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Performance of Avenue Tree Species Grown Through Seedballs Encapsulated with Varying Soil Media Mixtures in Subtropical Climate of Punjab

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Abstract: Seeding an extensive wasteland requires an ideal environment for seeds to germinate in arid ecosystems. This investigation was conducted to study the performance of seedballs of avenuetree species encapsulated in different media mixtures for their germination potential and growth behavior at Punjab Agricultural University, Ludhiana during 2020-22. Seeds from five avenue tree species (*Cassia fistula*, *Azadirachta indica*, *Schleichera oleosa*, *Pongamia pinnata* and *Putranjiva roxburghii*) were encapsulated. These seedballs were sown onthree different dates*viz.*15th July, 15th August and 15th September. In all sowing date, *Azadirachta indica* seedballs encapsulated in soil + cocopeat (1:1, v/v) exhibited maximum germination percentage (90, 89.67 and 78 %). *Cassia fistula* seed balls encapsulated in soil + cocopeat germinated earliest (7.35, 9.18 and 11.25 days, respectively) with maximum plant height (39.51, 40.35 and 38.12 cm), higher leaf area (73.11, 75.28 and 71.67 cm^2) and highestsurvival percentage (47.33, 50.67 and 41.33%). The seedball encapsulated in mixture of soil+ cocopeat (1:1, v/v) created an ideal micro-environmental condition for seed germination for these tree species and can be utilized them for the restoration of degraded landscapes and wastelands.

Keywords: Avenue tree, Subtropical climate, Germination, seedball, Soil media mixtures

Today's world is facing extreme climate breakdown. Global warming is one of the factors of climate irregularities causing unfavorable conditions for plant growth. In India, the reduction of natural forest cover was reported around 117 thousand ha (2022), which is equivalent to CO_2 emission of 62.9 MT (Anonymous 2023). This leads the changes in microclimate where the deforestation rate is quite high. One of the best strategies for preventing global warming effect and to sustain the life is afforestation. The success rate of afforestation initiatives is unfortunately impacted by high costs and risk considerations associated with handling tree saplings and providing initial care after planting. Since the seeds in the seed ball technique are shielded from outside stress and predators, it is an efficient method of growing plants from seed (Tamilarasan et al*.,* 2021a). To restore greening of these extensively degraded landscapes by encouraging seeding of perennial and multipurpose tree species, several alternatives have been tested by several researchers that could address the issue of seed germination under natural conditions.

Traditionally, seedball technique was being used to green wastelands by encapsulating healthy mature seeds having hard seed coat within the mixture of clay and soil (Fukuoka 1978). However, today different media like clay, cocopeat, FYM, garden soil and nutrient mixtures can be used for the formation of the seed balls. Seedballs are used for restoration of extensive barren and unproductive lands with minimal labour and resources. Areas inappropriate for conventional planting can be effectively rejuvenated through seedball dispersal (Ian et al*.,* 2015). Encapsulating seeds with soil and other media mixtures significantly helps in the protection of seeds from insect-pest and rodents. These media mixture maintain the structure of the seedballs and provide nutrients and required moisture to the seed for better germination and establishment.

A genetic diversity in cultivated plant material and eventually, capacity to adapt to a reintroduction site might be influenced by the methods used in production technique. Applying seed pretreatment especially in seed ball technique to reduce physiological seed dormancy and promote effective seed germination is a standard step in the plant production process (Diaz-Martin et al*.,* 2023). Limited literature is available with respect to identification of suitable tree species for greening degraded lands through seedball technique. Additionally, specific compositions that can enhance the survival and germination of the seeds in uncultivated lands are needed to be investigated. Hence, the present study was planned with the hypothesis that seeds of different indigenous avenue tree species encapsulated with different seed ball soil media mixtures and planted during

different months will likely show effect seed germination, survival and establishment.

MATERIAL AND METHODS

Seedballs of five avenue tree species (S_1 - *Cassia fistula,* S_2 - *Azadirachta indica,* S_3-*Schleichera oleosa,* S_4 - *Pongamia pinnata and* S_5- *Putranjiva roxburghii*) were prepared using five different media mixture viz. M_1 [soil + clay (1:1 v/v)], M_2 [soil + FYM (1:1 v/v)], M_3 [soil + cocopeat (1:1 v/v)], M_4 [soil + cocopeat + clay (4:3:3 v/v)] and M_5 (seed priming with clay). Each seedball contained one seed having diameter of 4 cm.

These prepared seedballs were sown in three locations in the PAU campus on three different sowing periods, *viz*., D_1 (15th July), D_2 (15th August) and D_3 (15th September) for two consecutive years, i.e. 2020-21 and 2021-22. The experiment was laid out in factorial randomized block design (FRBD) with 25 treatments with three replications. Ten number of seed balls per treatment per replication were taken with total 2250 seedball in experiment. The observations of germination percentage, days to germination was recorded at 10 days of sowing and plant height (cm), number of leaves were observed at 3-month interval while leaf area (cm^2), stem girth (mm), survival percentage of plants, pH (Jackson 1967) and EC (Jackson 1967) of media were recorded at 9 months to days of sowing. The interaction results of species and media have been discussed to interpret the conclusions out of this investigation. The statistical analysis of the data was conducted in SAS software version 9.0. Further the multiple comparison to separate the treatment means was performed using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Germination parameters: The germination percentage and days to germination were significantly affected by the treatments (species and media). In D_1 sowing (15th July), the maximum (90.00 %) and the minimum (52.00 %) germination percentage were obtained in S_2M_3 (*Azadirachta indica* grown in soil + cocopeat media) and S_3M_2 (*Schleichera oleosa* grown in soil + FYM media), respectively (Table 1). In D_2 (15th August) sowing, S_2M_3 (*Azadirachta indica* in soil + cocopeat media) and S_3M_1 (*Schleichera oleosa* in soil + clay media) exhibited maximum (89.67 %) and minimum (49.67 %) germination percentage, respectively. In D_3 sowing (15th September), the maximum (78.00 %) and minimum (42.00 %) germination percentage were in S_2M_3 (*Azadirachta indica* in soil + cocopeat media) and S_3M_1 (*Schleichera oleosa* in soil + clay media), respectively.

In D_1 (15th July), earlier germination (7.35 days) was recorded in the treatment S_1M_3 (*Cassia fistula* grown in soil + cocopeat media) whereas, the maximum days (15.50) taken for germination was in the interaction treatment of S_3M_5. In D_2 sowing (15th August), similar results were obtained in sowing of 15th July with maximum (16.78) and minimum (9.18) days to germination (Table 1). In D_3 sowing (15th September), earlier germination (11.25 days) was obtained in the treatment S_1M_3 whereas, the maximum days (18.46) were taken to germinate the seeds in seed ball were in the interaction treatment of S_3M_1. The enhanced and early germination observed in media containing cocopeat can be attributed to its higher water holding capacity (WHC) and increased porosity, facilitating greater water availability to seed sown. The augmented water absorption contributes to higher germination percentage and accelerating the overall process. Additionally, the conducive climate during monsoon rains (23.2 cm in July) creates favorable conditions for seed germination, eliminating potential water stress (Fig. 1). Seedballs sowing followed by 15mm rain enhanced the germination in pearl millet as seed ball enhances nutrient

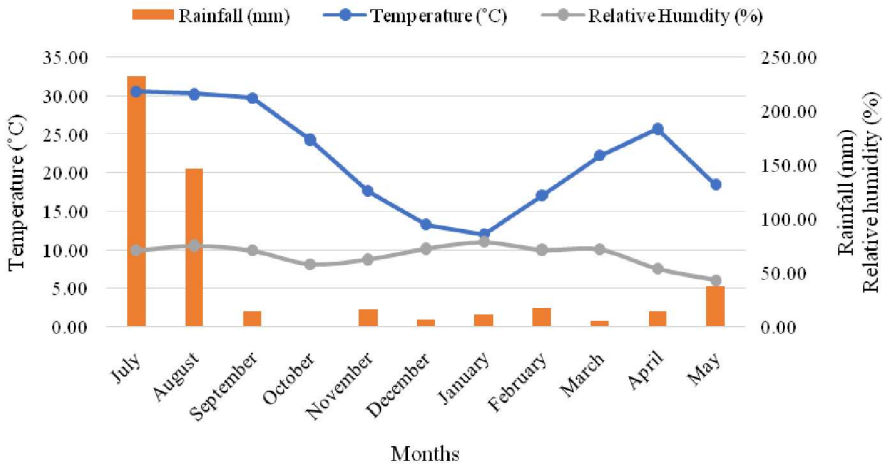

Fig. 1. Pooled average temperature (°C), relative humidity (%) and rainfall (mm) during the experiment

