



RESEARCH ARTICLE

Spathoglottis plicata Blume as a landscape element: Study on optimising shade conditions and plant spacings

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Abstract

The present study examined the potential of using *Spathoglottis plicata* Blume (Philippine ground orchid) as a sustainable landscape species by assessing the effects of different shade and spacing conditions. The experiment was conducted in a factorial randomised block design (RBD) with three levels of shade (0, 35 and 50 %) and three levels of spacing (60 × 45, 45 × 45 and 45 × 30 cm) in a 3 × 3 factorial arrangements giving nine treatment combinations with each treatment replicated three times. Growth and flowering characters were recorded to assess the best conditions for ornamental performance. Most traits showed significant interactions between shade and spacing. The treatment with 35 % shade and 60 × 45 cm spacing led to better vegetative growth and flowering performance such as better plant spread, bigger leaves, earlier bud visibility, earlier flowering, longer blooming period, larger flower diameter and a higher number of florets per inflorescence. On the other hand, heavier shade increased plant height but decreased flowering quality. Moderate shade and wider spacing will increase plant vigour, flower display and landscape value. Results indicate the good potential value of this species as a sustainable ornamental for landscape use, especially under partially shaded conditions. Further studies should test stress tolerance and management practices to refine practical cultivation guidelines for landscapes.

Keywords: flowering; growth; landscape; orchid; ornamentals; shade; spacing; *Spathoglottis plicata*; sustainable

Introduction

Orchidaceae is one of the largest and most diverse families of flowering plants which includes approximately 800 genera and 30000–35000 species. India is home to a rich diversity of orchids with approximately 1331 species belonging to 186 genera, representing approximately 10 % of the global orchid flora (1). The Himalayas, especially the Northeastern states, are the main habitat for many these orchid species. This remarkable diversity is particularly concentrated in the Northeastern states. This region harbours about 850 species of orchids, classified into 151 genera, making this region a hotspot for orchid biodiversity (2). Assam is renowned for its rich diversity of orchids, with approximately 293 species reported, accounting for about 44.39 % of the orchid species found in Northeast India and 24.42 % of the total species occurring in India.

Spathoglottis plicata Blume, commonly known as the Philippine ground orchid, is a resilient terrestrial member of the Orchidaceae family that flourishes in tropical and subtropical regions. Originally native to Southeast Asia, it has become widely

naturalised in other warm regions such as parts of Africa, the Caribbean and the Pacific Islands. This orchid is highly valued for its adaptability to a range of environments, making it a favoured choice for ornamental gardening. *Spathoglottis plicata* has broad, pleated leaves that arise from a pseudobulb and showy deep purple, pink or sometimes white flowers. The flowers are arranged in racemes for a long period of time and the plant is very lush and vibrant. This plant has considerable potential as a landscape element due to its striking appearance and ecological benefits, e.g., attraction of pollinators and contribution to biodiversity. *Spathoglottis plicata* is relatively low maintenance once established and adapts well to a variety of growing conditions. It does best in well-drained soils and in full sun to partial shade. This plant occurs naturally in grasslands and open woods, so it can grow in both cultivated and wild settings.

Through the knowledge of its attributes and needs, including the significance of shading and spacing for healthy growth and flower performance, the landscaping designer will be able to effectively incorporate this orchid into his landscaping projects. Shading is a major factor in determining the physiology and

appearance of ornamental plants in that it affects the process of photosynthesis, transpiration and the uptake of nutrients (3). Light shading has been found to increase chlorophyll formation and hence create greener leaves that improve the efficiency of light absorption while minimising heat stress and prolonging flowering by increasing the amount of moisture held. Overly shading, on the other hand, can have adverse effects on flower production and make the plants more susceptible to diseases by reducing the amount of air movement. Spacing of plants is highly interconnected with the phenomenon of shading in determining growth and aesthetic quality (4). Proper spacing enables efficient penetration of sunlight, good circulation of air and provision of necessary nutrients, thus ensuring proper growth without competition for resources (5). Spacing within urban settings not only considers the mature size of the plant but even acts as a measure for overcoming environmental challenges. Inefficient spacing, on the other hand, may lead to greater shading and increased competition for resources. A successful reconciliation of spacing and shading results in a balanced ornamental performance of plants.

Though it is a fact that the species is quite hardy and is an appropriate choice for growing as an ornamental orchid, there has been no systematic study conducted about how the combination of shade intensity and planting spacing affects its overall growth and flowering efficiency. The available studies give only generic information about adapting to shade and spacing yet fail to identify the best possible combination of *S. plicata*.

