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EVALUATION OF *Dracaena reflexa* 'SONG OF INDIA' FOR GROWTH AND QUALITY ATTRIBUTES UNDER DIFFERENT SHADE AND SPACING LEVELS

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Floriculture has emerged as a rapidly growing, highly competitive, and immensely profitable industry on a global scale. In 2023–24, India's floriculture sector generated USD 86.63 million in export revenue (Anonymous, 2024). The integration of scientific cultivation techniques has played a pivotal role in driving the sector's growth, with notable expansion observed in countries like India (Datta, 2019). Among the various sub-sectors of floriculture, cut foliage occupies a central role and presents significant potential for economic development (Herath *et al.*, 2013). Cut foliage, which refers to leaves used primarily for decorative purposes, either alone or in combination with flowers in floral arrangements, has seen a notable surge in demand. This trend is largely attributed to the growing preference for eco-friendly products, coupled with anticipated increases in the consumption of floral items. Prominent species used as cut foliage include *Asparagus* spp., *Ruscus hypophyllum*, *Dracaena* spp., *Codiaeum variegatum*, *Aspidistra elatior*, *Hedera helix*, *Cyperus* spp., and various wild grasses. Additionally, foliage and branches from woody plants such as *Eucalyptus* spp., *Callistemon* spp. (bottlebrush), *Euonymus* spp., *Murraya paniculata*, *Cycas revoluta*, *Cycas circinalis*, *Livistona* spp., and several palm species are frequently utilized in floral arrangements (Bhattacharjee, 1999). Cut foliage serves multiple functions in floral design, acting as filler, liner, and backdrop material. It enhances the visual appeal of bouquets, wreaths, and garlands, offering a refreshing contrast that rejuvenates otherwise plain arrangements. Over recent years, India's cut foliage exports have demonstrated substantial growth, with marked fluctuations but an overall upward trajectory. In 2022–23, the nation exported 149.51 metric tons of cut foliage, generating revenue of Rs. 154.77 lakhs-an impressive increase relative to prior years (Anonymous, 2023). Among the notable cut foliage crops cultivated in India, *Dracaena reflexa* 'Song of India,' a member of the *Asparagaceae* family, stands out. Indigenous to Madagascar and other Indian Ocean islands, this species has gained prominence in international markets due to its vibrant chartreuse foliage, an eye-catching yellow-green colour that imparts energy and vitality to floral designs. Furthermore, its extended vase life of approximately 8.5 days has contributed to its popularity in the global cut foliage trade (Athulya and Singh, 2021).

In India, *Dracaena reflexa* is cultivated for a variety of purposes, including its use as cut foliage, in bouquet-making, flower arrangements, ornamental gardening, indoor gardening, edging, and as a potted plant. Additionally, it has been recognized in the NASA Clean Air Study for its air-purifying properties, particularly its ability to remove formaldehyde, xylene, and trichloroethylene (Athulya and Singh, 2021). *Dracaena* thrives in partial shade to partial sun and exhibits tolerance to a range of soil types, including acidic, alkaline, sandy, loamy, and clay soils (Gilman, 1999). However, it is sensitive to extreme environmental conditions: high heat and humidity can increase the risk of fungal infections, excessive rainfall may lead to root rot, and intense sunlight can cause leaf burn (Kobata, 2024). Previous research has identified several key factors that enhance the growth, quality, and vase life of *D. reflexa*. For instance, the use of red shade nets (Singh *et al.*, 2023), a growing medium combination of silt, leaf manure, and coco coir (Abid *et al.*, 2017), and a 75 cm × 75 cm spacing pattern as part of an intercropping system with custard apple (*Annona squamosa* L.) (Athulya and Singh, 2021) have all been shown to significantly improve plant performance. Despite its commercial importance, however, there remains a notable gap in reliable information on production technology and optimal cultivation practices for *Dracaena* in tropical regions. Among the various aspects of cultivation, shade percentage and planting density are particularly crucial in achieving optimal productivity per unit area, as they ensure sufficient sunlight, nutrients, and moisture availability for high-quality crop production (Singh and Dubey, 2014). Appropriate shading not only promotes vibrant foliage but also preserves the ornamental quality of variegated leaves by enhancing chlorophyll content, regulating sunlight intensity, improving photosynthesis, and boosting overall plant health while preventing stress. On the other hand, excessive plant spacing, while reducing competition for resources, leads to a reduction in yield per unit area (Sudhagar *et al.*, 2019). On the other hand, too-close plant spacing can negatively impact growth, reducing both yield and

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quality. Optimal plant spacing, therefore, is essential to ensure superior plant production, efficient land and input utilization, and the attainment of high-quality foliage (Sudhagar *et al.*, 2019). Given the growing significance and market potential of cut foliage, both internationally and nationally, combined with the limited scientific understanding of cultivation practices for ornamental foliage filler plants like *Dracaena* in tropical regions, the present study aims to evaluate the impact of varying shade percentages and planting densities on the growth, yield, and quality attributes of *D. reflexa*. By optimizing these key cultivation factors, the study seeks to contribute to the development of more efficient production practices that can enhance the sustainability and profitability of *Dracaena* cultivation in tropical climates.

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The research was conducted between 2023 and 2024 at Kallampatti, Pattukkottai, Thanjavur, Tamil Nadu, with the quality analysis carried out at the Department of Horticulture, Annamalai University, Annamalainagar, Tamil Nadu, India. The experimental site was situated at an altitude of approximately 28 m above mean sea level, with coordinates at 10°19' North latitude and 79°15' East longitude. The mean maximum temperature at the site was 28°C, while the mean minimum temperature was 21°C. The average annual rainfall recorded was 0.1 mm, with a mean relative humidity of 75%. The experiment followed a Factorial Randomized Block Design (FRBD) and included five shade levels (S_1-S_5) and four spacing treatments (P_1-P_4), resulting in 20 treatment combinations, with three replications, totaling 60 plots. The shade levels were as follows: S_1 - Control (0% shade, open field), S_2 - 40%, S_3 - 50%, S_4 - 60%, and S_5 - 70%. The spacing treatments included: P_1 - 50 cm × 50 cm, P_2 - 60 cm × 60 cm, P_3 - 70 cm × 70 cm, and P_4 - 80 cm × 80 cm. The experimental plots were maintained under a shade net structure measuring approximately 20 m × 10 m, with a height of 4 m, ensuring uniform shading and proper ventilation. Planting densities varied according to spacing treatments: 50 cm × 50 cm (4 plants/m², totalling 2,160 plants), 60 cm × 60 cm (2.77 plants/m², totalling 1,500 plants), 70 cm × 70 cm (2.04 plants/m², totalling 1,080 plants), and 80 cm × 80 cm (1.56 plants/m², totalling 840 plants). In total, the experimental setup accommodated 5,580 plants, allowing for a comprehensive evaluation of the impact of different shade levels and planting densities on the growth and quality attributes of *D. reflexa*. Rooted cuttings of *D. reflexa* were sourced from a nursery and initially transplanted into polybags. After six months, uniform plants with a height of 15-20 cm were selected and transplanted into the main field. Upon transplantation, initial irrigation was provided, followed by subsequent irrigations at two-day intervals. Further irrigation was given as needed. Weeding was performed regularly throughout the growing period, with the first weeding occurring 20 days post-planting, followed by additional weeding as required. Biometric observations were conducted at 270 days after planting, focusing on various growth and physiological parameters, including plant height, plant spread, stem diameter, number of leaves per plant, leaf length, leaf breadth, number of cut stems per plant, number of cut stems per square meter, chlorophyll content, visual scoring, freshness index, colour index, and vase life of the cut foliage without pulsing. Chlorophyll content was measured using a portable chlorophyll meter (SPAD 502), and the results were recorded as SPAD index values. The visual scoring of the cut foliage was based on the Hedonic sensory evaluation method (Ranganna, 1986). The freshness index was determined through a visual assessment conducted by a panel of ten judges, following the scoring techniques outlined by Abinaya and Karuppaiah (2018). The colour index was also evaluated by the same panel of judges, using the RHS Colour Chart and scoring methodology recommended by Madhu (1999). Vase life without pulsing (in days) for the cut foliage in each treatment was recorded under room temperature conditions. The data collected were analyzed using the WASP statistical tool, enabling the formulation of appropriate conclusions regarding the effects of shade levels and spacing treatments on the growth and quality characteristics of *D. reflexa*.

The data presented in Table 1 clearly indicate that both shade percentage and optimal spacing significantly influence the growth of *D. reflexa*. The highest plant height (42.27 cm), plant spread (160.78 cm²), and stem diameter (3.98 cm) were recorded under the S_4 (60% shade net) combined with the P_2 (60 cm × 60 cm) spacing treatment. In contrast, the lowest values for plant height (27.20 cm), plant spread (122.56 cm²), and stem diameter (1.73 cm) were observed under S_1 (0% shade, open field) with the P_4 (80 cm × 80 cm) spacing. The enhanced growth parameters under 60% shade can be attributed to the reduced light intensity, which promotes better auxin transport and enhances cell elongation below the apical meristem. Plants grown under lower light intensity exhibit more pronounced apical dominance compared to those exposed to higher light intensity, as observed by Godi *et al.* (2018). These findings align with previous studies, such as those by Singh *et al.* (2017) on *Ruscus hypophyllum*, where shading resulted in improved plant growth. The reduced light intensity under 60% shade may facilitate improved energy allocation for vertical growth rather than excessive branching or leaf expansion. The positive effect of the P_2 (60 cm × 60 cm) spacing on plant growth is also evident, as this spacing allows for adequate vertical growth, better nutrient and water absorption, and more efficient utilization of sunlight. These factors

Table 1. Effect of different shade percentage, spacing levels and their interactions on growth and yield parameters of *Dracaena reflexa* 'Song of India' at 270 days after planting

Treatments	Plant height (cm)	Plant spread (cm^2)	Stem diameter (cm)	Number of leaves/ plant	Leaf length (cm)	Leaf breadth (cm)	Number of cut stems/ plant	Number of cut stems/ m^2
Shading								
S_1 (0% shade)	28.20	124.82	1.75	33.94	8.57	1.74	0.27	1.10
S_2 (40% shade)	31.88	127.92	1.93	38.52	9.39	1.91	0.82	3.31
S_3 (50% shade)	37.87	146.61	3.24	50.54	11.34	2.46	1.52	5.87
S_4 (60% shade)	39.44	153.42	3.50	56.24	12.55	2.63	1.49	6.65
S_5 (70% shade)	33.58	131.27	2.43	41.22	10.10	2.18	1.24	4.55
SE	0.31	1.18	0.01	0.30	0.08	0.01	0.00	0.03
CD (*p≤0.05*)	*0.88*	*3.28*	*0.04*	*0.86*	*0.24*	*0.04*	*0.02*	*0.11*
Plant spacing								
P_1 (50 cm x 50 cm)	35.15	138.96	2.76	46.19	10.78	2.27	1.21	4.77
P_2 (60 cm x 60 cm)	35.15	141.32	2.82	48.19	11.00	2.32	1.17	5.05
P_3 (70 cm x 70 cm)	33.61	134.35	2.41	41.76	9.96	2.13	0.93	3.89
P_4 (80 cm x 80 cm)	32.46	132.48	2.29	40.22	9.82	2.02	0.97	3.45
SE	0.24	0.92	0.01	0.24	0.69	0.01	0.00	0.03
CD (*p≤0.05*)	*0.79*	*2.93*	*0.04*	*0.77*	*0.22*	*0.04*	*0.02*	*0.10*
Interaction								
$S_1 \times P_1$	28.95	125.67	1.75	35.12	8.71	1.80	0.33	1.32
$S_1 \times P_2$	29.73	126.07	1.80	35.53	9.00	1.83	0.64	1.76
$S_1 \times P_3$	28.54	124.98	1.73	33.89	8.45	1.79	0.22	0.44
$S_1 \times P_4$	27.20	122.56	1.73	31.23	8.12	1.56	0.11	0.17
$S_2 \times P_1$	31.56	128.94	1.98	38.91	9.65	1.96	0.88	3.52
$S_2 \times P_2$	32.16	129.67	2.03	40.23	9.78	1.98	1.44	2.77
$S_2 \times P_3$	31.97	126.78	1.87	38.12	9.11	1.87	0.77	1.57
$S_2 \times P_4$	31.84	126.32	1.86	36.84	9.05	1.85	0.66	1.02
$S_3 \times P_1$	39.74	152.23	3.60	55.13	12.05	2.54	1.66	6.64
$S_3 \times P_2$	41.32	155.45	3.68	58.19	12.41	2.65	1.66	4.59
$S_3 \times P_3$	36.26	140.43	2.89	45.00	10.59	2.35	1.33	2.71
$S_3 \times P_4$	34.17	137.73	2.81	43.87	10.34	2.31	1.22	1.90
$S_4 \times P_1$	41.56	157.65	3.95	60.27	13.43	2.81	1.88	7.52
$S_4 \times P_2$	42.27	160.78	3.98	65.09	13.52	2.89	2.88	8.00
$S_4 \times P_3$	37.53	149.49	3.14	51.07	11.65	2.43	1.44	2.93
$S_4 \times P_4$	36.42	145.78	2.94	48.54	11.60	2.40	1.33	2.07
$S_5 \times P_1$	33.94	130.34	2.53	41.56	10.08	2.25	1.22	4.88
$S_5 \times P_2$	33.98	134.65	2.65	41.95	10.33	2.28	1.76	4.88
$S_5 \times P_3$	33.75	130.10	2.42	40.76	10.01	2.21	1.11	2.26
$S_5 \times P_4$	32.67	130.02	2.13	40.62	10.00	2.00	1.00	1.56
SE	0.81	3.01	0.04	0.79	0.22	0.04	0.02	0.10
CD (*p≤0.05*)	*1.77*	*6.56*	*0.09*	*1.73*	*0.49*	*0.09*	*0.05*	*0.22*

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Table 2. Effect of different shade percentage, spacing levels and their interactions on quality parameters of *Dracaena reflexa* 'Song of India' at 270 days after planting

Treatments	Chlorophyll content (SPAD index)	Visual scoring	Freshness index	Colour index	Vase life without pulsing (days)
Shading					
S_1 (0% shade)	30.53	4.55	87.39	84.73	10.87
S_2 (40% shade)	32.51	5.74	89.83	89.00	11.91
S_3 (50% shade)	41.02	7.94	94.48	93.03	14.71
S_4 (60% shade)	43.52	8.54	94.98	93.96	15.45
S_5 (70% shade)	36.45	7.09	92.90	91.24	12.84
SE	0.29	0.05	0.72	0.79	0.09
CD ($p \leq 0.05$)	*0.81*	*0.15*	*2.02*	*2.22*	*0.27*
Plant spacing					
P_1 (50cm x 50cm)	37.73	6.87	92.12	90.67	13.66
P_2 (60cm x 60cm)	38.72	7.44	93.09	91.62	13.82
P_3 (70cm x 70cm)	35.65	6.49	91.58	90.24	12.81
P_4 (80cm x 80cm)	35.13	6.29	90.86	89.03	12.34
SE	0.22	0.04	0.56	0.62	0.07
CD ($p \leq 0.05$)	*0.72*	*0.14*	*1.80*	*1.99*	*0.24*
Interaction					
$S_1 \times P_1$	30.57	4.57	87.89	84.78	11.29
$S_1 \times P_2$	31.65	4.78	88.56	85.98	11.50
$S_1 \times P_3$	30.06	4.51	87.67	84.71	10.51
$S_1 \times P_4$	29.87	4.36	85.45	83.45	10.19
$S_2 \times P_1$	33.00	5.75	90.05	89.93	12.02
$S_2 \times P_2$	33.03	6.47	91.56	90.12	12.11
$S_2 \times P_3$	32.06	5.63	88.94	89.67	12.00
$S_2 \times P_4$	31.97	5.14	88.78	86.28	11.53
$S_3 \times P_1$	41.98	8.01	94.87	93.54	15.86
$S_3 \times P_2$	43.52	8.67	95.64	93.56	15.98
$S_3 \times P_3$	39.88	7.56	93.84	92.57	13.97
$S_3 \times P_4$	38.70	7.54	93.57	92.45	13.05
$S_4 \times P_1$	45.56	8.67	94.67	93.56	16.16
$S_4 \times P_2$	47.67	9.80	96.16	96.03	16.51
$S_4 \times P_3$	40.89	7.98	94.56	93.52	14.75
$S_4 \times P_4$	39.99	7.72	94.53	92.74	14.41
$S_5 \times P_1$	37.56	7.37	93.16	91.56	13.00
$S_5 \times P_2$	37.77	7.51	93.53	92.42	13.01
$S_5 \times P_3$	35.36	6.79	92.92	90.76	12.85
$S_5 \times P_4$	35.14	6.70	91.99	90.25	12.52
SE	0.74	0.14	1.85	2.04	0.24
CD ($p \leq 0.05$)	*1.63*	*0.31*	*4.04*	*4.45*	*0.54*

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collectively enhance plant productivity, contributing to greater carbohydrate synthesis and the production of growth-promoting hormones like GA_3, which support longitudinal growth and result in taller plants and longer internodal lengths (Kumar *et al.*, 2016). In contrast, the wider spacing (P_4, 80 cm × 80 cm) may have resulted in suboptimal use of resources, including land, water, and nutrients.

The number of leaves per plant (65.09) (Table 1) was maximized under the conditions of S_4 (60% shade) and P_2 (60 cm × 60 cm) plant spacing, in comparison to both the control (S_1) and P_4 treatments. This increase in leaf production can be attributed to the reduction in light intensity and heat stress under the 60% shade, which helps maintain an optimal leaf temperature. This, in turn, reduces transpiration losses and enhances moisture retention within the plant. Under moderate shading, photosynthetic efficiency is improved due to the reduction in photoinhibition, enabling more effective carbon assimilation and promoting sustained leaf initiation and expansion. Furthermore, the reduction in heat stress minimizes oxidative damage, extending the functional lifespan of leaves and, consequently, enhancing overall foliage production. Supporting these findings, Singh *et al.* (2017) observed that *Ruscus hypophyllum* plants grown under shade nets exhibited a significantly higher number of leaves. In this study, the optimal leaf production under the P_2 (60 cm × 60 cm) spacing pattern, compared to the wider spacing pattern P_4 (80 cm × 80 cm), may be due to more efficient resource utilization in the denser planting configuration. The closer spacing ensures better light interception, more efficient nutrient and water uptake, and reduced competition between plants, all of which contribute to increased leaf proliferation and enhanced canopy development. These results are consistent with those of Nagdeve *et al.* (2021) in *Chrysanthemum* and Poornima *et al.* (2020) in *Gypsophila*, where optimal plant spacing and shading positively influenced leaf production.

Leaf size exhibited significant variation in response to different shade levels and planting patterns (Table 1). The maximum leaf length (13.52 cm) and leaf breadth (2.89 cm) were observed in plants grown under the S_4 (60% shade) level and the P_2 (60 cm × 60 cm) plant spacing, compared to both the control (S_1) and P_4 treatments. The increase in leaf size can be attributed to the favourable microclimatic conditions created under optimal-density planting, which positively influence leaf expansion and growth. Plants grown under moderate shade benefit from reduced light intensity and heat stress, which contribute to better leaf development. Optimal shade levels have been shown to promote longer stems and larger leaves compared to those grown under lower levels of shading (Anonymous, 2006). Similarly, Singh *et al.* (2017) reported that the use of shade nets significantly enhanced the vegetative growth rate and vigour of *Ruscus hypophyllum*, which corroborates the current findings. The optimal spacing pattern (P_2) also plays a critical role in promoting leaf growth. By reducing competition for resources such as light, water, and nutrients, plants in this spacing configuration can allocate more energy toward leaf expansion. Moreover, optimal spacing encourages better air circulation around the plants, further enhancing photosynthetic efficiency and contributing to larger, healthier leaves. In contrast, wider plant spacing (P_4) may not always result in increased leaf size. Although it reduces competition for resources, the more open canopy structure associated with wider spacing may lead to reduced sunlight interception. Sunlight is crucial for photosynthesis and leaf expansion, and insufficient light may limit leaf growth. This observation aligns with the findings of Poornima *et al.* (2020) on *Gypsophila* and Sowmiya and Karuppaiah (2021) on *Asparagus*, where tighter spacing enhanced vegetative growth, including leaf size, due to more efficient resource utilization and light capture.

The number of cut stems per plant (2.88) and the number of cut stems harvested per square meter (8.00) (Table 1) were highest in plants arranged with P_2 (60 cm × 60 cm) spacing and 60% shade. Adequate shading ensures balanced light exposure, which enhances photosynthesis while preventing leaf stress. Under 60% shade, light diffusion is optimized, which enables efficient photosynthesis while minimizing stress-related chlorophyll degradation. This controlled light environment facilitates enhanced carbohydrate accumulation, supporting branching and shoot proliferation. Moreover, shading helps moderate temperature fluctuations, reducing transpiration rates and conserving soil moisture. This creates a favourable microclimate that promotes sustained vegetative growth, as emphasized by Singh *et al.* (2017). The increased foliage yield observed under optimal spacing results from more available resources, particularly the higher number of leaves per plant, which promotes early and vigorous vegetative growth. In line with these findings, Marino *et al.* (2003) concluded that optimum planting density enhances stem production in *Asparagus plumosus* Baker and *Asparagus densiflorus* cv. Jessop. Similarly, Lalhruaitluangi *et al.* (2023) reported that increased plant density and appropriate shading resulted in higher stem yields in *Asparagus densiflorus* 'Sprengeri'.

The intensity of leaf coloration is closely tied to the quality of cut foliage, with a clear correlation between SPAD values and chlorophyll content in plants. In the case of *D. reflexa*, the highest SPAD values, indicative of optimal chlorophyll content, were recorded under the conditions of 60% shade nets (S_4) and the P_2 (60

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cm × 60 cm) plant spacing, achieving a value of 47.67 SPAD. In contrast, the minimum SPAD value of 29.87 was observed under the control condition (S_1) (Table 2). The improved SPAD index under shade nets can be attributed to the plants' indirect exposure to sunlight. This reduced light intensity stimulates higher chlorophyll production to effectively capture the diffuse radiation available, facilitating improved photosynthesis. This adaptive response enables the plants to synthesize carbohydrates, which are essential for sustained growth and overall development. These findings are consistent with those of Singh *et al.* (2023), who observed similar improvements in chlorophyll content and plant health in *Pleomele reflexa*, further supporting the association between chlorophyll enhancement and optimal plant spacing. However, while the benefits of optimal spacing are clear, it is important to note that wider spacing may also result in an uneven distribution of resources across the field. Factors such as soil fertility, irrigation practices, and other management strategies can affect the efficiency with which plants access light, water, and nutrients.

Regarding quality parameters such as visual scoring (9.80), freshness index (96.16), colour index (96.03), and vase life of foliage without pulsing (16.51 days), the highest values were recorded under the S_4 (60% shade) and P_2 (60 cm × 60 cm) plant spacing treatments, with the lowest values observed under the control conditions (Table 2). The quality of cut foliage is notably influenced by optimal shade levels, which provide the ideal light intensity, spectrum, and duration to enhance plant physiology and post-harvest characteristics. The 60% shade net, in particular, creates a balanced light environment that supports photosynthesis and mitigates the adverse effects of excessive sunlight, which can stress the plant and negatively impact foliage quality. The improved quality of cut foliage under optimal plant spacing can be attributed to the effective utilization of key resources such as light, moisture, space, nutrients, and aeration. This ensures that the plants receive adequate inputs for growth and development, leading to enhanced photosynthetic efficiency. The increased synthesis of photosynthates contributes to higher carbohydrate levels in plant tissues, which, in turn, enhances the overall appearance and prolongs the vase life of the cut foliage. These findings are consistent with research by Singh and Dubey (2014) on *Boston fern* and Malik *et al.* (2019) on *Snapdragon*, both of which demonstrated the positive effects of optimal spacing and shading on the quality of ornamental plants. From these results, it can be concluded that the combination of S_4 (60% shade) and P_2 (60 cm × 60 cm) plant spacing led to optimal performance in *D. reflexa*, improving growth, yield, and quality attributes. However, to further enhance the cultivation and post-harvest quality of this species, future research should focus on the influence of nutrient application and hormonal treatments. Exploring these factors will provide deeper insights into optimizing the growth, health, and overall performance of *D. reflexa*, paving the way for improved productivity and marketability in both domestic and international markets.

Authors' contribution

Conceptualization and designing of the research work (RR, PK); Execution of field/lab experiments and data collection (RR); Analysis of data and interpretation (RR); Preparation of manuscript (RR).

Conflicts of interest

Authors declare that they have no conflicts of interest.

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