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Seasonal Variation in Clonal Propagation Performance among *Dendrocalamus stocksii* (Munro) Accessions

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ABSTRACT

The investigation was conducted at the ICFRE–Institute of Wood Science and Technology (IWST), Forest Research Station, Gottipura, Hoskote Taluk, Bengaluru Rural, Karnataka, India to evaluate the clonal propagation efficiency of 59 accessions of *Dendrocalamus stocksii* (Munro) during winter and summer seasons. The experiment was conducted separately during winter (December 2023–February 2024) and summer (March–May 2024) using a Randomized Block Design (RBD), with 59 accessions evaluated under nursery conditions. Each treatment consisted of uniform culm cuttings maintained under controlled nursery conditions. Analysis of variance conducted separately for each season revealed significant (p<0.05) differences among accessions for sprouting percentage, number of shoots node^{-1}, shoot length at 30, 60 and 90 days, shoot diameter at 90 days, root length at 90 days, and number of roots at 90 days. Descriptively, propagation performance was higher during summer, with a mean sprouting percentage of 58.72% compared with 51.96% during winter. Considerable variation among accessions was observed for shoot and root development traits in both seasons, indicating substantial phenotypic variation in clonal propagation performance. The results highlight the importance of selecting an appropriate propagation season for optimizing propagation success and provide a useful basis for identifying promising *D. stocksii* accessions and improving clonal propagation practices for nursery production and germplasm utilization.

KEYWORDS: *D. stocksii*, vegetative propagation, seasons, accessions

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1. INTRODUCTION

Bamboo is one of the most versatile and ecologically important members of the grass family, which has become vital in rural livelihoods and environmental sustainability (Dutta et al., 2025; Lobovikov et al., 2012). It is widely utilized for construction, furniture, handicrafts, paper production, bioenergy, and erosion control (Van Dam et al., 2018; Ahmad et al., 2025). Its rapid growth, renewable nature, and suitability to diverse ecological conditions embed economic value within this highly valued resource, especially within tropical and subtropical regions of the world (Sapovadia et al., 2025). Beyond its commercial value, this plant also supports soil conservation, carbon sequestration, and biodiversity maintenance, adding more to its ecological importance (Xinzhang et al., 2011). Among the different species of bamboo, *D. stocksii* (Munro) is a clump-forming, fast-growing species that is native to the central western Ghats, which is considered its main distribution area (Lubina et al., 2019). This species is highly valued for its strong and durable culms, suitable for construction and other industrial applications (Rane et al., 2016). Its adaptability to a wide range of agro-climatic conditions further heightens its potential for sustainable cultivation and commercial exploitation (Kumar et al., 2023). Considering the increasing demand for the products from this bamboo species, there is an urgent need to develop effective propagation strategies for *D. stocksii* so as to ensure regular supply of quality planting material. However, an important bottleneck in bamboo cultivation is the irregular and infrequent flowering of most species, including *D. stocksii* (Kundu et al., 2025). Some species flower only once in several decades, producing seeds intermittently, which makes seed-based propagation unreliable (Fernandez and Gielis, 2003; Prain and Naziri, 2020). In consequence, vegetative propagation has emerged as the most practical and widely adopted approach for the rapid multiplication of superior bamboo genotypes (Kundu et al., 2025; Sandhu et al., 2018). Methods such as culm cuttings, branch cuttings, and rhizome division not only help in mass propagation but also retain desirable traits like high growth rate, culm thickness, strength, and adaptability (Awotedu et al., 2021). Vegetative propagation thus assumes prime importance for both conserving the germplasm and meeting the ever-increasing commercial demand for bamboo (Bajaj, 1986). Vegetative propagation in bamboo is significantly influenced by environmental factors, especially temperature and humidity (Shirin et al., 2021). Seasonal variation significantly affects the sprouting success, shoot elongation, culm diameter, root formation, and overall growth performance (Gulabrao et al., 2012). Generally, there are higher sprouting percentages and more uniform growth under moderate temperatures with adequate soil moisture (Xue et al., 2021). Extreme conditions often reduce sprouting and limit vegetative development. In addition, genotypic variation among accessions influences growth responses, highlighting the need to evaluate both seasonal and genetic effects to optimize propagation protocols. Despite the economic and ecological importance of *Dendrocalamus stocksii*, limited information is available on seasonal variation in clonal propagation performance and accession-level differences in propagation traits. Such information is important for identifying promising accessions and determining suitable periods for clonal propagation. In this context, the present study evaluated the clonal propagation performance of 59 *D. stocksii* accessions during winter and summer seasons. The study aimed to quantify variation among accessions for sprouting, shoot, and root development traits and to compare their propagation performance between winter and summer seasons. The experiment was conducted separately during winter and summer using a Randomized Block Design (RBD), with 59 accessions evaluated under nursery conditions.

2. MATERIALS AND METHODS

2.1. Experimental site

The experiment was conducted separately during the winter (December, 2023–February, 2024) and summer (March–May, 2024) seasons at the ICFRE–IWST Forest Research Station, Gottipura, Hoskote Taluk, Bengaluru Rural, Karnataka, India (13.106491° N latitude, 77.844632° E longitude, and 888.91 m elevation). In each season, the experiment was laid out in a Randomized Block Design (RBD) to evaluate 59 *Dendrocalamus stocksii* accessions under nursery conditions.

2.2. Meteorological data

Maximum and minimum temperatures and mean relative humidity (%) during winter (December to February) and summer (March to May) were depicted in Figure 1, representing the arid climate of ICFRE-IWST Forest

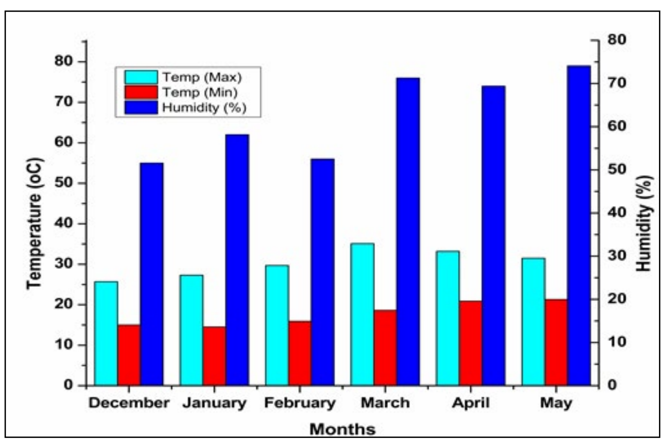


Figure 1: Maximum and minimum temperatures and mean relative humidity (%) (December, 2023 to May, 2024)

Research Station nursery, Gottipura, Bengaluru rural.

2.3. Collection of planting material

Fifty-nine accessions of *D. stocksii* were maintained as vigorously growing clumps in the germplasm bank at Dapoli, and healthy clumps (approximately 10 years old) were selected for this study. The details were presented in Table 1. Culms were collected during two different seasons, namely, winter (December to February) and summer (March to May), to determine the best season for raising the saplings through cuttings and also to assess their performance thereafter (These seasons classified according to Anonymous, 2024). The experimental material consisted of culm cuttings collected in December and April; fresh cuttings were put in goni bags filled with water to avoid desiccation and then transported to Gottipura nursery for further processing.

2.4. Selection of fresh or young culms

For vegetative propagation through culm cuttings, fresh and young culms, generally 1–2 years old, were preferred. However, many species have been reported to be successfully propagated from culms aged between 1 and 5 years (Ray and Ali et al., 2017). Research on the optimal age of stock plants for culm cuttings was scarce in *D. stocksii*, but most studies reported a trend that culms between one and five years old were superior in most bamboo species. Some authors have shown successful propagation with one-year-old culms in *Bambusa balcooa* (Joshi et al., 2012; Gantait et al., 2016) and 1.5–2 years old for *B. vulgaris* (Bhol and Nayak, 2012; Hossain et al., 2006; Senyanzobe et al., 2013). The same has been reported for *Arundinaria alpina* (Senyanzobe et al., 2013), *Oxytenanthera abyssinica* (Elbasheer and Raddad, 2013), and for a five-year-old culm of *D. asper* (Singh et al., 2004) and *B. vulgaris* (Islam et al., 2011). Even though culms of different ages have successfully been used for propagation in various species, relatively younger culms tended to perform better, possibly due to their more vigorous and physiologically active buds, critical for rooting and shoot emergence (Elbasheer and Raddad, 2013). Although Bhatnagar, (1974) postulated that one-year-old culms were generally suitable for culm-cutting propagation, Saharia and Sen, (1990) found survival was higher in two-year-old culms than one or three-year-old culms in *B. balcooa, B. pallida, B. bamboos,* and *Melocanna bambusoides*. This was the age when

Table 1: List of accessions used as an experimental material

Sl. No.	Acc code	Accession name	Sl. No.	Acc code	Accession name	Sl. No.	Acc code	Accession name
1.	2	Shedve	21.	38	Taraguda	41.	64	Madavle
2.	2a	Sirsi-2	22.	39	Ullar	42.	67	Haleshe
3.	6	Shendri	23.	40	Kadra	43.	68	Duesur
4.	7	Idalhond	24.	41	Assessor	44.	69	Nilji
5.	9	Sarambel	25.	42	Ramnagar	45.	71	Yeryadaka
6.	10	Pangarwadi	26.	45	Kanangad	46.	78	Betode
7.	14	Sirsi-14	27.	48	Chengala	47.	79	Mandopa
8.	15	Sirsi-15	28.	49	Muliyar	48.	80	Nuve
9.	17	Sirsi-17	29.	51	Chadyakal	49.	81	Uchgaon
10.	18	Sirsi-18	30.	52	Girode	50.	82	Khotode
11.	22	Markholl	31.	53	Ravan	51.	87	Sheral
12.	23	Ghavnala	32.	54	Nagzar	52.	90	Burambi
13.	24	Vados	33.	56	Pedne	53.	92	Sakarpa
14.	24 A	Sirsi-24	34.	57	Dhangarmala	54.	93	Ambaghat
15.	26	Harugaru	35.	58	Yelvatti	55.	94	Kurne
16.	27	Gadhalli	36.	58A	Sirsi-58	56.	95	Beni
17.	27A	Sirsi-27	37.	59	Dabhevadii	57.	97	Umbarle
18.	31	Tyagli	38.	60	Masewadii	58.	100	Kumbhve
19.	32	Sirsi-32	39.	62	Gudavale	59.	102	Sirsi-102
20.	36	Baragadde	40.	63	Halkarni			

the culm exhibited optimum growth potential and rooting can be more successful. In the present investigation, only healthy culms 1–2 years old were selected to ensure effective propagation and vigorous shoot development. Selection of young culms was, thus, very important in ensuring maximum success of the propagation endeavor.

2.5. Preparation of culm cuttings

After harvesting, the long culms were cut into shorter sections to facilitate transportation. shoots were carefully removed from the node portions without causing any damage to the nodes, and the culms were then prepared as two node sections for propagation in nursery beds according to Xaxa (2024). The detailed procedure was represented in Figure 2.

2.6. Data collection

This experiment was conducted in two different seasons viz., winter and summer. Data were collected Sprouting percentage (%), Number of shoots node^{-1} at 30 days after sowing, shoot length at 30, 60 and 90 days after sowing. Diameter of shoot at 90 days, Root length of saplings after 90 days, Number of roots saplings^{-1} after 90 days. The following parameters were recorded.

2.6.1. Sprouting percentage (%)

Sprouting percentage (%) was calculated by considering the number of nodes sprouted after 30 days of cuttings sowing to the number of culm nodes planted.

Sprouting Percentage (%)=$N_s/N_p \times 100$

Where: N_s: Number of nodes sprouted, N_p: Number of nodes planted.

2.6.2. Number of shoots node^{-1}

To find out the number of shoots node^{-1}, bamboo culm cuttings were planted in the nursery beds, and shoot emergence was counted at each node. The shoots were counted 30 days after planting, and the data were recorded for all nodes across the accessions. This provided an accurate measurement of shoot production and helped to assess the growth of the bamboo species under nursery conditions.

2.6.3. Shoot length

For the measurement of shoot length, culms were planted in nursery beds. Shoot length was measured at 30, 60, and 90 days from planting by measuring the length from the base to the tip of the longest shoot (Figure 3a). Data on each cutting were taken for the different periods as mentioned

Figure 2: Preparation of two-node culm cuttings of *D. stocksii* for nursery propagation; (Steps shown included: Initial harvested culms, removal of shoots from nodes, preparation of two-node cuttings, dipping in water to maintain freshness, arrangement in nursery sand beds, covering with sand, regular watering, and emergence of new shoots)

above to study the pattern of shoot growth. Measurements are taken in centimeters to monitor elongation in controlled conditions in the nursery. This is a straightforward way of assessing shoot growth in bamboo over time.

2.6.4. Shoot diameter

The collar diameter of the shoots was measured at 90 days using a digital Vernier caliper. Measurements were taken at the base, 5 cm above the soil surface (Figure 3b), and recorded in millimeters (Alahmad, 2022).

2.6.5. Root length of saplings

For the measurement of bamboo sapling root length, culm cuttings were planted in nursery beds and grown for 90 days. At the time of transplanting, the root length of each sapling was measured from its base to the tip of the longest root with a standard measuring scale (Figure 3c). Data for each sapling was recorded to assess the growth and development of the root.

2.6.6. Number of roots saplings^{-1}

To determine the number of roots sapling^{-1}, bamboo culm cuttings were planted in nursery beds. After 90 days, during transplanting, the soil around each sapling was gently removed to expose the root system. All roots emerging from the base were counted and recorded (Figure 3d). Each root was considered a separate growth, and the total number of roots was documented to asses root development.

2.6.7. Statistical analysis

The data were analyzed for assessing variation among the accessions and seasons using INDOSTAT software, version 9.3. ANOVA analysis was performed to determine the significance of differences between the means of all measured parameters. Mean values were compared by the appropriate post-hoc test at a p=0.05 level of significance.

3. RESULTS AND DISCUSSION

3.1. Analysis of variance

The ANOVA showed that there were significant differences among the fifty-nine *D. stocksii* accessions across winter and summer seasons for all studied traits, namely Sprouting (%), number of shoots node^{-1}, shoot length at 30 days, 60 days, and 90 days (cm), shoot diameter at 90 days (mm), root length at 90 days (cm), and number of roots at 90 days. The probability values for all traits were highly significant (p<0.05), indicating that both accession and seasonal effects contributed significantly to the observed variation (Table 2). In *Bambusa vulgaris*, growth parameters from culm cuttings, such as height and diameter, showed non-significant variation as reported by Ananfack et al. (2022). However, in our study, height and diameter across accessions and seasons showed significant differences. In *D. stocksii,* sprouting and root length parameters from culm cuttings showed significant variation

3a) Shoot length of cuttings

3b) Shoot diameter of cuttings

Figure 3: Continue...

3c) Root length of cuttings

3d) Number of roots per node

Figure 3: Measurements of growth characteristics of *D. stocksii*

Table 2: Analysis of variance for sprouting and growth characteristics of *D. stocksii*

Sl. No.	Characteristics	Source of variation (Mean sum of square)					
		Winter			Summer		
		Rep (2)	Acc (58)	Error (116)	Rep (2)	Acc (58)	Error (116)
1.	SP	97.18	212.296*	73.87	153.33	120.153*	50.49
2.	NSN	1.45	0.9659*	0.27	0.89	0.663*	0.28
3.	SL-30	216.16	274.509*	88.85	87.94	380.616*	41.67
4.	SL-60	158.16	247.991*	106.93	91.53	516.060*	62.07
5.	SL-90	140.46	323.019*	126.81	56.70	629.550*	76.29
6.	SD-90	0.12	0.572*	0.10	0.09	0.482*	0.09
7.	RL-90	0.30	3.0518*	1.18	0.37	1.520*	0.50
8.	NR-90	0.04	0.471*	0.23	0.20	0.326*	0.15

Note: SP: Sprouting percentage (%); NSN: Number of shoots node^{-1}; SL-30: Shoot length at 30 days (cm); SL-60: Shoot length at 60 days (cm); SL-90: Shoot length at 90 days (cm); SD-90: Shoot diameter at 90 days (mm); RL-90: Root length at 90 days (cm); NR-90: Number of roots at 90 days, Rep: Replication; Acc: Accessions

in both summer and winter, as reported by Sindhu et al., (2024). Similarly, in our study, sprouting and root length across accessions and seasons (i.e. winter and summer) also showed significant differences.

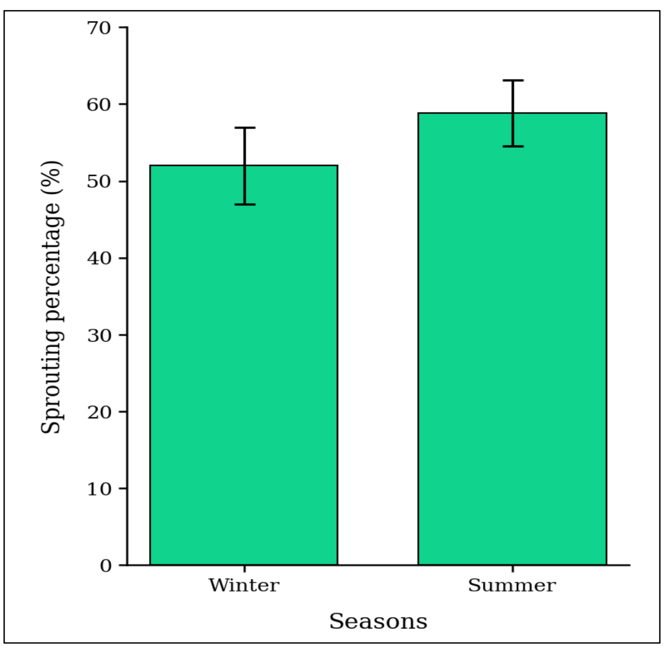
3.2. Interactive effects of seasons and accessions (S×T) on sprouting percentage

Sprouting percentage was 33.33–67.78% among fifty-nine *D. stocksii* accessions during the winter season, from December to February, with a mean value of 51.96%. The highest sprouting percentage was recorded in accession number 78 (67.78%), and the lowest was observed in accession number 82 (33.33%). Overall, 68% of the accessions showed more than 50% sprouting, whereas the rest of the accessions showed less than 50% sprouting during this winter season. In the summer season, starting from March and lasting up to May,

Table 3: Variation in sprouting percentage across different seasons and accessions in *D. stocksii*

Sprouting percentage (%)								
Acc. No.	Winter	Summer	Acc. No.	Winter	Summer	Acc. No.	Winter	Summer
2	36.67	64.44	40	53.33	62.22	71	46.67	52.22
2a	55.56	56.67	41	57.78	64.44	78	67.78	61.11
6	56.67	67.78	42	35.55	53.33	79	50.00	66.67
7	53.33	68.89	45	47.78	62.22	80	60.00	60.00
9	47.78	54.44	48	51.11	57.78	81	63.33	64.44
10	48.89	58.89	49	64.44	51.11	82	33.33	57.78
14	56.67	61.11	51	62.22	58.89	87	42.22	61.11
15	60.00	63.33	52	52.22	66.67	90	43.34	62.22
17	61.11	64.44	53	38.89	54.44	92	46.67	62.22
18	58.89	54.44	54	38.89	60.00	93	48.89	47.78
22	57.78	55.56	56	34.45	55.56	94	38.89	52.22
23	61.11	48.89	57	55.55	61.11	95	54.45	65.56
24	51.11	52.22	58	60.00	57.78	97	50.00	67.78
24a	55.56	48.89	58a	52.22	65.56	100	46.67	57.78
26	63.33	62.22	59	52.22	50.00	102	56.67	58.89
27	51.11	57.78	60	51.11	64.44	Mean	51.96	58.72
27a	54.44	66.67	62	55.55	61.11	C.V.	16.54	12.10
31	40.00	71.11	63	52.22	55.56	F Prob.	0.00	0.00
32	55.55	54.44	64	61.11	61.11	C.D. 5%	13.90	11.49
36	61.11	55.56	67	45.55	36.67	Range	33.33–67.78	36.67–71.11
38	53.33	61.11	68	54.45	51.11			
39	36.67	52.22	69	63.33	54.45			

*Acc.no: Accession number



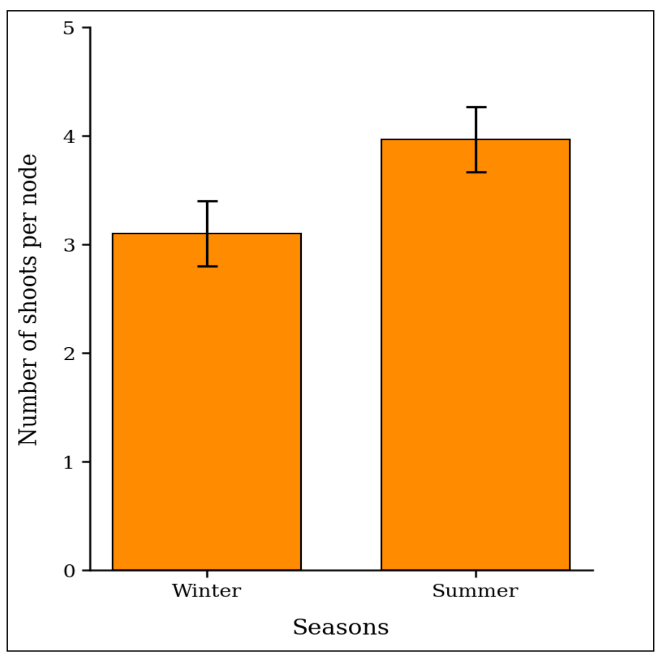


Figure 4: Continue...

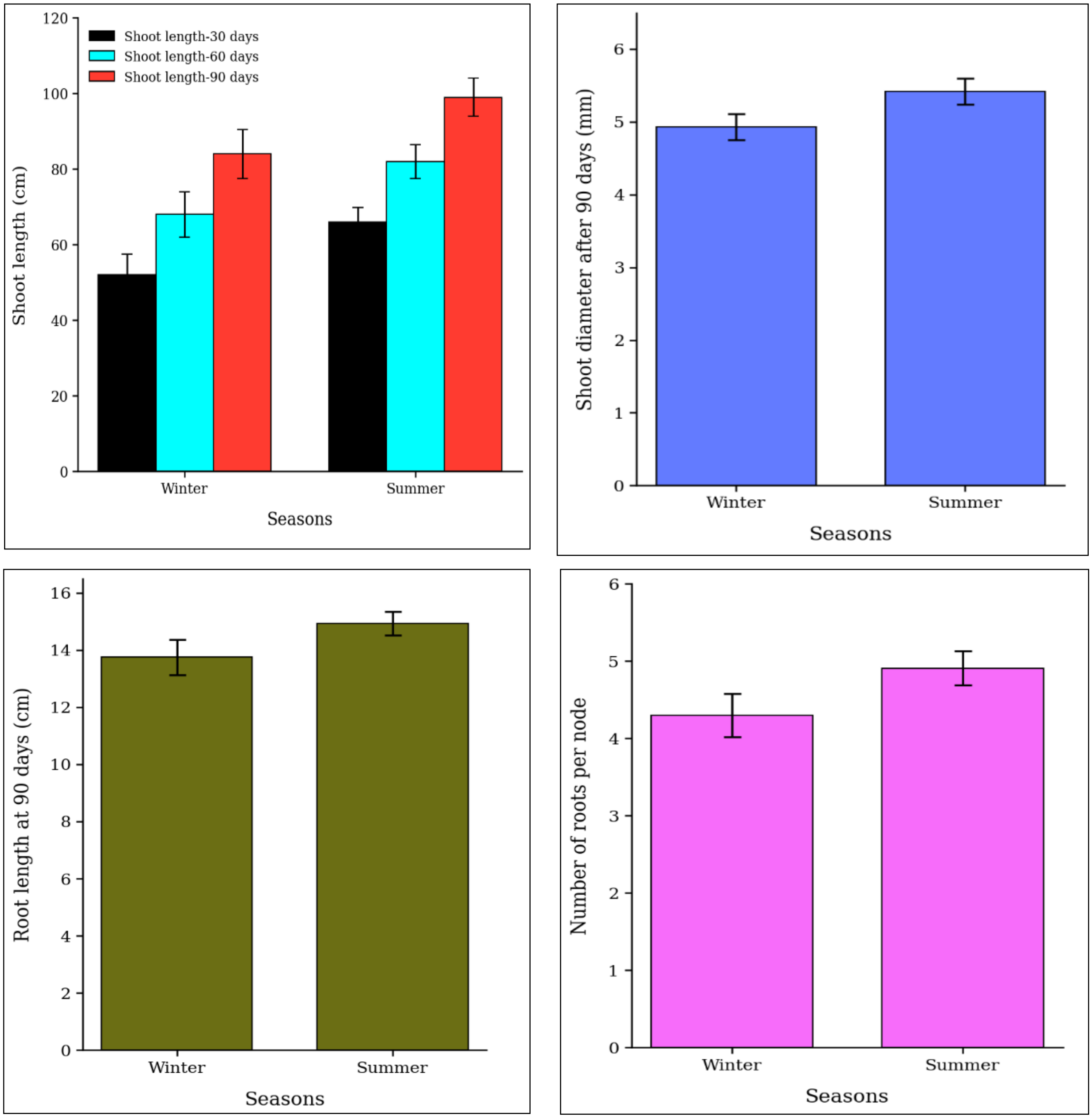


Figure 4: Mean±SE values of sprouting and growth parameters of *D. stocksii* culm cuttings

sprouting percentage ranged from 36.67–71.11%, while its mean value accounted for 58.72% (Table 3; Figure 4). In *D. stocksii*, sprouting percentage was reported to be 11% in winter and 71.67% in summer by Sindhu et al., (2024). Similarly, in our study, the sprouting percentage was 51.96% in winter and 58.72% in summer. Earlier reports also indicated better sprouting performance in summer compared to winter, and these findings supporting the results of the present study. The maximum sprouting percentage has been observed in accession no. 31 (71.11%), and minimum in accession no. 67 (36.67%). During this season, 95% of accessions showed above 50% sprouting, while the rest showed less than 50%.

3.3. Variation in the number of shoots node^{-1}

The number of shoots per node for the fifty-nine *D. stocksii* accessions varied from 1.80–4.27 for the winter season (December to February), with a mean value of 3.09. The highest number of shoots node^{-1} was observed for accession number 26, which was 4.27, while the lowest was accession number 58, which was 1.80. The number of shoots node^{-1} for the summer season (March to May) varied from 3.27–5.40, with a mean value of 3.96. The maximum number of shoots node^{-1} was observed for accession number 80, which was 5.40, and the minimum was for accession number 58, 93 and 94, which had 3.27 (Table 4; Figure 4). The studies reported that generally 2 to 3 tillers or shoots in *D. stocksii* were observed by Joshi et al., (2010). However, in present study, 3.09 shoots in winter and 3.96 in summer shoots node^{-1} were observed. These results supported the findings of the present study.

3.4. Variations in shoot length at 30, 60 and 90 days across different seasons and accessions

3.4.1. Shoot length at 30 days

The shoot length in 30 days, for fifty-nine *D. stocksii* accessions in the winter season, that was, from December to February, ranged between 35.78 cm and 76.88 cm, with a mean value of 52.05 cm. The maximum shoot length in 30 days was recorded in accession number 51, that is, 76.88 cm, while the least was accession number 59, recording 35.78 cm. During the summer period, that was, from March to May, shoot length at 30 days ranged from 49.00–100.29cm, with a mean value of 65.71 cm. Maximum shoot length in 30 days was observed in accession number 36, that is, 100.29cm, while minimum in accession number 59, recording 49.00cm.

3.5. Shoot length at 60 days

In fifty-nine *D. stocksii* accessions, the Shoot length at 60 days during the winter season (December to February) was within a range of 51.72 cm to 93.29 cm, while the mean value was 65.73 cm. The maximum Shoot length at 60 days was in accession number 51, 93.29 cm, and minimum in accession number 59, 51.72 cm. In the summer season (March to May), Shoot length at 60 days was from 64.64 cm –122.29 cm, with an average value of 81.78 cm. Shoot length at 60 days was maximum in accession number 36, 122.29 cm and minimum in accession number 59, 64.64 cm.

Table 4: Variation in number of shoots per node across different seasons and accessions in *D. stocksii*

Number of shoots node-1 (No's)								
Acc.no	Winter	Summer	Acc.no	Winter	Summer	Acc.no	Winter	Summer
2	3.87	4.40	40	2.93	3.80	71	2.73	3.93
2a	3.73	4.27	41	3.20	4.80	78	2.93	4.20
6	3.40	4.00	42	2.93	4.60	79	1.93	3.60
7	4.20	4.67	45	3.47	4.07	80	4.00	5.40
9	4.20	4.53	48	3.93	4.93	81	3.80	3.93
10	2.60	3.47	49	3.07	3.73	82	2.87	3.60
14	2.80	3.80	51	2.53	3.67	87	3.67	4.87
15	2.47	3.67	52	2.80	3.53	90	3.53	3.67
17	3.40	3.73	53	2.87	3.40	92	3.07	4.87
18	3.40	3.87	54	2.87	3.87	93	2.60	3.27
22	2.67	3.47	56	3.13	3.67	94	2.87	3.27
23	3.73	4.20	57	3.33	3.93	95	3.00	3.93
24	3.33	4.00	58	1.80	3.27	97	2.73	3.60
24a	3.40	4.00	58a	3.20	3.67	100	3.27	4.27
26	4.27	4.60	59	2.20	3.33	102	3.13	4.00
27	3.47	4.20	60	2.47	3.80	Mean	3.09	3.96
27a	2.20	3.87	62	2.13	3.60	C.V.	16.83	13.28
31	2.33	3.33	63	2.87	4.27	F Prob.	0.00	0.00
32	2.87	3.80	64	2.60	4.20	C.D. 5%	0.84	0.85
36	3.13	3.60	67	2.87	3.67	Range	1.80–4.27	3.27–5.40
38	3.40	4.07	68	4.07	4.47			
39	3.00	3.53	69	3.07	3.80			

*Acc.no: Accession number

3.6. *Shoot length at 90 days*

In fifty-nine *D. stocksii* accessions, during the winter season (December to February), the Shoot length at 90 days ranged from 66.61 cm to 108.94 cm with a mean value of 83.75 cm. The highest Shoot length at 90 days was recorded in accession number 90 (108.94 cm), while the lowest was observed in accession number 10 (66.61 cm). During the summer season, i.e., during March to May, the Shoot length at 90 days was between 77.50 cm–144.09 cm with a mean value of 99.05 cm. The maximum Shoot length at 90 days

Table 5: Variation in shoot length at 30, 60 and 90 days across different seasons and accessions in *D. stocksii*

	Shoot length (cm)					
Acc. No.	30 days		60 days		90 days	
	Winter	Summer	Winter	Summer	Winter	Summer
2	55.85	59.65	67.52	74.44	87.75	90.07
2a	58.33	55.08	75.01	69.03	101.19	85.82
6	52.35	86.39	69.92	108.44	86.22	128.63
7	47.49	66.47	69.85	84.08	92.56	102.90
9	43.91	59.57	57.31	74.49	72.13	95.33
10	40.83	60.33	53.55	74.47	66.61	89.64
14	47.55	52.63	61.67	66.35	73.96	79.75
15	51.79	61.41	65.41	72.91	77.63	87.12
17	52.55	57.65	66.34	70.77	80.75	85.73
18	50.03	63.93	71.69	83.69	91.27	100.50
22	46.37	77.08	67.65	97.82	83.96	114.77
23	49.44	95.17	65.15	115.54	78.89	134.48
24	61.73	66.21	74.59	81.85	91.35	99.09
24a	58.20	63.67	72.21	79.21	85.39	96.29
26	76.48	77.12	89.92	92.53	106.45	112.09
27	53.71	61.93	66.19	75.58	81.00	91.11
27a	46.59	78.49	72.39	92.25	93.41	112.73
31	39.59	52.87	58.45	67.29	73.25	86.01
32	54.04	73.23	69.47	87.97	81.77	103.89
36	47.87	100.29	62.24	122.99	78.83	144.09
38	56.93	77.25	71.71	91.10	88.11	107.79
39	47.91	74.77	63.95	90.45	75.93	103.25
40	58.31	64.45	72.91	80.85	91.18	96.40
41	61.62	61.65	74.10	76.28	91.19	93.64
42	48.93	64.76	62.37	78.53	75.55	95.75
45	45.38	65.55	58.19	79.50	72.56	92.53
48	71.07	78.67	83.72	94.87	100.45	111.47
49	73.16	73.31	84.81	88.41	105.97	108.42
51	76.88	87.20	93.29	108.07	108.22	121.91
52	39.49	95.31	54.27	117.56	69.57	142.31
53	58.71	73.02	73.46	89.34	88.07	106.02
54	42.01	69.55	60.25	90.62	75.52	107.13
56	54.89	61.15	67.29	74.05	80.83	88.27

Table 5: Continue...

Acc. No.	Shoot length (cm)					
	30 days		60 days		90 days	
	Winter	Summer	Winter	Summer	Winter	Summer
57	54.10	61.85	68.03	78.21	82.37	95.05
58	46.34	54.73	64.55	74.39	88.51	95.69
58a	43.02	53.58	58.28	71.08	72.44	90.79
59	35.78	49.00	51.72	64.64	69.21	83.49
60	47.63	61.44	65.90	87.36	80.24	107.29
62	40.35	57.17	65.46	73.38	82.97	94.99
63	58.83	66.39	76.31	84.15	92.13	104.66
64	42.37	56.41	57.71	73.55	71.85	89.96
67	44.32	59.09	57.75	75.99	75.99	93.05
68	61.29	70.38	73.89	90.98	89.40	110.23
69	56.09	69.09	72.84	87.13	87.66	109.11
71	46.14	54.84	62.10	72.43	79.63	90.99
78	40.59	54.71	54.85	68.79	67.95	83.25
79	41.60	53.86	60.44	67.61	76.31	84.49
80	65.71	68.90	80.03	83.39	97.13	101.65
81	47.30	57.13	62.15	71.46	76.68	88.33
82	64.75	68.57	80.63	83.36	97.85	102.12
87	53.86	65.39	69.13	78.47	86.65	96.83
90	71.51	73.71	90.08	88.85	108.94	109.99
92	43.40	59.61	60.27	73.11	77.51	87.01
93	42.07	55.61	61.57	69.49	78.56	83.17
94	50.70	56.36	64.46	69.31	79.08	85.11
95	54.23	62.90	69.19	76.88	82.47	91.94
97	51.27	57.61	66.07	70.71	80.48	84.55
100	46.94	53.63	61.09	65.41	73.69	77.50
102	50.54	59.07	64.79	73.46	77.85	87.69
Mean	52.05	65.71	67.73	81.78	83.75	99.05
C.V.	18.11	9.82	15.27	9.63	13.45	8.82
Prob.	0.00	0.00	0.00	0.00	0.00	0.00
CD (p=0.05)	15.24	10.44	16.72	12.74	18.21	14.12
Range	35.78–76.88	49.00–100.29	51.72–93.29	64.64–122.99	66.61–108.94	77.50–144.09

*Acc.no: Accession number

was observed in accession number 36 (144.09 cm), and the minimum in accession number 100 (77.50 cm) (Table 5; Figure 4).

3.7. Shoot diameter variation across accessions and seasons

Shoot diameter amongst fifty-nine *D. stocksii* accessions in the winter season (December to February) varied from 3.77 mm–5.88 mm, with an average of 4.93 mm. Maximum shoot diameter was noted in accession number 97, which was 5.88 mm while minimum Shoot diameter was found in accession number 48, recording 3.77 mm. In summer (March to May), Shoot diameter ranged between 4.61 mm–6.87 mm, with a mean of 5.42 mm. The maximum Shoot diameter was noted in accession number 100, which was 6.87 mm and minimum in accession number 22, which recorded 4.61 mm (Table 6; Figure 4).

Table 6: Variation in shoot diameter across different seasons and accessions in *D. stocksii*

Shoot diameter at 90 days (mm)								
Acc. No.	Winter	Summer	Acc. No.	Winter	Summer	Acc. No.	Winter	Summer
2	4.76	6.42	40	5.28	5.43	71	5.17	5.56
2a	4.67	5.56	41	5.37	5.89	78	4.44	5.12
6	5.28	6.32	42	5.30	5.51	79	4.72	5.27
7	4.46	5.35	45	4.91	5.54	80	4.35	5.20
9	4.39	6.09	48	3.77	4.93	81	5.08	5.05
10	4.48	5.44	49	5.44	4.79	82	5.05	5.34
14	4.92	5.31	51	5.69	5.74	87	3.96	4.96
15	4.76	4.90	52	4.34	5.04	90	4.98	5.53
17	4.88	5.19	53	5.20	5.65	92	4.58	5.28
18	5.57	5.94	54	4.80	5.41	93	4.44	5.10
22	4.33	4.61	56	4.81	5.37	94	4.67	5.22
23	5.66	5.84	57	5.00	5.58	95	5.45	5.56
24	4.95	5.15	58	4.82	5.37	97	5.88	5.85
24a	4.44	5.05	58a	4.84	5.50	100	5.14	6.87
26	5.43	5.32	59	5.02	5.49	102	5.10	5.53
27	5.55	5.57	60	4.87	5.26	Mean	4.93	5.42
27a	4.97	5.35	62	5.21	5.10	CV	6.43	5.60
31	5.06	5.68	63	5.13	5.33	F Prob.	0.00	0.00
32	4.71	4.66	64	4.60	5.12	CD p=0.05	0.51	0.49
36	5.40	5.61	67	5.03	5.39	Range	3.77– 5.88	4.61–6.87
38	4.13	5.09	68	5.40	5.53			
39	5.04	5.32	69	5.21	5.62			

*Acc.no: Accession number

3.8. *Variation in root length*

The root length among fifty-nine *D. stocksii* accessions during the winter season (December to February) ranged from 11.04 cm–15.26 cm, with a mean value of 13.74 cm (Figure 4). the highest root length was recorded in accession number 64 (15.26 cm), while the lowest was observed in accession number 58 (11.04 cm). In the summer season (March to May), the root length ranged from 12.84 cm–16.99 cm with a mean value of 14.92 cm. the maximum Root length was observed in accession number 6 (16.99 cm), and the minimum in accession number 32 (12.84 cm). In *D. stocksii,* root length was reported to be 2.17 cm in winter and 4.07 cm in summer by Sindhu et al., (2024). Similarly, in our study, the root length was 13.74 cm in winter and 14.92 cm in winter. Earlier reports also indicated better root length in summer compared to winter, and these findings supporting the results of the present study (Table 7).

3.9. *Variation in the number of roots*

The range of roots in the fifty-nine *D. stocksii* accessions varied from 3.33–5.00 during the winter (December to February), with the mean number recorded at 4.29 (Table 8; Figure 4). Accession number 9 had the highest number of roots, 5.00, and Accession number 45 had the lowest of 3.33. In the summer season (March to May), the range is from 4.00–5.53 with a mean value of 4.91. The maximum number of roots was seen in accession number 94, 5.53 and minimum in accession number 29, 4.00.

3.10. *Overall growth response under seasonal conditions*

During the winter season, the mean maximum and minimum temperatures were 27.6°C and 15.1°C, respectively, with an average relative humidity of 57.67%. In contrast, the summer season recorded higher mean maximum and minimum temperatures of 33.3°C and 20.3°C, respectively, along with higher relative humidity (76.33%). Overall, better growth performance including number of shoots node^{-1}, shoot length, shoot diameter, root length, and number of roots was generally observed during the summer season. However, variations among accessions indicated

Table 7: Variation in Root length across different seasons and accessions in *D. stocksii*

Root length at 90 days (cm)								
Acc. No.	Winter	Summer	Acc.no	Winter	Summer	Acc. No.	Winter	Summer
2	12.51	15.64	40	14.23	13.87	71	14.52	15.69
2a	12.47	15.31	41	11.77	13.82	78	13.18	14.71
6	15.15	16.99	42	14.21	14.96	79	14.91	14.44
7	12.79	15.15	45	14.45	15.67	80	13.72	14.38
9	12.77	13.86	48	13.07	14.91	81	14.30	15.04
10	14.09	16.06	49	13.84	14.46	82	14.68	14.75
14	12.59	13.98	51	14.83	15.75	87	14.87	14.50
15	13.76	14.81	52	12.30	14.93	90	13.51	15.20
17	13.44	14.18	53	15.09	16.04	92	13.87	14.88
18	15.05	14.88	54	14.79	15.39	93	13.00	14.63
22	12.98	13.74	56	12.44	14.68	94	14.49	15.88
23	12.01	13.59	57	14.01	15.45	95	14.47	15.33
24	13.13	13.95	58	11.04	14.55	97	13.31	14.43
24a	14.69	15.73	58a	13.73	15.41	100	12.54	15.54
26	15.11	15.00	59	14.33	15.10	102	13.02	15.05
27	14.83	15.25	60	13.07	14.49	Mean	13.74	14.92
27a	13.14	14.87	62	13.51	14.48	CV	7.92	4.73
31	14.55	15.27	63	13.21	14.91	F Prob.	0.00	0.00
32	12.16	12.84	64	15.26	15.69	CD p=0.05	1.76	1.14
36	14.66	15.41	67	14.33	14.87	Range	11.04–15.26	12.84–16.99
38	15.24	15.13	68	14.01	14.83			
39	14.64	15.49	69	13.05	14.35			

*Acc.no: Accession number

Table 8: Variation in Number of roots across different seasons and accessions in *D. stocksii*

Number of roots at 90 days								
Acc. No.	Winter	Summer	Acc. No.	Winter	Summer	Acc. No.	Winter	Summer
2	3.93	5.00	40	4.27	4.20	71	4.13	5.33
2a	3.54	4.00	41	4.27	4.67	78	4.13	4.93
6	4.82	5.40	42	4.87	5.40	79	3.87	4.73
7	4.22	4.87	45	3.33	4.73	80	4.60	5.07
9	5.00	5.27	48	4.27	4.80	81	4.27	5.07
10	4.07	4.80	49	3.73	4.87	82	4.93	5.27
14	4.13	4.33	51	4.27	4.93	87	4.27	5.27
15	4.20	4.27	52	4.67	4.73	90	4.40	5.00
17	4.00	4.80	53	4.67	5.47	92	3.67	4.87
18	4.27	4.80	54	4.53	5.00	93	4.93	5.33
22	5.00	5.13	56	4.40	5.00	94	4.80	5.53
23	4.47	4.73	57	4.20	5.07	95	4.33	4.93

Table 8: Continue...

			Number of roots at 90 days					
Acc.no	Winter	Summer	Acc.no	Winter	Summer	Acc.no	Winter	Summer
24	4.00	4.47	58	4.13	5.00	97	4.40	4.80
24a	4.00	4.73	58a	4.53	5.40	100	3.73	5.13
26	4.67	4.87	59	4.40	5.20	102	4.00	5.27
27	4.33	4.60	60	4.60	5.33	Mean	4.29	4.91
27a	4.36	4.80	62	3.93	4.40	C.V.	11.29	7.76
31	4.73	4.73	63	4.73	4.73	F Prob.	0.00	0.00
32	3.67	4.33	64	3.87	4.73	C.D. p=0.05	1.03	0.82
36	4.80	5.07	67	4.40	5.20	Range	3.33–5.00	4.00– 5.53
38	4.60	4.93	68	4.00	5.07			
39	3.47	4.67	69	4.07	4.87			

*Acc.no: Accession number

that both temperature and humidity played significant roles in influencing these growth parameters in *D. stocksii*. The results suggested that moderately high temperatures combined with adequate humidity favour improved and more uniform growth responses across different accessions.

4. CONCLUSION

Substantial variability among the 59 accessions revealed considerable differences in propagation performance across seasons. Accession 36 demonstrated superior overall performance in summer, while accessions 78, 51, and 90 showed comparatively stable growth during winter. These findings emphasized the importance of aligning superior genotypes with optimal seasonal windows to enhance propagation efficiency and supported large-scale multiplication and germplasm improvement programs.

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