Materials and Methods

The experiment was conducted at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat-13, in the year 2024–25, which lies within the Upper Brahmaputra Valley Agro-Climatic Zone of Assam. The site is located at 26°47' N latitude, 94°12' E longitude, at an elevation of 86.8 m above mean sea level (AMSL). The topography of the land at the experimental site is uniform.

The meteorological data collected during the investigation period at the Meteorological Observatory of the Department of Agro-Meteorology, Assam Agricultural University in Jorhat is illustrated graphically in Fig. 1.

Layout and preparation of experimental plot

The experiment was laid out using a factorial randomised block design (RBD) with two factors (conditions and spacing) in nine treatment combinations as mentioned in Tables 1 and 2. The experiment consisted of 3 replications. Each experimental bed measured 2.5 m by 1.6 m and a spacing of 0.5 m was maintained between plots. Two shade net houses oriented in a North-South

Table 1. Experimental factors and their respective levels used in the factorial randomised block design (RBD)

Conditions (C)	
C ₁	0 %
C ₂	35 %
C ₃	50 %
Spacing (S)	
S ₁	60 × 45 cm
S ₂	45 × 45 cm
S ₃	45 × 30 cm

Table 2. Treatment combinations of growing conditions used in the factorial randomised block design (RBD)

Sl. No.	Notations	Treatment combinations
1.	T ₁	C ₁ S ₁
2.	T ₂	C ₁ S ₂
3.	T ₃	C ₁ S ₃
4.	T ₄	C ₂ S ₁
5.	T ₅	C ₂ S ₂
6.	T ₆	C ₂ S ₃
7.	T ₇	C ₃ S ₁
8.	T ₈	C ₃ S ₂
9.	T ₉	C ₃ S ₃

direction with a size of 14 m x 7.5 m x 3 m were constructed. The frame of the houses was constructed with bamboo and was covered with a 50 % roof screen and a 35 % roof screen of green colour to resemble shading conditions. An open field condition without any shade net was used to resemble 0 % shade. The planting materials were collected from the experimental farm, Department of Horticulture, Assam Agricultural University, Jorhat. Pseudobulb divisions of 15 cm were taken from 3-year-old mother plants and used for the study. Planting was carried out during the months of July and August. Each bed consisted of 12 plants per plot. The soil was acidic with a pH of 5.5 with texture of sandy loam. Vermicompost (100 g/plant) was applied evenly across all treatments during bed preparation to maintain uniform growing conditions. The irrigation was provided evenly at weekly intervals throughout the study. To enable accurate measurement, the chosen plants in each plot were tagged 1–5. Every parameter, from planting to flowering, was recorded at 2 month intervals and the observations were documented.

Growth and flowering characteristics of *S. plicata* were systematically recorded throughout the experiment.

Growth characters

The number of leaves per plant was counted for each sample and the average was noted. Leaf length and breadth were measured in centimetres (cm) using a scale and the mean values were calculated. Plant height was measured as the distance from the base to the tip of the longest leaf in cm, while plant spread was assessed by averaging the distances between the outermost leaves in both East-West and North-South directions.

Flower characters

The number of days from planting to bud visibility was recorded, followed by the number of days taken from bud visibility to full bloom. Blooming duration was noted from the first bloom until senescence. Stalk length was measured from the base to the tip just below the flower head in cm and flower diameter was recorded at full bloom as the average of sampled flowers. In addition, the total number of florets per inflorescence was counted at full bloom to provide a complete assessment of flowering performance.

Statistical analysis

Data on growth and flowering were statistically evaluated in factorial RBD using analysis of variance (ANOVA) in SPSS software (version 21.0.0.0 IBM® SPSS® Statistics). Analyses were performed in 3 replications and the results are represented as means. Subsequent analysis utilised these means, with treatment effects tested via *F*-test at a 5 % significance level ($p = 0.05$). Critical difference (CD) values were computed exclusively when the *F*-test indicated statistically significant differences between treatments.

