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Cocopeat-amended leaf mould compost yields quality potted dahlia specimens under shade net intercepting one-third sunlight

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Abstract: Growers in tropical and subtropical climates with higher afternoon solar intensities face challenges while cultivating potted dahlias. Dahlias that are cultivated in pots with limited capacity lose a great deal of their quality when it gets hot outside. Heat waves that occur suddenly damage dahlia plants' appearance by exposing dry petal margins and marginal leaf blistering. Despite these difficulties, no research has been done to yet to advise growers on the best organic growth medium for dahlias that can maintain high-quality flower production in an appropriate shadow regime. The dahlia cv. Babylon lila rooted cuttings were transplanted into five-gallon (18.92-liter) earthen pots that were filled with six distinct organic growing media formulations. According to our research, dahlia plants grown in a medium containing soil, leaf mould, and cocopeat (50:25:25 v/v) not only produced healthy tubers but also showed better vegetative growth and flowering characteristics. In order to produce higher-quality potted dahlia specimens in hot weather, the study especially advises growing dahlia under shade nets that intercept at least one-third of the incoming solar radiation in areas receiving scorching afternoon sun rays.

1. Introduction

Dahlia variabilis (Desf.), a member of the 'Asteraceae family, is a popular tuberous-rooted flower native to Mexico and parts of Central and South America (Dalda Sekere and Gülşen, 2016). People prize Dahlia flowers for their exquisite blooms, which display a variety of inflorescence styles and blossom colours (Evans, 1998; McClaren, 2004; Romer, 2008). Dahlia is commercially grown in Australia, France, Germany, Italy, Japan, Mexico, New Zealand, South Africa, the United States, and The Netherlands (Marina, 2015). Every year, the Dutch dahlia producers host the "Holland Dahlia Event" throughout the country to showcase the wide variety of flowers and export about 50 million dahlia tubers annually. Dahlia cultivation for the domestic flower market in India is restricted to

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the plains of the northwestern and central areas (De and Bhattacharjee, 2011; Bhattacharjee *et al*., 2019). The dahlia prefers temperatures between 18 to 23°C, relative humidity between 75% to 78% and well-drained, medium fertility sandy loam soils rich in organic matter with a pH range between 6.0 to 8.0 for their successful growth and reproductive development (De Hertogh and Le Nard, 1992; Marina, 2015). Dahlia cultivation in pots and as bedding has grown in popularity recently to beautify community parks and residential gardens (Yazici and Gunes, 2018). In addition to conventional field cultural practices, the capacity of potted dahlia to sustain growth and flower production is largely dependent on the growing media (GM) composition and the amount of sunlight received. The physical and chemical characteristics of the GM ingredients are essential for creating a favorable root zone environment that supports plant growth in a finite volume of pot.

The physical and chemical characteristics of GM have a substantial impact on the ability to retain water, provide aeration, and maintain nutritional status in a finite pot volume (Younis *et al*., 2014). Furthermore, throughout a plant's life cycle, the amount of light it receives influences its growth, development, and other physiological processes. The quality and intensity of light influence leaf expansion, stem length, branching patterns, flowering, and tuberization in dahlia, besides shaping the overall architecture of the plant (Hamrick, 2003). An adequate light intensity induces transition from vegetative to flowering phase and thereafter influences the presentable life of flowers with varying hues of colour (Paik and Huq, 2019).

Growers in tropical and subtropical regions face certain challenges in cultivating potted dahlias because of the higher light intensities (above 70,000 Lux) under open field conditions. Particularly during the afternoon, dahlia leaves exhibit scorching, fading of flower and leaf colour, and may often reveal temporary wilting of plants when exposed to sun for an extended time period. In subtropical locales, high air temperatures (exceeding 40^{o}C) coinciding with heat wave events throughout summers are prevalent. Because of the much lower humidity levels (less than 40%), these hot and dry weather conditions scorch dahlia leaf margins and attract thrips and mite attack. Although dahlias require full sunlight, they also benefit from moderate shade, provided by shade nets that block heat waves, particularly during the afternoon (Menzel, 2016).

The vegetative growth, reproductive development, and tuber production of dahlia are significantly influenced by edaphic factors, including the texture and structure of GM, nutrient composition, water retention capacity, total porosity, and air-filled porosity of medium in a finite pot volume (Reddy *et al.*, 2023). The purpose of this study is to examine how different levels of shade affect *Dahlia x hybrida* growth, flowering, and tuber formation in relation to different GM formulations. To date, there is no scientific research that supports the aforementioned claim.

Therefore, our study hypothesis suggests that growing potted dahlia in GM amended with organic manures will impact the plant's development, flowering, and ability to produce tubers at different shade levels. With this research, we hope to provide valuable insights and practical recommendations for improving potted dahlia cultivation in regions receiving higher sunlight intensity, inducing leaf scorching, especially during afternoon hours.

2. Materials and Methods

Experimental site

The experiment was carried out in the Punjab State in northwest India in the city of Ludhiana (30°45' N, 75°40' E). The city has a uniform topography, is 247 meters above sea level, and has sandy loam soil with a pH of 7.80. The city receives a mean annual rainfall of 640 mm, with sub-tropical exhibiting distinct seasonal variations throughout the year. It is divided into five distinct seasons: hot and dry summer (April to June), hot and humid monsoon (July to September), autumn (October), and winter (November to January). The distribution of the precipitation is irregular, with July through September accounting for around 70-80% of the total. The meteorological information, including air temperature, relative humidity, and light intensity during the period of study, has been provided in figure 1.

Treatment details

The terminal softwood cuttings of the *Dahlia x hybrida* 'Babylon lila' were derived from mother stock plants. The tubers that were planted on nursery beds on October 1, 2022, were used to raise the stock plants at the research farm of the department of Floriculture and Landscaping at Punjab Agricultural University, Ludhiana, Punjab, (India). The variety is

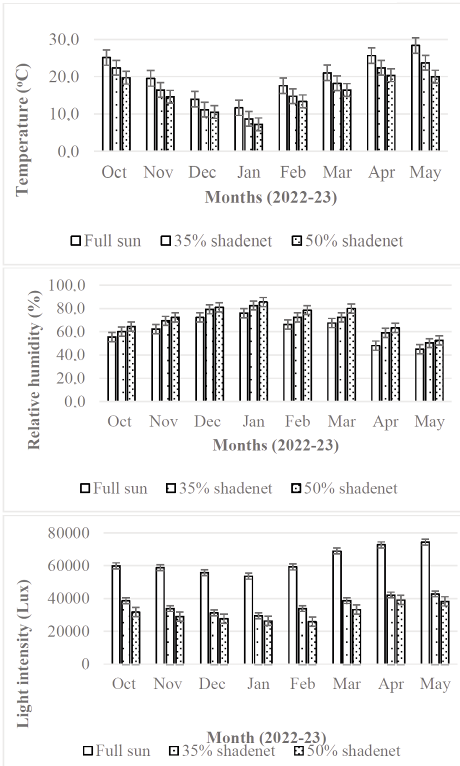

Fig. 1 - Meteorological data of air temperature (degree Celsius, °C), relative humidity (%) and light intensity, Lux) during the period of study (October 2022 to May 2023).

characterized by informal decorative inflorescence of purple colored ray florets. The cuttings were planted on raised nursery beds comprising sandy loam soil on October 22, 2022. The basal portion of cuttings was given a quick dip (5 sec) in 1500 mg L^{-1} IBA (powder initially dissolved in 20 ml of 70% ethanol). Thereafter, the cuttings were gently inserted for rooting on raised nursery beds composed of sandy loam soil. The cuttings were placed in sand beds for 35 days, during which time they grew roots and were subsequently transferred as a single rooted plant.

The rooted cuttings were transplanted in 5 gallon (18.92 litres) earthen pots filled with six different GM formulations with ingredients mixed in volumetric proportions. Soil, well-rotted farmyard manure (FYM), leaf mold (LM), and cocopeat (CP) were the main components of GM. The different ingredients of these media mixtures consisted of GM1 - Soil: FYM: CP (75:25:0) control; GM 2 - Soil: FYM: CP (50:25:25); GM 3 - Soil: 103 FYM: CP (25:25:50); GM 4 - Soil: LM: CP (75:25:0); GM 5 - Soil: LM: CP (50:25:25); and GM 6 - 104 Soil: LM: CP (25:25:50). The GM were filled by carefully tapping the pots to ensure consistent compaction levels. To ensure the establishment of young, tender cuttings, the potted dahlia plants were first kept in partial shade for 20 days. After that, they were exposed to morning sunlight (until 12:00 pm) for an additional 20 days before being placed under two separate green shade nets of 35% (S2) and 50% (S3) light transmittance with varying densities of mesh size (9 pores per square inch and 60 pores per square inch, respectively). The pore size of 35% shade net measured 5 mm x 7 mm, and for 50% shade net it was 4 mm x 2 mm. Until the completion of the trial, the potted dahlia in the control treatment was kept in full sunshine (S1, 0% shade).

Experimental design and statistical analysis

Using a factorial completely randomized design, a total of three pots per three replications were positioned in each of the treatments, for a total of nine pots per treatment. Two fixed factors comprising factor A, shade levels (3 levels), and factor B, growing media (6 levels), were assessed for their effects on vegetative growth, reproductive development, and tuber production in potted dahlia. Observational data were subjected to a two-way analysis of variance (ANOVA) in SPSS IBM statistical software (Version 26) to examine treatment effects through the general linear model (GLM) approach. Tukey's confidence intervals were used to determine the significance of mean differences at the $p \leq 0.05$ level of significance (Table S1).

Cultural practices

Fermented mustard cake was used as fertilizer for the potted dahlia plants in each treatment. An organic fertilizer, mustard cake contains essential plant micronutrients (zinc, calcium, sulphur, magnesium, manganese, iron, and copper) and nitrogen, phosphorus, and potassium in a 4-1-1 ratio. In an earthen pitcher, one kilogram of mustard cake was diluted with 10 liters of water. Using a wooden stick, the mixture was stirred once a day for up to 20 days, making sure the cake was properly dissolved into the slurry until the characteristic odor emanated, which indicated completion of fermentation, which took 21 days. This fermented mustard cake slurry was given as a soil drench by diluting in water (1:10 v/v), every two weeks, beginning one month after planting and continuing until the emergence of flower buds. No additional supply of inorganic fertilizers was made during the plant growth. The potted dahlias were maintained following necessary cultural practices (staking, removal of dead or dried leaves, spent flowers, and disbudding).

Measurements

During the vegetative phase, 110 days after transplanting, before bud initiation, observations were made on vegetative characters such as height (cm), stem internodal length (INL, mm), stem girth (S_G, mm), and stem length (SL, cm); leaf characters, such as leaf length (L_L, cm), leaf width (L_W, cm), number of leaf pairs (NoLP), leaf area (LA, cm^2), leaf dry weight (L_{DW}), and specific leaf area (SLA, cm^{-2} g^{-1} DM), computed as the ratio of LA to L_{DW}. The following flowering traits were also noted during the harvesting process: flower diameter (FD, cm), flower fresh weight (FFW, g), days to full bloom (DtFB), duration of flowering (DoF), number of tubers per plant (NoT), and tuber weight (Tw, g).

Physical parameters such as bulk density (g cm^{-3}), water holding capacity (%), total porosity (%), and air-filled porosity (%) were also analyzed for various GM using standard laboratory protocols. Chemical properties such as pH, EC, per cent nitrogen (N), per cent phosphorus (P), per cent potasssium (K), and per cent organic carbon (OC) were also examined (Table 1). The soil core method (Blake and Hartge 1986) was used to calculate the bulk density (Db, Mg m^{-3}). The water holding capacity (WHC) of the air-dried media samples was specifically determined using Keen's box, which had a perforated bottom, a filter paper disc fixed with a steel ring at the bottom end. The following formula was used to calculate the overall porosity:

$$\% f = (1- Db/Dp) \times 100$$

Where 'f' is total porosity (%), Db and Dp are bulk density and particle density (Mg m^{-3}).

The air-filled porosity (fa) was determined at container capacity moisture content as per the following equation:

$$fa = (f-\theta)$$

where 'f' is the total porosity (%) and θ is the volumetric moisture content at field capacity (%). The pH was determined in suspension by mixing 10 g of GM with 50 ml of distilled water. The EC was measured in the same suspension after 24 h in the supernatant solution. The estimation of N was determined by the alkaline potassium permanganate ($KMNO_4$) method described by Subbiah and Asija (1956). The available P was determined on a spectrophotometer at 760 µm wavelength after shaking the media with extractant and filtering the suspension. The K in the media was determined after digestion of the media mixture and filtering the suspension for recording readings on a flame photometer at 420 µm. The determination of OC was made with the standard procedure (Nelson and Sommers, 1982).

3. Results

Vegetative characteristics

With the exception of the number of leaf pairs, different GM had a substantial impact on the mean values for vegetative and leaf attributes of dahlia. When compared to the control group (GM1), the mean height of plants grown in LM-based media containing 25% CP (GM5) was 17.2% higher and substantially different. But in FYM-based formulations (GM2 and GM3) amended with 25% and 50% CP, as well as in LM-based media with 50% CP (GM6), no dis-

Table 1 - Physico-chemical properties* of different growing media mixtures used for potted dahlia production

Growing media (GM)	Physical properties				Chemical properties					
	Bulk density (g cm^{-3})	Water holding capacity (%)	Total porosity (%)	Air filled porosity (%)	pH	EC (ds m^{-1})	N (%)	P (%)	K (%)	OC (%)
GM1	1.10	46.81	47.2	22.3	7.38	0.12	0.51	0.19	1.61	0.58
GM 2	0.96	77.27	52.5	24.5	7.04	0.25	0.47	0.24	3.02	0.69
GM 3	0.44	115.31	62.1	30.4	6.75	0.37	0.42	0.37	3.54	0.78
GM 4	1.23	43.00	51.3	24.6	7.93	0.11	0.71	0.27	1.70	0.44
GM 5	1.14	58.83	59.4	28.7	7.48	0.38	0.42	0.34	3.17	0.59
GM 6	0.63	104.40	64.2	38.5	7.20	0.58	0.35	0.45	3.75	0.81

* Representative GM samples were estimated prior to the start of the experiment. GM1 - Soil: FYM: CP (75:25:0) control; GM 2 - Soil: FYM: CP (50:25:25); GM 3 - Soil: FYM: CP (25:25:50); GM 4 - Soil: leaf mould: CP (75:25:0); GM 5 - Soil: leaf mould: CP (50:25:25); GM 6 - Soil: leaf mould: CP (25:25:50).

cernible variation in height was seen (Table 2). The mean height of dahlia plants grown under different shade levels showed a statistically significant difference (Fig. 2). Growing under 50% shade produced plants that were 1.6 times taller than those exposed to full sun (0% shade) and growing in 35% shade produced plants that were 28.1% taller. The maximum stem INL was recorded in plants grown in LM-based media (GM6), with a significantly higher (15.1%) mean INL compared to the control (GM1). These differences in stem INL were particularly pronounced in plants grown under shaded conditions.

When plants were cultivated under 50% shade, their maximum mean stem INL was observed to be 2.7 times longer than when plants were grown under controlled conditions (S1). On the other hand, compared to plants grown under control, plants exposed to 35% shade showed a smaller (1.71 times) increase in INL compared to the plants that were cultivated under 50% shade, revealing a higher (2.7 times) increment in stem INL relative to the plants under full sun (S1). The maximum S_G in LM-based GM amended with 50% CP was reported, and this was considerably different from the S_G (which was measured to be 27.5% wider) in plants grown in GM1 (control). There were no appreciable changes in the S_G measured in any FYM-based GM when compared to control. Significant variations in mean S_G were also observed in dahlia plants subjected to different levels of shade. The plants exposed to 50% and 35% shade showed a greater increase (39.1% and 21.5%, respectively) in S_G, in comparison to plants exposed to full sun (control). The variation in mean SL varied from 6.76-7.26, which was determined to be non-significant. Following increased plant exposure to shade, the SL rose linearly. In comparison, the percentage increase in S_L for plants grown in 50% and 35% shade was 28.2% and 33.8%, respectively, compared to those plants that were exposed to full sun.

Leaf characteristics

In comparison to the plants grown in FYM and LM-based media mixtures, the mean L_L in media devoid of CP was found to be lower (Table 2).

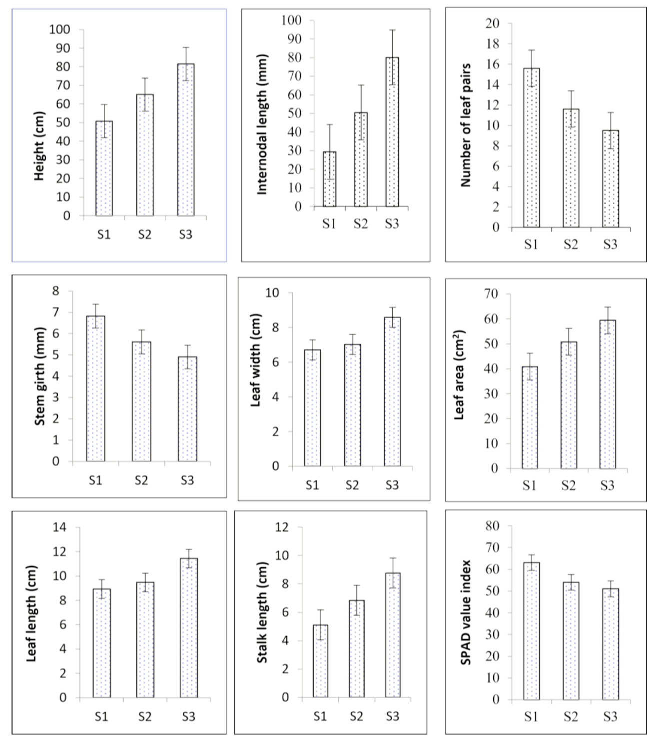

Fig. 2 - Effect of varying shade levels on vegetative growth parameters of potted dahlia. Values represent mean values (n=9) ± SEM for different observations. Letters above

Table 2 - Effect of growing media on vegetative and leaf characteristics of dahlia raised in earthen pots for the period 16 November 2022 to 10 May 2023

Growing media	Vegetative characteristics				Leaf characteristics					
	Height	INL (mm)	SG (mm)	SL (cm)	LL (cm)	LW (cm)	LP (No.)	LA (cm^2)	LDW (g)	SLA (cm^{-1} g^{-1} DM)
GM1	59.78 a	48.78 a	5.16 a	6.44 c	9.61 a	7.1 a	10.74	47.4 a	0.080 a	584.32 ab
GM 2	65.70 ab	52.40 b	5.49 a	6.86 ab	10.31 b	7.6 ab	12.28	48.1 ab	0.084 ab	569.25 a
GM 3	70.09 b	55.24 c	5.73 ab	6.90 ab	10.10 ab	7.4 ab	12.52	51.6 bc	0.086 bc	596.29 ab
GM 4	61.47 a	52.34 b	5.43 a	6.76 ab	9.51 a	7.2 ab	12.89	46.3 a	0.082 ab	560.13 a
GM 5	69.12 b	54.82 bc	6.26 cd	7.26 a	10.10 ab	7.6 ab	12.59	54.5 c	0.081 ab	668.05 c
GM 6	68.62 b	56.18 c	6.58 d	7.23 a	10.03 ab	7.8 b	12.48	54.2 c	0.088 c	615.33 b

INL-stem internodal length; SG-stem girth; SL-stem length; LL- leaf length; LW- leaf width; NoLP-number of leaf pairs; LA-leaf area, LDW-leaf dry weight; SLA- specific leaf area; Mean values are representative of observations obtained from nine pots from each of the treatment. Values followed by different letters differ significantly within different growing media treatments, computed following Tukey's mean separation test at p = 0.05 level of significance.

Significant differences in L_L were seen between the various shade levels, and these differences grew as shade exposure increased while the percentage increment differed from the control. In comparison to plants grown in full sun, the mean L_L of plants exposed to 35% and 50% shade levels showed an increase of 6% and 28.1%, respectively, suggesting a higher degree of variability in L_L in plants exposed to higher shade levels. When comparing the maximum mean L_W of plants produced in LM-based media formulation modified with 50% CP to the mean L_W of plants raised in control, a statistically significant difference was observed, indicating a 9.8% increase in L_W. When compared to plants grown in full sun, the mean LW of plants exposed to 50% shade levels showed a 27.8% increase; however, the change was not determined to be significant for plants raised under 35% shade.

The research showed that dahlia exposed to 50% shade had a decreased NoLP count. There was a drop in the NoLP, with plants exposed to 50% shade showing a larger percentage decline (38.7%) than plants that were exposed to 35% shade (25.6%). Dahlia plants cultivated in various GM showed substantial variance in LA, with the highest value found in plants grown in LM-based media modified with 25% CP, which differed significantly from the control, which showed a drop (13.0%) in LA. Dahlia plants exposed to varying degrees of shade showed a substantial variance in LA, which rose linearly with higher exposure. In comparison to plants exposed to 35% shade, which reported an increase of 24.4%, plants exposed to 50% shade showed a higher percentage increment (45.5%) in LA, relative to those exposed to full light. Potted dahlia plants grown in GM amended with 50% CP had the highest LDW (0.088 g), which was significantly different from the LDW of plants exposed to full sun. Statistically significant variations were also indicated by the SLA. A notably elevated average SLA was recorded for the potted dahlia grown in the GM supplemented with LM and CP (25% v/v), with an increment of 14.3% over the SLA measured in control. The plants exposed to 35% and 50% shade displayed an identical LDW but had a substantial increment over control. Compared to plants exposed to full light, the SLA rose in the plants exposed to higher shade levels, increasing by 19.4% and 36.9%, respectively, under 35% and 50% shade.

Flowering characteristics

The DtFBA ranged between 113.8 and 137.2 days. In contrast to plants grown in control, those raised in LM-based GM amended with 50% CP initiated their first bud considerably earlier (24 days) (Table 3). The variation in DtFBA in plants raised in LM-based GM amended with 25% and 50% CP was found to be non-significant. When compared to plants grown in media altered with CP, the plants cultivated in FYM and LM-based GM without CP as an amendment showed a noticeably slower commencement of first bud. The initial bud's emergence was significantly impacted by varying shade levels (Fig. 3). The plants exposed to 50% shade showed a comparatively early (15 days) mean DtFBA. However, the variation was found non-significant in plants that were exposed to sun and at 35% shade.

Table 3 - Effect of growing media on flowering and tuber characteristics of dahlia plants raised in earthen pots for the period 16 November 2022 to 10 May 2023

Growing media	Flowering characteristics					Tuber characteristics*	
	DtBA	DtFBS	DoF	FD	FFW (g)	NoT	TW (g)
GM1	137.22 d	150.89 a	12.16	12.81 a	22.57 a	2.89 b	35.43 b
GM 2	132.44 c	145.33 c	11.62	12.92 a	25.45 c	5.23 a	61.98 a
GM 3	122.56 b	132.33 d	11.81	14.17 bc	25.22 bc	5.42 ab	56.99 a
GM 4	136.67 d	149.22 b	12.39	13.59 ab	23.97 b	4.10 ab	55.14 a
GM 5	115.11 a	125.56 f	11.92	13.98 bc	25.20 bc	5.11 ab	62.93 a
GM 6	113.89 a	123.11 e	11.58	14.50 c	25.39 c	5.08 ab	67.97 a

DtFBA-days to first bud appearance; DtFB- days to full bloom; DoF- duration of flowering; FD-Flower diameter; FFW- flower fresh weight; NoT- number of tubers per plant; Tw- tuber weight; Mean values are representative of observations obtained from nine pots from each of the treatment; *Obtained at the end of the experiment; NoT represents count for healthy intact tubers within a clump without separation; Tw comprises weight of whole clump; Values followed by different letters differ significantly within different growing media treatments, computed following Tukey's mean separation test at p = 0.05 level of significance.

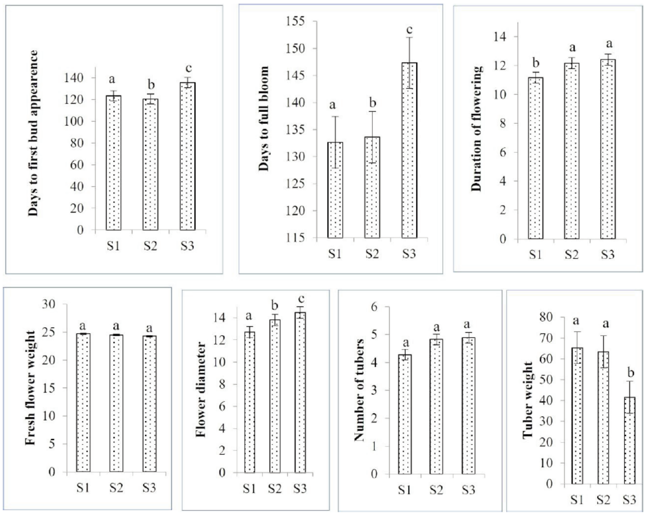

Fig. 3 - Column graphs representing the effect of varying shade levels on flowering and tuber parameters of potted dahlia. Values represent mean values (n=9) ± SEM for different observations. Letters above the error bars represent significant differences computed at P<0.05 following the Tukey's mean separation test. S1: Full sun; S2: 35% shade; S3: 50% shade.

Significant differences were reported in DtFB across plants grown in various media, with LM-based GM supplemented with 25% and 50% CP showing earlier blooming. The plants raised in FYM-based media initiated relatively earlier blooming compared to plants cultivated in control conditions. The DtFBA showed that plants exposed to full light bloomed about two weeks earlier than plants placed under 50% shade. Plants grown in various GM combinations showed a DoF ranging from 11.58 to 12.39 days; nevertheless, the observed variance was deemed non-significant. When placed under varying shade levels, the plants showed noticeably longer DoF than when they were left in full sunlight.

It was discovered that the difference in mean FD across plants grown in various GM was statistically significant. The data showed that, in comparison to the control group, which measured the least diameter, plants grown in CP amended media had a larger FD. The highest diameter of blooms was observed in plants grown in LM-based media supplemented with 50% CP, which showed a 13.1% increase in FD over control.

The amount of shade that plants received also had a substantial impact on FD, which was more pronounced in plants subjected to more intense shadow. When comparing the FD in plants exposed to 50% and 35% shade levels, the diameter of blooms was found to be 13.8% and 8.5%, respectively, larger relative to the control. The difference in FFW between plants grown in different GM was found to be significant, with plants raised in GM altered with CP having a comparatively greater FFW weighed in comparison to those lacking CP. While LM-based media amended with 25% and 50% CP showed non-significant changes, a higher mean FFW was discovered in FYM-based GM amended with 50% CP, which varied substantially from control. The FFW, which ranged from 24.5 to 24.7 g, did not exhibit any significant difference when the shade levels were changed.

Tuber characteristics

When compared to plants grown under control circumstances, there were notable changes in the average NoT per clump. The NoT per clump was nearly two times (1.88) higher in FYM-based media amended with 25% CP (Table 3). Comparing GM2 to other FYM and LM-based media, it was discovered that the NoT per clump obtained in media GM2 was statistically non-significant. The NoT per clump did not significantly differ amongst plants subjected to varying degrees of shade. When compared to tubers collected from plants grown in full sun, the tubers grown in LM-based media supplemented with 50% CP weighed almost twice as much (1.91). While the differences in TW between tubers collected from FYM and LM-based medium were not statistically significant, they were found significant when compared to the control group. When tubers collected from plants exposed to 50% shade were compared to tubers harvested from plants exposed to full sun, the TW reduced to 36.4%. Nevertheless, it was shown that the difference in TW between plants exposed to full light and 35% shade was not statistically significant.

4. Discussion and Conclusions

According to our research, planting dahlias under a green shade net that blocks off 35% of the sun's incoming radiation promotes better-quality flowers and healthier tubers. While dahlia plants need full sun during their growth, these guidelines are appropriate for temperate zones; they do not apply to tropical and subtropical regions that receive higher intensity of sunlight. Dahlias require shade from the afternoon sun, which can scorch their leaves and cause earlier fading of flowers. While beige or sandstone-colored nets work just as well in blocking out 35% of the sun (Menzel, 2016), the potted dahlia in our study were housed under green shade nets with varied densities of woven nylon. In comparison to plants grown in full sun, those exposed to shade seemed taller. Similar results were found when dahlias were grown under shade nets that captured 35% of the sun's incoming light. These plants typically exhibit a higher level of apical dominance as a means of adaptation for absorbing low light (Yazici and Gunes, 2018)

When plants are subjected to shade, their stem INL increases, which suggests a phototropic reaction to capture available sunlight at higher strata. In addition, plants often exhibit specific structural alterations in their leaves (such as enlarged LL and LW) to optimize leaf surface area and capture enough light for photosynthesis. The outcomes are consistent with several studies that were subjected to partially shaded conditions, including Wang *et al.*, 2009 (in Chrysanthemum); Hlatshwayo and Wahome, 2010 (in Carnation); Mapes and Xu, 2014 (in Salvia). In comparison to the plants cultivated in full sunlight, the damask rose (*Rosa damascena* Mill.) plants planted in 50% shade grew substantially taller and had fewer branches overall (Thakur *et al*., 2019).

A certain light intensity is necessary for plant growth; too much or too little light will damage photosystems and decrease photosynthetic efficiency (Devlin *et al*., 2007). In addition to filtering light, shade nets also regulate the microclimate that surrounds plants (Zhao *et al*., 2012). According to Mathur *et al*. (2018), plants grown in low-light conditions tend to devote more of their energy to vegetative growth for longer periods of time. Other studies also show that shade inhibits the onset of the reproductive phase transition in *Antirrhinum majus*, Lisianthus, and other bedding plants (Faust *et al*., 2005; Lugassi-Ben-Hamo *et al*., 2010).

According to Munir *et al.* (2004), plants exposed to shade exhibited higher fresh and dry biomass weight above ground. However, our research showed that when plants were exposed to a higher shade level, the fresh weight of the tubers decreased. This may be explained by the quantitative effects of light on the growth of tuberous roots (Salisbury and Ross, 1991). The findings are consistent with those of Schulz *et al.* (2019) and Clark and Burge (1999), who reported a decrease in tuber weight in potatoes due to self-shading by leaves as a result of increasing planting density. Because some species are photoperiodically sensitive, the effects of light intensity on blooming are greater in the early phases of development (Adams, 1999).

It was observed that the plants exposed to little shade grow thinner with larger leaves in order to capture as much light as possible (Mathur *et al.*, 2018). Our findings are consistent with those of Kumar *et al.* (2013), who found that plants exposed to up to 50% shade experienced greater levels of LA in sage plants. According to Zervoudakis *et al.* (2012), sage plants exposed to full sunshine had a greater leaf count. However, as the plants were shaded up to 75%, the mean leaf count declined. In plants exposed to shade, the longer stem INL can be the reason for the reduced leaf number that emerged from the node axils.

Research indicates that plants exposed to low light levels had a higher specific light absorption (SLA) (Feng and van Kleunen, 2014). This is thought to be a plant's adaptive reaction to boost photosynthetic efficiency (Gommers *et al*., 2013). It has been demonstrated that species unable to tolerate shade typically have greater light compensation points to maintain their rates of photosynthetic activity. The flexibility and tolerance of leaves in reaction to shade is thus indicated by changing the SLA per unit of dry weight (Valladares and Niinemets, 2008; Liu *et al*., 2016).

In an LM-based CP amended GM, the greater percentage of total porosity combined with air-filled porosity led to an improved aeration status, which is fundamentally necessary for efficient gaseous exchange in a limited pot volume. The study's conclusions are consistent with previous reports by Wazir *et al.* (2009) in Alstroemeria, Awang *et al.* (2009) in *Celosia cristata*, and Dubey *et al*. (2013) in Petunia. *Dahlia hortensis* 'Figaro' has also yielded comparable results (Tariq *et al*., 2012), recommending CP as a preferred amendment for raising potted dahlias. Additionally, research conducted by Riaz *et al*. (2008) supports the use of LM modified with CP for high-quality herbaceous *Zinnia elegans* cv. "Blue Point" production. Several studies [Kiran *et al*., 2007 (*Dahlia pinnata*); Younis *et al*., 2014 (Dahlia cv. Red Skin); Richardville *et al*., 2022 (Tomato); Singh *et al*., 2023 (Petunia)] have explored the benefits of amending the GM with LM. These studies have demonstrated LM's potential to improve the physical properties of potting substrate by enriching it with organic matter, in addition to providing crucial micronutrients for plant uptake. Furthermore, because CP is high in K, flowers have better quality with intense hues. The authors do recommend using washed CP that has a lower salt (NaCl) content, though. To lower the rate of N immobilization by the microorganisms in the substrate mix, the washed CP should ideally be stocked for at least one month (Handreck, 1993; Singh *et al.*, 2022).

The tubers that were taken from plants grown in GM with LM amendments were disease-free and in good health. A well decomposed LM has been shown to have a disease-suppressive effect (Bonanomi *et al*., 2010). Furthermore, dahlia plants grown in GM amended with CP showed greater NoT than control plants (GM1). When compared to soil-based media, the CP tends to retain moisture and controls the media's temperature, which is comparatively lower (1±0.5°C). According to Bethke (2023), the lower temperature in GM has been proven to be favorable for tuber growth and clump formation in potatoes, leading to a larger tuber count.

The current results pave the way for more research into the off-season cultivation of dahlia in nutrient-enriched substrates by adjusting temperature, photoperiod, and light intensity to produce high-quality flowers and robust tubers. Furthermore, shade nets that block at least one-third of the sun's rays can be used to create a favorable environment for cultivars that are sensitive to higher temperatures. This could increase the diversity of dahlia germplasm, particularly in tropical and subtropical regions of the world.

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References

ADAMS S.R., 1999 - *The effects of temperature and light integral on the phases of photoperiod sensitivity in* Petunia hybrida. - Ann. Bot., 83(3): 263-69.

AWANG Y., SHAHAROM S.A., MOHAMAD R.B., SELAMAT A., 2009 - *Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of* Celosia cristata. - Am. J. Agric. Biol. Sci., 4(1): 63-71.

BETHKE P.C., 2023 - *Cool soil increases Potato (*Solanum tuberosum*) tuber number in multiple varieties and alters skin color intensity of 'Red Norland'and 'Adirondack Blue*'. - Am. J. Potato Res., 100(1): 79-86.

BHATTACHARJEE S.K., VINAYANANDA S., DE L.C., 2019 - *Dahlia*, pp. 181-200. - In: BHATTACHARJEE S.K (ed.) *Advances in ornamental horticulture*. Pointer Publishers, Jaipur, Rajasthan, India, pp. 375.

BLAKE G.R., HARTGE K.H., 1986 - *Bulk density*, pp. 363-376. - In: KLUTE A. (ed) *Methods of soil analysis*, Part I. ASA Monograph No 9. Madison, Wisconsin, USA, pp. 1358.

BONANOMI G., ANTIGNANI V., CAPODILUPO M., SCALA F., 2010 - *Identifying the characteristics of organic amendments that suppress soilborne plant diseases*. - Soil Biol. Biochem., 42(2): 136-144.

CLARK G.E., BURGE G.K., 1999 - *Effects of nutrition, planting density, and stem pruning treatments on tuber weight and secondary tuber development in* Sandersonia aurantiaca. - New Zealand J. Crop Hort. Sci., 27: 319-324.

DALDA SEKERCI A., GÜLŞEN O., 2016 - *Overview of* dahlia *breeding*. Scientific Papers. Series B, Horticulture. LX, pp. 199-204.

DE HERTOGH A., LE NARD M., 1992 - *The physiology of flower bulbs. A comprehensive treatise on the physiology and utilization of ornamental flowering bulbous and tuberous plants*. - Elsevier, Amsterdam, The Netherlands, pp. 811.

DE L.C., BHATTACHARJEE S.K., 2011- *Ornamental crop breeding*. - Aavishkar Publishers Distributers, Jaipur, Rajasthan, India, pp. 454.

DEVLIN P.F., CHRISTIE J.M., TERRY M.J., 2007 - *Many hands make light work*. - J. Exp. Bot., 58(12): 3071-3077.

DUBEY R.K., SINGH S., KUKAL S.S., KALSI H.S., 2013 - *Evaluation of different organic growing media for growth and flowering of petunia*. - Commun. Soil Sci. Plant Anal., 44(12): 1777-1785.

EVANS E., 1998 - *Dahlias for the home landscape*. - Department of Horticultural Science, Cooperative Extension Service, North Carolina State University College of Agriculture & Life Sciences, North Carolina, USA.

FAUST J.E., HOLCOMBE V., RAJAPAKSE N.C., LAYNE D.R., 2005 - *The effect of daily light integral on bedding plant growth and flowering*. - Hortic. Sci., 40(3): 645-649.

FENG Y., VAN KLEUNEN M., 2014 - *Responses to shading of naturalized and non-naturalized exotic woody species*. - Ann. Bot., 114: 981-989.

GOMMERS C.M.M., VISSER E.J.W., ONGE K.R.S., VOESENEK L.A.C.J., PIERIK R., 2013 - *Shade tolerance: when growing tall is not an option*. - Trends Plant Sci., 18: 65-71.

HAMRICK D., 2003 - *Dahlia*, pp. 329-332. - In: HAMRICK D. (ed.) *Ball redbook. