vermicompost (1:1:1:1) along with water soaking of seeds for 24 hours (M_5T_3) recorded the best performance in terms of early germination, higher germination percentage, seedling growth and survival. This treatment proved superior over other combinations due to improved physical properties of the media and enhanced seed hydration. Hence, the combination of sand + red soil + cocopeat + vermicompost (1:1:1:1) with 24 h water soaking can be recommended for raising vigorous cashew rootstocks under nursery conditions.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Al-Ajlouni, M.G., Othman, Y.A., Abu-Shanab, N.S. and Alzyoud, L.F. (2024). Evaluating the performance of cocopeat and volcanic tuff in soilless cultivation of roses. *Plants*. **13(16):** 2293. doi: 10.3390/plants13162293.

Atiyeh, R.M., Lee, S., Edwards, C.A., Arancon, N.Q. and Metzger, J.D. (2002). The influence of humic acids derived from earthworm processed organic wastes on plant growth. *Bioresource Technology.* **84(1):** 7-14. doi:10.1016/S0960-8524(02)00017-2.

Bradford, K.J. (1986). Manipulation of seed water relations *via* osmotic priming to improve germination under stress conditions. *HortScience.* **21(5):** 1105-1112. doi: 10.21273/HORTSCI.21.5.1105.

Devi K., Barua, K.P. and Barua, M. (2021). Integrated effect of pre-sowing seed treatment, sowing windows and seasons on seed yield and quality of greengram. *Legume Research.* **44(8):** 956-961. doi: 10.18805/LR-4174.

El-Maarouf-Bouteau, H. (2022). The seed and the metabolism regulation. *Biology.* **11(2):** 168. doi: 10.3390/biology11020168.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, USA.

Hamid El Abd, S.E.A. and Bugaev, P.D. (2020). Impact of seed treatments pre-sowing and organo-mineral fertilizer on spring barley production. *Indian Journal of Agricultural Research.* **54(5):** 611-616. doi: 10.18805/IJARe.A-519.

Hartmann, H.T., Kester, D.E., Davies, F.T. and Geneve, R.L. (2011). Plant Propagation: Principles and Practices. 8th Edn. Prentice Hall, New Jersey, USA.

Hussain, N. and Abbasi, S.A. (2018). Efficacy of the vermicomposts of different organic wastes as clean fertilizers: State-of-the-art. *Sustainability.* **10(4):** 1205. doi:10.3390/su10041205.

Kumaresan, M., Khanchana, K. and Anbarasu, M. (2024a). A review on organic composting technology by using different microorganisms. *Ecology, Environment and Conservation.* **30(Suppl.):** S503-S512. doi: 10.53550/EEC.2024.v30i04s.082.

Kumaresan, M., Khanchana, K., Bavya, N., Arthi, R. and Yogambal, C. (2024b). Effect of different organic media on growth and quality of radish (*Raphanus sativus* L.). *Ecology, Environment and Conservation.* **30(3):** 1149-1153.

Kumaresan, M., Shanmugasundaram, P., Sridhar, R., Madhumita, G. and Kamalakkannan, S. (2026). Exploring the multifaceted pharmaceutical and medicinal applications of cashew nut shell liquid (CNSL): Antimicrobial, anti-inflammatory and drug delivery potential. *Journal of Applied and Natural Science.* **18(1):** 399-418. doi: 10.31018/jans.v18i1.7337.

Kyei, S.K., Eke, W.I., Nagre, R.D., Mensah, I. and Akaranta, O. (2023). A comprehensive review on waste valorization of cashew nutshell liquid: Sustainable development and industrial applications. *Cleaner Waste Systems.* **6:** 100116. doi: 10.1016/j.clwas.2023.100116.

Maddipoti, K., Prashant, R.K., Haritha, B., Karthik, R.K., Hemanth, A.K. and Sarita, K. (2022). Standardization of different pre-sowing seed treatments on growth, yield and yield attributing traits of kodo millet (*Paspalum scrobiculatum*). *Indian Journal of Agricultural Research.* **56(2):** 162-169. doi: 10.18805/IJARe.A-5755.

Martí-Guillén, J.M., Martínez-Lorente, S.E., Pedreño, M.A., Almagro, L. and Sabater-Jara, A.B. (2026). Seed priming as a tool to improve crop resilience to abiotic stress: Methodology, mechanisms of action and usefulness in crops of agronomic interest. *Plant Stress.* **21:** 101366. doi: 10.1016/j.stress.2026.101366.

Mog, B., Adiga, J.D., Nayak, M.G. and Mohana, G.S. (2017). Germination and seedling establishment in cashew (*Anacardium occidentale* L.): An interaction between seed size, relative growth rate and seedling biomass. *Journal of Plantation Crops.* **45(2):** 110-120. doi: 10.19071/jpc.2017.v45.i2.3305.

Mohammed, A.A., Cheema, A.I., Cely-Vargas, L.Y., Lv, N. and Dong, B. (2026). Optimizing earthworm stocking density for process efficiency and compost maturity in food waste and sewage sludge vermicomposting. *Bioresource Technology Reports.* **33:** 102602. doi:10.1016/j.biteb.2026.102602.

Nair, P.K.R. (2010). Improvement of seed germination and early growth in cashew (*Anacardium occidentale* L.) through pre-sowing treatments. *Journal of Plantation Crops.* **38(2):** 123-129.

Oliveira, N.N., Mothé, C.G., Mothé, M.G. and de Oliveira, L.G. (2020). Cashew nut and cashew apple: A scientific and technological monitoring worldwide review. *Journal of Food Science and Technology.* **57(1):** 12-21. doi: 10.1007/s13197-019-04051-7.

Rasool, A., Mansoor, S., Bhat, K.M., Hassan, G.I., Baba, T.R., Alyemeni, M.N., Alsahli, A.A., El-Serehy, H.A., Paray, B.A. and Ahmad, P. (2020). Mechanisms underlying graft union formation and rootstock-scion interaction in horticultural plants. *Frontiers in Plant Science.* **11:** 590847. doi: 10.3389/fpls.2020.590847.

Rico, R., Bulló, M. and Salas-Salvadó, J. (2016). Nutritional composition of raw fresh cashew (*Anacardium occidentale* L.) kernels from different origin. *Food Science and Nutrition.* **4:** 329-338. https://doi.org/10.1002/fsn3.294.

Salehi, B., Gültekin-Özgüven, M., Kırkın, C., Özçelik, B., Morais-Braga, M.F.B., Carneiro, J.N.P., Bezerra, C.F., *et al.* (2019). *Anacardium* plants: Chemical, nutritional composition and biotechnological applications. *Biomolecules.* **9(9):** 465. doi: 10.3390/biom9090465.

Sarath, C.M., Rao Sahib, P., Achuthan, K. and Chandran, R. (2025). From farm to table: India's transition towards cashew production and sustainable livelihood of smallholder farmers. *International Journal of Agricultural Sustainability.* **23(1).** doi:10.1080/14735903.2025.2557083.

Šerá, B. and Hnilička, F. (2023). Genetic and environmental factors affecting seed germination. *Plants.* **12(24):** 4106. doi: 10.3390/plants12244106.

Umamaheswari, P., Gayathri, N.K. and Subbarao, M. (2021). Effect of nitrogen fertilizer doses and pre-sowing seed treatments on yield and yield attributing characters in foxtail millet [*Setaria italica* (L.) Beauv]. *Indian Journal of Agricultural Research.* **55(5):** 634-638. doi: 10.18805/IJARe.A-5511.