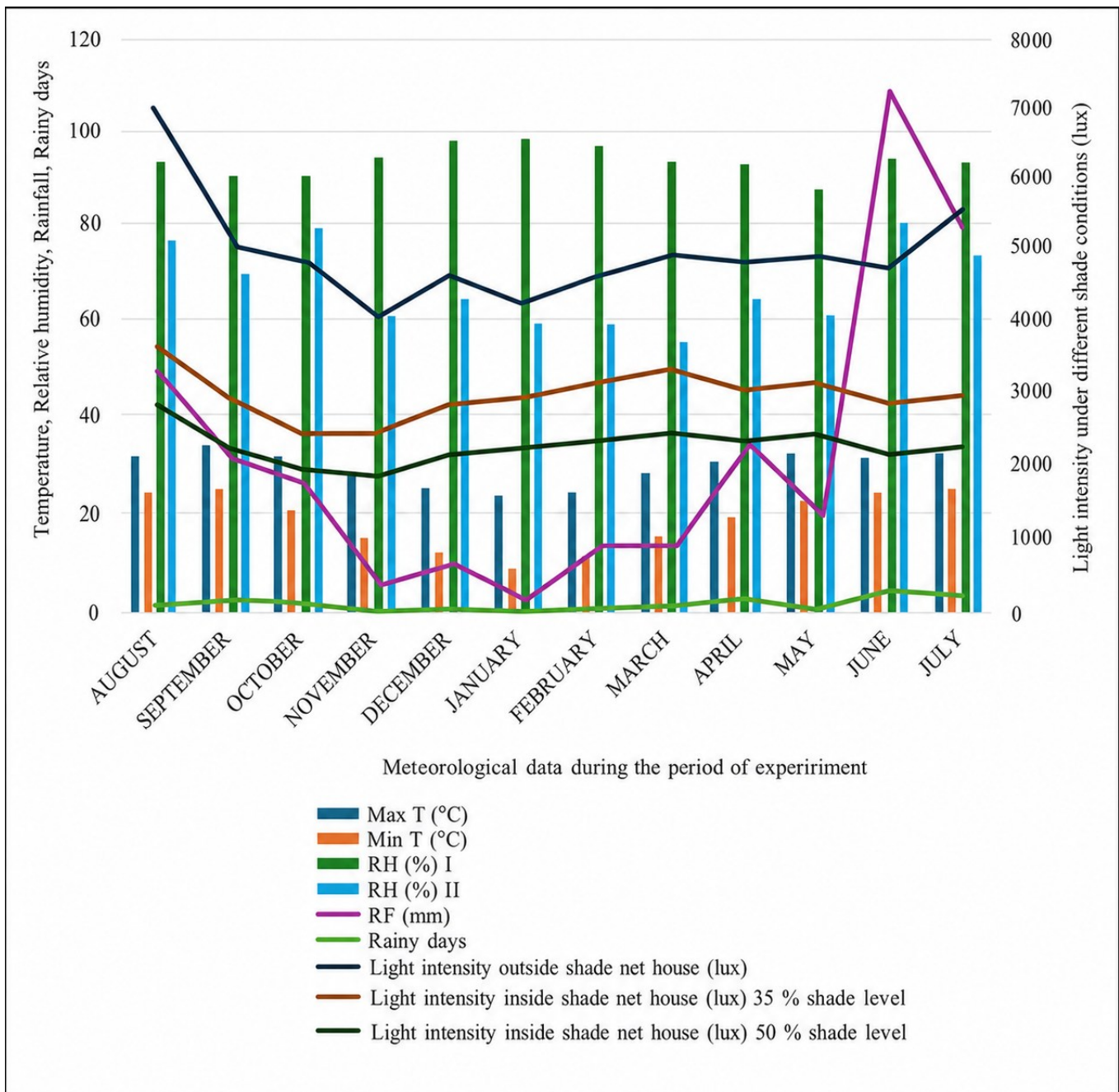


Fig. 1. Monthly meteorological data during the period of experimentation (2024–25).

Results and Discussions

Shade intensity and growth trade-offs

The study revealed contrasting growth trajectories under 35 % and 50 % shade that do not follow a simple pattern. It was observed that under 50 % shade, *S. plicata* showed a strong investment in vegetative elongation which produces the tallest plants (52.89 cm), the longest stalks (79.24 cm) as mentioned in Tables 3 and 4. This condition also showed the most elongated leaves (52.23 cm), shown in Fig. 2, but this did not result in superior ornamental quality. By contrast, plants under 35 % shade were shorter than the plants under 50 % shade but consistently produced better flowering outcomes across all recorded parameters. This pattern suggests a trade-off between vegetative elongation and reproductive performance, where deeper shade favours axial elongation while moderate shade supports more productive and ornamentally desirable flowering.

These differences in growth form are consistent with the general concept of shade-avoidance, in which plants allocate more to vertical extension under reduced light, while moderate shade can support balanced vegetative and reproductive growth. The taller plants and longer stalks recorded under 50 % shade in this study resemble responses reported in *Paonia lactiflora*, where progressively heavier shade suppressed flowering in favour of shoot extension and in other species where excessive shade has been associated with reduced floral development due to altered C allocation (6).

The results show that the growth patterns were different in plants grown in 35 and 50 % shades, which do not seem to fit into any trend. On the contrary, those grown in 35 % shades did not demonstrate significant elongation growth, but instead grew laterally, with wider leaves (5.28 cm) and bigger canopy width (51.30 cm), showing that their growth pattern was related to canopy expansion rather than elongation escape. This kind of response has been shown by plants such as rose grown under

Table 3. Leaves per plant (LP); leaf length (LL) and leaf breadth (LB) in centimetres (cm)

Treatment	60 DAP			120 DAP			180 DAP			240 DAP			300 DAP		
	LP	LL	LB	LP	LL	LB	LP	LL	LB	LP	LL	LB	LP	LL	LB
Conditions															
C ₁ (0 %)	6.17	14.67	2.76	8.47	23.04	3.12	11.02	28.80	3.62	11.60	32.52	4.04	11.97	40.53	4.37
C ₂ (35 %)	6.50	15.47	2.84	10.07	24.60	3.37	12.09	32.64	3.66	12.59	37.74	4.40	12.90	43.28	5.28
C ₃ (50 %)	6.11	17.00	2.72	9.22	26.53	3.11	10.78	36.38	3.53	10.76	41.61	4.08	11.02	52.23	4.38
SEd (±)	0.08	0.21	0.03	0.29	0.78	0.06	0.32	0.65	0.04	0.33	0.47	0.07	0.17	0.53	0.06
CD (<i>P</i> = 0.05)	0.17	0.45	0.08	0.63	1.67	0.14	0.68	1.38	0.10	0.71	1.00	0.16	0.37	1.13	0.12
Spacing															
S ₁ (60 × 45)	6.36	15.93	2.82	9.60	25.40	3.27	11.78	33.67	3.67	12.06	38.17	4.26	12.30	47.12	4.78
S ₂ (45 × 45)	5.17	15.77	2.76	9.38	24.60	3.20	11.11	32.33	3.60	11.63	37.25	4.18	11.87	44.70	4.64
S ₃ (45 × 30)	4.72	15.43	2.73	8.78	24.27	3.13	10.76	31.82	3.53	11.26	36.44	4.07	11.68	44.23	4.60
SEd (±)	0.08	0.31	0.03	0.29	0.36	0.06	0.32	0.46	0.04	0.33	0.47	0.07	0.17	0.53	0.06
CD (<i>P</i> = 0.05)	0.17	0.65	0.08	0.63	0.77	0.14	0.68	0.98	0.10	0.71	1.00	0.16	0.37	1.13	0.12
Interaction (C × S)															
Treatment combinations	60 DAP			120 DAP			180 DAP			240 DAP			300 DAP		
	LP	LL	LB	LP	LL	LB	LP	LL	LB	LP	LL	LB	LP	LL	LB
C ₁ S ₁	6.06	14.80	2.83	8.53	23.80	3.20	11.33	29.80	3.67	11.70	33.20	4.07	11.83	41.40	4.47
C ₁ S ₂	6.33	14.70	2.74	8.60	23.00	3.10	11.00	28.40	3.61	11.90	32.80	4.01	12.13	40.20	4.27
C ₁ S ₃	6.11	14.50	2.72	8.27	22.60	3.07	10.00	28.20	3.58	11.20	31.55	4.05	11.80	40.00	4.37
C ₂ S ₁	6.80	15.80	2.90	11.00	25.00	3.42	13.00	33.80	3.78	13.80	38.88	4.53	13.87	45.55	5.39
C ₂ S ₂	6.48	15.60	2.81	10.20	24.60	3.38	11.67	32.40	3.65	12.13	37.55	4.47	12.47	42.50	5.29
C ₂ S ₃	6.33	15.00	2.79	9.00	24.20	3.31	11.60	31.72	3.55	11.83	36.78	4.20	12.37	41.80	5.17
C ₃ S ₁	6.22	17.20	2.75	9.27	27.40	3.20	11.00	37.40	3.57	10.67	42.44	4.19	11.20	54.40	4.50
C ₃ S ₂	6.10	17.00	2.72	9.33	26.20	3.13	10.67	36.20	3.55	10.87	41.40	4.07	11.00	51.40	4.37
C ₃ S ₃	6.00	16.80	2.68	9.07	26.00	3.00	10.67	35.55	3.47	10.73	41.00	3.97	10.87	50.88	4.27
SEd (±)	0.17	0.36	0.06	0.51	0.63	0.11	0.55	0.80	0.08	0.58	0.73	0.13	0.30	0.93	0.10
CD (<i>P</i> = 0.05)	0.30	0.78	0.14	1.09	1.33	0.25	1.18	1.69	0.18	1.24	1.55	0.28	0.65	1.97	0.22

LP: leaves per plant; LL: leaf length; LB: leaf breadth; DAP: days after planting.

Table 4. Plant height (PH) and plant spread (PS) in centimetres (cm)

Treatment	60 DAP		120 DAP		180 DAP		240 DAP		300 DAP	
	PH	PS	PH	PS	PH	PS	PH	PS	PH	PS
Conditions										
C ₁ (0 %)	29.78	17.22	31.85	23.06	35.31	30.33	43.53	38.83	47.55	45.24
C ₂ (35 %)	17.22	18.82	33.13	26.80	34.71	34.32	43.94	43.53	50.82	51.30
C ₃ (50 %)	31.20	17.04	34.31	22.04	36.90	29.56	45.48	36.78	52.89	44.29
SEd (±)	15.39	0.12	0.14	0.17	0.30	0.12	0.63	0.20	0.51	0.27
CD (<i>P</i> = 0.05)	32.33	0.27	0.29	0.37	0.65	0.27	1.35	0.44	1.09	0.57
Spacing										
S ₁ (60 × 45)	29.78	18.27	33.87	25.20	36.97	32.67	45.79	41.11	51.77	48.49
S ₂ (45 × 45)	17.22	17.69	33.06	24.07	35.46	31.34	44.11	39.66	50.09	47.06
S ₃ (45 × 30)	31.20	17.33	32.38	22.64	34.50	30.20	43.06	38.38	49.41	45.29
SEd (±)	15.39	0.12	0.14	0.17	0.30	0.12	0.63	0.20	0.51	0.27
CD (<i>P</i> = 0.05)	32.33	0.27	0.29	0.37	0.65	0.27	1.35	0.44	1.09	0.57
Interaction (C × S)										
Treatment combinations	60 DAP		120 DAP		180 DAP		240 DAP		300 DAP	
	PH	PS	PH	PS	PH	PS	PH	PS	PH	PS
C ₁ S ₁	30.33	17.53	32.33	23.93	36.07	31.87	45.00	39.33	48.47	47.27
C ₁ S ₂	30.00	17.13	32.10	23.07	35.33	30.13	42.87	39.17	47.23	45.17
C ₁ S ₃	29.00	17.00	31.13	22.20	34.53	29.00	42.73	38.00	46.97	43.30
C ₂ S ₁	31.67	20.13	34.07	28.87	36.60	36.00	44.60	45.67	51.50	53.00
C ₂ S ₂	31.00	18.87	32.73	26.93	34.07	34.30	43.67	43.13	50.63	51.00
C ₂ S ₃	30.93	17.47	32.60	24.60	33.47	32.67	43.57	41.80	50.33	49.90
C ₃ S ₁	32.87	17.13	35.20	22.80	38.23	30.13	47.77	38.33	55.33	45.20
C ₃ S ₂	32.27	17.07	34.33	22.20	36.97	29.60	45.80	36.67	52.40	45.00
C ₃ S ₃	31.86	16.93	33.40	21.13	35.50	28.93	42.87	35.33	50.94	42.67
SEd (±)	0.31	0.22	0.24	0.30	0.53	0.22	1.10	0.36	0.89	0.47
CD (<i>P</i> = 0.05)	0.66	0.47	0.51	0.64	1.12	0.47	2.33	0.76	1.89	0.99

PH: plant height; PS: plant spread; DAP: days after planting.

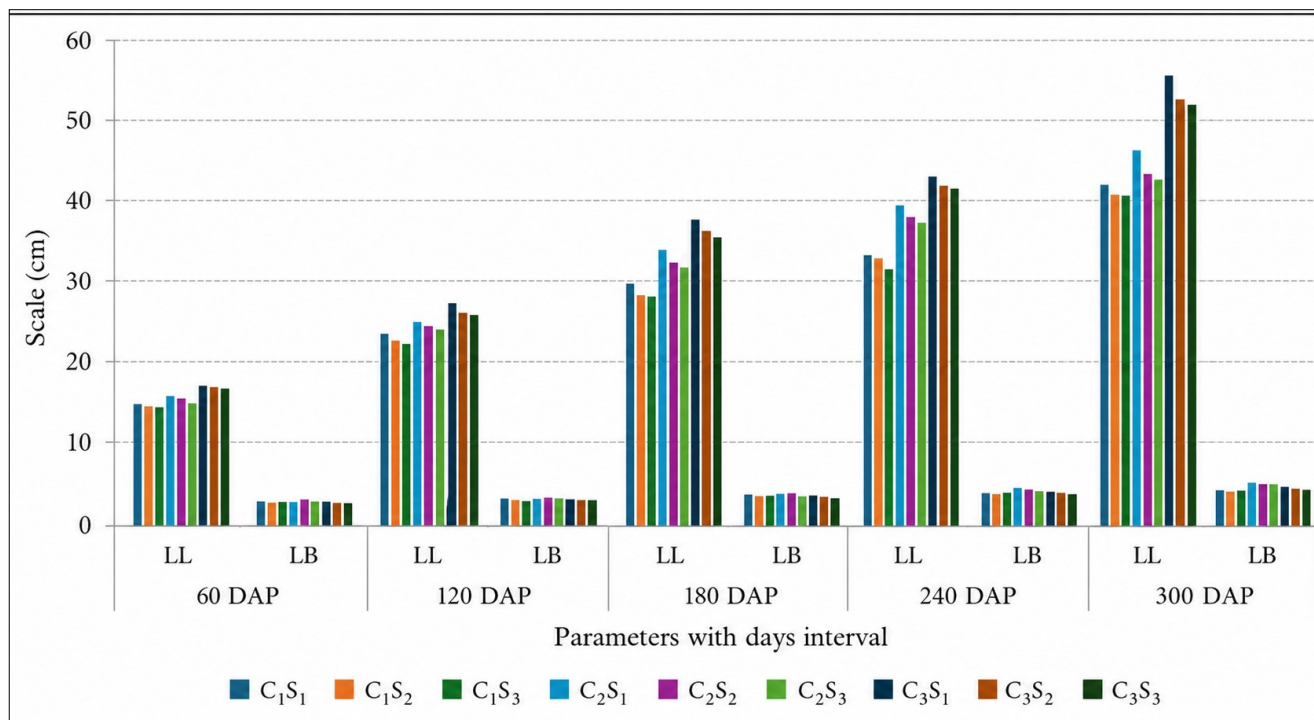


Fig. 2. Leaf length (LL) and leaf breadth (LB).

photo-selective shade nets, where better growth and longer-lasting flowers had been achieved due to moderate light intensity, supporting the conclusion that 35 % shading represented optimum growth conditions in this case (7).

Flower characters influenced by shade

The effect of interaction of shade levels and planting distances on reproduction was most important. The combination of 35 % shade and 60 × 45 cm planting distances (C₂S₁) resulted in early

appearance of flower buds (66.43 days), short time for bud to flower (31.47 days), longer period of flowering (86.33 days), higher number of florets in an inflorescence (12.64) and large size of flowers (5.43 cm) as mentioned in Tables 5 and 6. It can be deduced that the combination of moderate shade and low planting density contributed to an environment where there are efficient assimilation of C and its partitioning into reproductive tissues.

Table 5. Days taken to bud visibility, days to bloom from bud visibility and blooming duration (days)

Treatment	Days taken to bud visibility	Days taken to bloom from bud visibility	Blooming duration (from first bloom to senescence)
Conditions			
C ₁ (0 %)	71.69	40.02	80.67
C ₂ (35 %)	67.67	34.07	84.67
C ₃ (50 %)	82.17	47.81	78.33
SEd (±)	0.97	0.50	0.98
CD (P = 0.05)	2.06	1.86	2.09
Spacing (cm)			
S ₁ (60 × 45)	72.08	38.78	83.11
S ₂ (45 × 45)	73.74	40.36	82.22
S ₃ (45 × 30)	75.70	42.77	78.33
SEd (±)	0.97	0.50	0.98
CD (P = 0.05)	2.06	1.86	2.09
Interaction (C × S)			
Treatment combinations	Days taken to bud visibility	Days taken to bloom from bud visibility	Blooming duration (from first bloom to senescence)
C ₁ S ₁	70.53	38.00	81.67
C ₁ S ₂	71.87	39.60	80.67
C ₁ S ₃	72.67	42.47	79.67
C ₂ S ₁	66.43	31.47	86.33
C ₂ S ₂	67.10	34.33	85.67
C ₂ S ₃	69.47	36.40	82.00
C ₃ S ₁	79.27	46.87	81.33
C ₃ S ₂	82.27	47.13	80.33
C ₃ S ₃	84.97	49.43	73.33
SEd (±)	1.68	0.87	1.71
CD (P = 0.05)	3.5	1.86	3.63

Table 6. Stalk length (cm), flower diameter (cm) and number of florets per inflorescence

Treatment	Stalk length (cm)	Flower diameter (cm)	Number of florets per inflorescence
Conditions			
C ₁ (0 %)	67.30	4.15	9.97
C ₂ (35 %)	76.20	4.95	11.06
C ₃ (50 %)	79.24	3.99	8.74
SEd (±)	2.74	0.25	0.18
CD (P=0.05)	5.82	0.54	0.39
Spacing (cm)			
S ₁ (60 × 45)	76.70	4.64	10.77
S ₂ (45 × 45)	76.06	4.47	9.69
S ₃ (45 × 30)	69.99	3.98	9.31
SEd (±)	2.74	0.25	0.18
CD (P=0.05)	5.82	0.54	0.39
Interaction (C × S)			
Treatment combinations	Stalk length (cm)	Flower diameter (cm)	Number of florets per inflorescence
C ₁ S ₁	64.08	4.23	10.68
C ₁ S ₂	76.15	4.28	9.73
C ₁ S ₃	61.68	3.93	9.50
C ₂ S ₁	79.94	5.43	12.64
C ₂ S ₂	74.34	5.21	10.47
C ₂ S ₃	74.32	4.19	10.07
C ₃ S ₁	86.07	4.23	9.00
C ₃ S ₂	77.68	3.91	8.87
C ₃ S ₃	73.97	3.80	8.37
SEd (±)	4.75	0.44	0.32
CD (P=0.05)	10.08	0.93	0.68

Under 35 % shade, light was reduced but not to the extent that it impaired flowering, while wider spacing reduced competition for resources, together supporting earlier flowering and improved flower size. Although specific physiological mechanisms such as changes in spectral quality, hormone regulation or photorespiration were not measured, the present results are consistent with reports that intermediate shading and adequate plant spacing can advance flowering, increase floret number and extend the blooming period in several ornamental species (8). Within these limitations, the combination of 35 % shade and 60 × 45 cm spacing can be recommended as an ornamentally favourable regime for *S. plicata* under the conditions of this study.

Effect of plant spacing on resource competition and growth

Plant spacing exerted a clear and complementary influence on growth and flowering, with the widest spacing (60 × 45 cm) consistently outperforming narrower arrangements. The highest values for leaf number (12.30) as mentioned in Fig. 3, plant spread (48.49 cm), bud visibility (72.08 days) and flower quality at this spacing underline the role of reduced intraspecific competition in enhancing individual plant performance, even under favourable light conditions (9). At lower planting densities, each plant has access to a larger soil volume and greater shared light environment, which together support more robust vegetative and reproductive growth (10).

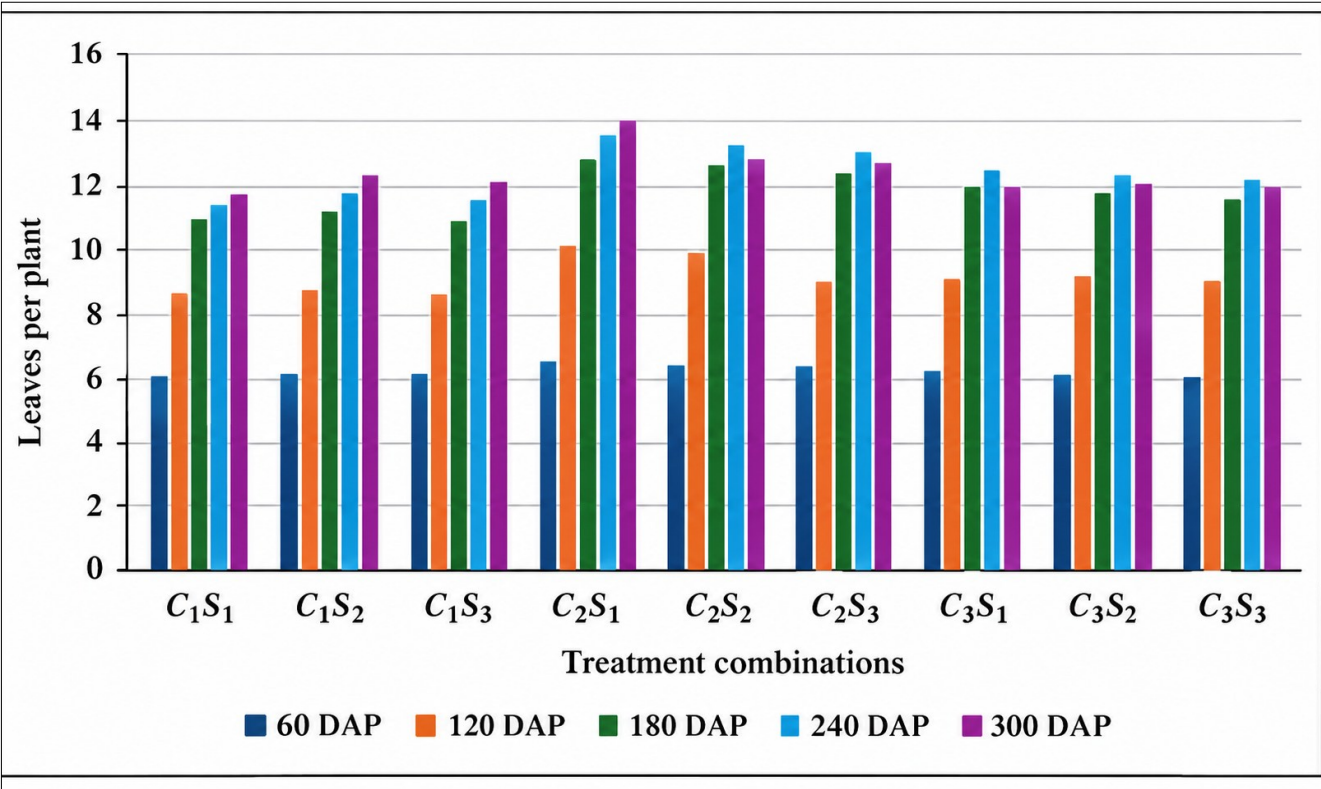


Fig. 3. Leaves per plant (LP).

The findings are consistent with earlier studies conducted on other ornamental monocots. In gladiolus, wider planting distance considerably enhanced growth of corms and inflorescences (11), while in tuberose, lowering of plant density resulted in improved vegetative growth and cut-flower yield (12).

Studies in China aster and marigold likewise report improved plant architecture and flower size at lower densities, illustrating the general principle that increased spacing tends to reduce competition and improve individual reproductive output (13). In ornamental sunflower, optimum plant density was shown to maximise floret size through improved light interception per plant (14); a similar mechanism is consistent with the larger flower diameter (4.64 cm) observed at 60 × 45 cm spacing in the present study.

Wider spacing in this experiment also likely improved air movement around the canopy, which has practical implications for microclimate and plant health, although these variables were not directly measured. Improved airflow is generally associated with reduced humidity and a lower incidence of microclimatic stress, conditions that may favour more rapid and uniform floral development (15). The shorter bud visibility to bloom interval (38.78 days) at the widest spacing therefore appears to be associated with a more favourable physical environment around developing inflorescences, in addition to the benefits of reduced competition for water, nutrients and light (16).

Integrating the findings

The results showed that *S. plicata* distributed its resources under different growing conditions. When shade is too deep, the plant responds by growing taller and extending its leaves, but that comes at the expense of flowering. When grown in full sun, heat and stress suppress reproductive development from the other direction. At 35 % shade, neither extreme applies, the plant receives enough light to photosynthesise productively while being shielded from the most damaging aspects of direct solar radiation and there is no strong signal to elongate. Adding wider spacing to this setting makes the situations become even more favourable. Under these combined conditions, plants at C₂S₁ channelled more of their fixed C into flowers rather than stems and leaves, an outcome that reflects findings in other herbaceous ornamentals where moderate shade and reduced competition together enhanced reproductive output.

Conclusion

Clearly, shade and distance have an important role to play for *Spathoglottis plicata*, not only for the growth pattern but also when it comes to appearance and performance within landscapes. According to the data collected, the 35 % shade at a distance of 60 × 45 cm had produced the best overall outcomes, where healthy and well-developed leaves together with plentiful blooms could be observed throughout the period of observation. For tropical growers and gardeners, this information would be very easy to implement in practice since it is based on consistent evidence obtained regarding all traits evaluated within the framework of this research project. There is one forewarning here since all this information was obtained within the scope of a 1-year experiment. Plant responses can shift with seasonal weather patterns and what holds true in one season does not always repeat in the next. Running similar trials across multiple seasons

would go a long way toward confirming how reliably *S. plicata* responds to these conditions and whether the recommended treatment holds up over time.

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Authors' contributions

NB conducted the experiment, performed formal data collection and prepared the initial draft of the manuscript. TS conducted the plagiarism verification and refinement of the final manuscript. TT conducted the statistical analysis. KT participated in study design and coordination efforts. EL was involved in manuscript writing. SS conceptualised and managed the research and provided overall supervision. KD offered critical guidance and oversight during the experimental phase. SD helped in manuscript editing. RMP and MHM provided help in collection of data throughout the research process. All authors reviewed and approved the final version of the manuscript.

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