enrichment around the seed (Muhlena 2013). The coated seeds exhibit higher germination percentages in both laboratory and field conditions, safeguarding them from predators and reducing dormancy respectively (Choi et al., 2008; Gornish 2019; Jin et al., 2023). Cocopeat-containing seedballs yielded higher germination percentages in *Stereospermum suaveolens* (Trivedi and Joshi 2014). Similarly, *Bryonia laciniosa, Datura stramonium, Pongamia pinata* exhibited 100 per cent germination in seedball composed of soil: cow dung (1:1) and soil: cocopeat (1:1) (Patil et al., 2022). These results align with the outcomes of Afzal et al. (2020), emphasizing the advantages of coated seeds for achieving earlier germination.

Growth parameters: Plant height was significantly affected by the treatments in this study (Table 2). In sowing of 15th July (D_1), the maximum (39.51 cm) and the minimum (21.89 cm) plant heights were exhibited by S_1M_3 (*Cassia fistula* grown in soil + cocopeat media) and S_3M_2 (*Schleichera oleosa* in soil + FYM media) treatments, respectively. Similar trend as in 15th July sowing period was observed of plant height under sowing of 15th August and 15th September. In sowing of 15th July, S_5M_4 (*Putranjiva roxburghii* in soil + cocopeat + clay media) and S_2M_2 (*Azadirachta indica* in soil + FYM media) resulted the maximum (15.88) and the minimum (5.89) leaf number, respectively (Table 2). In 15th August sowing, *Putranjiva roxburghii* seeds grown in soil + cocopeat media and *Azadirachta indica* in soil + FYM media exhibited the maximum (18.43) and the minimum (6.44) number of leaves, respectively. In 15th September sowing, similar trend as in sowing of 15th August was observed regarding number of leaves. In case of 15th July sowing, the maximum (73.11 cm^2) and minimum (18.65 cm^2) leaf areas were obtained in S_1M_3 (*Cassia fistula* in soil + cocopeat media) and S_5M_2 (*Putranjiva roxburghii* in soil + FYM media), respectively (Table 3). Similar trend of leaf area was observed in sowing of 15th August and 15th September as in 15th July sowing.

Different media of seed balls significantly affected the stem girth of tree species (Table 3). In sowing of 15th July (D_1), the maximum (26.22 mm) and the minimum (17.01 mm) stem girth were exhibited by S_2M_3 (*Azadirachta indica* in soil + cocopeat media) and S_5M_2 (*Putranjiva roxburghii* in soil +FYM media), respectively. In D_2 sowing (15th August), the maximum (29.01 mm) and the minimum (18.72 mm) stem girth were obtained in S_2M_3 (*Azadirachta indica* in soil + cocopeat media) and S_4M_2 (*Pongamia pinnata* in soil +FYM media), respectively. In sowing of D_3 (15th September), similar trend of stem girth as in sowing of 15th July was obtained. *Azadirachta indica* germinated and established well in cocopeat used media which further enhanced its growth. Therefore, the stem girth was more in this than other species.

The growth attributes of the plants showed superior results when planted on August 15th, possibly influenced by the favorable characteristics of the planting media, which facilitated enhanced germination and establishment of the seedballs. The climatic conditions during this period, marked by frequent monsoon rains in Punjab, provided an optimal

Table 1. Effect of different media on the germination percentage (%) and number of days to germination of trees species

Germination percentage (%)

	D_1 (15th July)						D_2 (15th August)						D_3 (15th September)					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	75.00	76.00	52.33	70.00	70.67	68.80 ^{d}	78.00	73.67	49.67	65.00	70.33	67.33 ^{d}	63.00	63.67	42.00	59.00	60.00	57.53 ^{c}
M_2	78.67	81.33	52.00	76.67	79.33	73.60^{bc}	78.67	80.33	53.00	71.00	72.00	71.00^{bc}	69.00	65.67	45.00	64.00	63.33	61.40 ^{b}
M_3	89.00	90.00	60.67	79.00	80.00	79.73 ^{a}	88.33	89.67	57.67	75.33	80.00	78.20 ^{a}	75.67	78.00	50.00	70.67	71.00	69.07 ^{a}
M_4	85.33	87.67	57.67	75.33	75.67	76.33 ^{b}	83.00	85.67	55.33	72.67	72.00	73.73 ^{b}	71.67	73.33	48.33	72.67	67.33	66.67 ^{a}
M_5	80.00	84.67	53.33	74.33	71.00	72.67 ^{c}	80.33	80.00	52.00	70.67	70.00	70.60 ^{c}	68.00	70.00	45.00	66.67	65.00	62.93 ^{b}
Mean	81.60 ^{a}	83.93 ^{a}	55.20 ^{c}	75.07 ^{b}	75.33 ^{b}		81.67 ^{a}	81.87 ^{a}	53.53 ^{c}	70.93 ^{b}	72.87 ^{b}		69.47 ^{a}	70.13 ^{a}	46.07 ^{c}	66.60 ^{b}	65.33 ^{b}	

Number of days to germination (Days)

	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	8.21	9.15	15.00	12.00	15.05	11.88^{ab}	11.25	13.00	16.17	12.00	15.67	13.62 ^{a}	13.50	12.67	18.46	17.54	12.97	15.03 ^{a}
M_2	8.00	8.85	14.89	10.76	14.56	11.41 ^{b}	10.05	10.00	16.00	10.45	14.00	12.10 ^{b}	12.15	11.50	17.73	16.00	13.00	14.08 ^{b}
M_3	7.35	7.50	13.00	9.95	13.25	10.21 ^{c}	9.18	9.45	15.23	9.50	13.00	11.27 ^{c}	11.25	11.45	17.02	15.00	11.45	13.23 ^{c}
M_4	7.67	8.25	13.00	10.00	13.45	10.47 ^{c}	9.75	9.78	15.83	10.00	13.76	11.82^{bc}	12.00	12.00	17.00	16.56	12.32	13.98 ^{b}
M_5	9.00	10.00	15.50	11.13	15.00	12.13 ^{a}	11.56	12.00	16.78	12.34	14.02	13.34 ^{a}	14.00	13.00	18.34	17.89	13.56	15.36 ^{a}
Mean	8.05 ^{d}	8.75 ^{c}	14.28 ^{a}	10.77 ^{b}	14.26 ^{a}		10.36 ^{c}	10.85 ^{c}	16.00 ^{a}	10.86 ^{c}	14.09 ^{b}		12.58 ^{c}	12.12 ^{c}	17.71 ^{a}	16.60 ^{b}	12.66 ^{c}	

The mean followed by different alphabetical letters were computed using Duncan's Multiple Range Test are significantly different (p≤0.05)

environment for plant growth (Fig. 1), contributing to the observed improvements in growth on August 15th. The frequent rains and bright sunlight initiate the new growth and better growth of the existing leaves and help the plant in maintaining the proper physiological functions. The obtained results of growth attributes were better in the planting of 15th August. The results of plant height align with Bhardwaj (2014) who emphasized the positive impact of cocopeat media on seedling growth. Increased nutrient availability has been linked to improved shoot growth and yield in sorghum

Table 2. Effect of different media on the plant height (cm) and number of leaves after 9 months of sowing of trees species

Plant height (cm)

	D_1 (15th July)						D_2 (15th August)						D_3 (15th September)					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	34.52	31.89	22.45	29.66	30.51	29.81 ^{c}	35.71	35.61	24.81	32.67	31.67	32.09 ^{c}	32.12	31.65	19.87	29.41	25.12	27.63 ^{c}
M_2	32.89	30.05	21.89	28.92	28.69	28.49 ^{c}	34.09	33.52	23.77	31.55	30.50	30.69 ^{c}	30.09	29.75	19.03	27.99	23.89	26.15 ^{c}
M_3	39.51	37.77	25.54	34.61	33.61	34.21 ^{a}	40.35	40.31	29.51	37.21	35.71	36.62 ^{a}	38.12	35.98	23.15	32.78	30.88	32.18 ^{a}
M_4	37.65	35.33	24.67	32.85	32.55	32.61 ^{b}	39.11	36.88	27.66	36.41	33.78	34.77 ^{b}	36.87	34.21	22.61	32.02	28.76	30.89 ^{a}
M_5	36.41	33.78	23.71	31.15	31.98	31.41 ^{b}	38.81	37.89	26.01	34.87	32.18	33.95 ^{b}	35.44	32.87	20.18	30.95	26.20	29.13 ^{b}
Mean	36.20 ^{a}	33.76 ^{b}	23.65 ^{d}	31.44 ^{c}	31.47 ^{c}		37.61 ^{a}	36.84 ^{a}	26.35 ^{d}	34.54 ^{b}	32.77 ^{c}		34.53 ^{a}	32.89 ^{b}	20.97 ^{e}	30.63 ^{c}	26.97 ^{d}	

Number of leaves

	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	8.42	6.21	7.46	11.62	13.78	9.50 ^{c}	9.33	7.01	8.40	14.89	16.03	11.13 ^{d}	7.38	6.01	6.98	13.51	14.31	9.64 ^{c}
M_2	7.56	5.89	7.10	10.98	12.89	8.88 ^{d}	8.78	6.44	8.00	14.21	15.61	10.61 ^{e}	7.01	5.88	6.41	13.16	13.59	9.21 ^{c}
M_3	10.31	8.01	8.45	13.65	15.67	11.22 ^{a}	11.31	9.55	9.20	16.98	18.43	13.09 ^{a}	9.67	7.66	8.55	14.58	16.41	11.37 ^{a}
M_4	9.78	7.34	8.17	13.55	15.88	10.94 ^{a}	10.77	8.21	8.98	16.22	17.39	12.31 ^{b}	8.51	7.12	8.05	14.02	15.79	10.70 ^{b}
M_5	9.21	6.87	7.67	12.04	14.34	10.03 ^{b}	10.43	7.65	8.72	15.31	16.98	11.82 ^{c}	8.11	6.52	7.65	13.86	15.25	10.28 ^{b}
Mean	9.06 ^{c}	6.86 ^{e}	7.77 ^{d}	12.37 ^{b}	14.51 ^{a}		10.12 ^{c}	7.77 ^{e}	8.66 ^{d}	15.52 ^{b}	16.89 ^{a}		8.14 ^{c}	6.64 ^{e}	7.53 ^{d}	13.83 ^{b}	15.07 ^{a}	

The mean followed by different alphabetical letters were computed using Duncan's Multiple Range Test are significantly different (p≤0.05)

Table 3. Effect of different media on the leaf area (cm^2 ground area) and stem girth (mm) of trees species

Leaf area (cm^2 ground area)

	D_1 (15th July)						D_2 (15th August)						D_3 (15th September)					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	69.18	26.65	57.99	21.87	19.02	38.94 ^{c}	70.73	28.15	61.89	23.87	20.17	40.96^{cd}	63.76	24.08	56.25	21.37	19.89	37.07
M_2	67.89	25.91	56.78	21.05	18.65	38.06 ^{c}	68.87	28.01	60.25	22.69	19.34	39.83 ^{d}	62.56	23.79	55.46	21.01	19.02	36.37 ^{d}
M_3	73.11	29.18	62.17	25.88	23.17	42.70 ^{a}	75.28	32.11	67.39	27.65	24.75	45.44 ^{a}	71.67	28.66	60.59	24.79	23.15	41.77 ^{a}
M_4	72.98	28.75	60.88	24.75	21.66	41.81^{ab}	74.01	30.87	64.22	26.71	22.17	43.60^{ab}	68.98	26.16	59.13	23.45	21.66	39.88^{ab}
M_5	70.54	28.09	59.18	22.10	19.86	39.96^{bc}	72.87	29.77	63.91	25.01	20.98	42.51	66.15	25.84	57.89	22.71	20.51	38.62
Mean	70.74 ^{a}	27.72 ^{c}	59.40 ^{b}	23.13 ^{d}	20.47 ^{e}		72.35 ^{a}	29.78 ^{c}	63.53 ^{b}	25.19 ^{d}	21.48 ^{e}		66.62 ^{a}	25.71 ^{c}	57.86 ^{b}	22.67 ^{d}	20.85 ^{d}	

Stem girth (mm)

	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	20.56	21.29	18.76	17.75	17.81	19.23 ^{d}	23.56	24.68	21.88	19.17	20.08	21.87 ^{d}	19.92	18.01	18.25	17.97	17.67	18.37 ^{d}
M_2	19.01	20.98	17.97	17.18	17.01	18.43 ^{d}	21.89	23.12	20.02	18.72	19.55	20.66 ^{e}	18.25	17.48	17.82	17.45	16.99	17.60 ^{d}
M_3	24.56	26.22	23.11	21.12	20.88	23.18 ^{a}	28.88	29.01	25.03	22.89	23.92	25.95 ^{a}	23.78	23.79	21.95	19.90	20.52	21.99 ^{a}
M_4	23.07	24.89	21.79	20.88	19.01	21.93 ^{b}	26.03	27.81	23.12	21.61	22.08	24.13 ^{b}	22.91	21.53	20.37	19.07	19.02	20.58 ^{b}
M_5	21.89	23.04	20.56	18.12	18.68	20.46 ^{c}	25.19	26.04	22.35	20.26	21.41	23.05 ^{c}	21.28	19.99	19.27	18.75	18.78	19.62 ^{c}
Mean	21.82 ^{b}	23.28 ^{a}	20.44 ^{c}	19.01 ^{d}	18.68 ^{d}		25.11 ^{b}	26.13 ^{a}	22.48 ^{c}	20.53 ^{d}	21.41 ^{d}		21.23 ^{a}	20.16 ^{b}	19.53^{bc}	18.63 ^{c}	18.60 ^{c}	

The mean followed by different alphabetical letters were computed using Duncan's Multiple Range Test are significantly different (p≤0.05)

Table 4. Effect of different media on the survival percentage (%) of sowing of trees species

	D_1 (15th July)						D_2 (15th August)						D_3 (15th September)					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	47.00	39.00	34.00	41.00	39.00	40.00^{bc}	46.67	45.00	37.67	43.00	44.00	43.27^{b}	41.33	35.00	34.00	34.33	35.00	35.93^{b}
M_2	46.00	40.00	34.00	37.00	41.33	39.67^{c}	45.00	44.00	36.00	43.00	45.00	42.60^{b}	41.00	35.00	33.00	34.00	38.00	36.20^{b}
M_3	47.33	45.33	37.00	44.00	45.67	43.87^{a}	50.67	50.00	40.67	46.67	47.00	47.00^{a}	41.00	41.00	34.00	37.67	39.00	38.53^{a}
M_4	45.00	42.00	39.67	41.00	40.00	41.53^{bc}	49.00	49.33	39.00	44.00	47.33	45.73^{a}	41.00	37.00	35.00	37.00	34.00	36.80^{b}
M_5	45.00	43.00	35.67	43.33	41.00	41.60^{b}	47.00	46.33	36.00	41.56	46.00	43.38^{b}	40.00	38.67	31.00	38.00	35.00	36.53^{b}
Mean	46.07^{a}	41.87^{b}	36.07^{c}	41.27^{b}	41.40^{b}		47.67^{a}	46.93^{ab}	37.87^{d}	43.65^{c}	45.87^{b}		40.87^{a}	37.33^{b}	33.40^{c}	36.20^{b}	36.20^{b}	

The mean followed by different alphabetical letters were computed using Duncan's Multiple Range Test are significantly different (p≤0.05)

Table 5. pH and EC (dS/m) of different media treatments

Treatments	pH	EC (dS/m)
M_1 [Soil + Clay (1:1 v/v)]	7.60^{b}	2.80^{b}
M_2 [Soil + FYM (1:1 v/v)]	7.80^{a}	0.25^{e}
M_3 [Soil + Cocopeat (1:1 v/v)]	6.80^{d}	0.85^{d}
M_4 [Soil + Cocopeat + Clay (4:3:3)]	6.50^{e}	2.10^{c}
M_5 (Seed priming with clay)	7.40^{c}	3.40^{a}

(Tamilarasan et al., 2021b). The use of clay in seed balls demonstrated enhanced seedling establishment even in the presence of predators (Overdyck et al., 2013). Plants exhibiting robust growth displayed a higher number of leaves (Sudrajat and Rustam 2020). However, the specific number of leaves varied based on the growth habits and the physiology of individual tree species in coated seeds of drumstick tree (Soares et al., 2023). Environmental factors such as light, temperature, and nutrient availability, along with overall plant health, influenced vegetative attributed as leaf area, stem girth, maximum fresh and dry weight of the leaves. Well-established seedlings originating from seedballs typically develop robust root and shoot systems, enabling efficient nutrient and water uptake from the soil and ensuring effective photosynthesis. This nutritional enrichment contributes to enhanced plant growth and vigor. Further, growth was also improved when seed balls were broadcasted on the uncultivated land followed by monsoon (Maity et al., 2015). Gawankar et al. (2019) also observed that cocopeat media increased the seedling vigour which may contribute to the increase in fresh and dry weight.

Field survival percentage: In sowing of 15th July (D_1), the maximum (47.33 %) survival percentage was exhibited by S_1M_3 (*Cassia fistula* grown in soil + cocopeat media) whereas, the minimum (34.00 %) survival percentage was obtained in S_3M_1 (*Schleichera oleosa* in soil + clay media) and S_3M_2 (*Schleichera oleosa* in soil + FYM media) (Table 4). In D_2 (15th August) sowing, S_1M_3 exhibited the maximum (50.67 %) survival percentage and minimum (36.00 %) was in S_3M_2 and S_3M_5 (*Schleichera oleosa* grown in seed priming with clay). In sowing time of 15th September (D_3), again the maximum (41.33 %) survival percentage was exhibited by *Cassia fistula* in soil + cocopeat media), whereas, minimum (31.00 %) survival percentage was obtained in *Schleichera oleosa* in seed priming with clay. The germinated seedlings received frequent rains by monsoon which provided favorable climate for their growth and survival. Loss due to predatory animals and bird also results in higher survival rate as observed in paddy (Fenangad and Orge 2015). Improved establishment and survival of *Leucaena leucocephala* using seed ball technique due to low abiotic stress and higher nutrient availability near rhizosphere (Tamilarasan et al., 2021a). Moreover, the seedball technique reduce the pathogen infestation which results in healthy seedlings which further influence the survival rate and establishment as concluded by Afzal et al. (2020). Sudrajat and Rustam (2020) and Qiu et al. (2020) also concluded that the coated seeds exhibited better establishment of the growing seedlings, hence more survival rate.

Media M_3 (Soil + cocopeat) had the closest pH (6.80) to the neutral pH (7.0). The pH of the used media was be in order $M_2>M_1>M_5>M_3>M_4$ (7.80 >7.60 > 7.40 > 6.80 > 6.50). In all the above-mentioned results of all parameters, M_3 (soil + cocopeat) exhibited best results (Table 4). In case of EC, the media M_5 (seed priming with clay) exhibited maximum EC (3.40 dS/m) whereas, M_2 (soil + FYM) exhibited minimum EC (0.25 dS/m). EC of all used media was in order of $M_5>M_1>M_4>M_3>M_2$.

CONCLUSION

Seedball technique can be promising to produce the quality tree seedling on unmanaged and degraded landscape where the seedling survival is major concern. Through the meticulous examination of five avenue tree species and five growing media mixtures of seed ball, it becomes evident that the choice of media for enclosing seedballs significantly influences the germination and subsequent establishment of seeds in natural conditions and

followed by better survival success. The combination of soil and cocopeat emerged as the most conducive growing medium for preparing the seed balls for successful germination and robust plant development, particularly when sown in August. *Azadirachta indica* and *Cassia fistula* hold great potential for the broader application of seed ball technology in environmental restoration efforts for avenue tree plantations.

AUTHORS' CONTRIBUTIONS

R K Dubey, Madhu Bala and Simrat Singh developed the concept of the experiment. Arshdeep Singh executed the trial and collected and analysed the data. Arshdeep Singh, R K Dubey, Arshdeep Kaur and Kritika Pant prepared the manuscrip**t.**

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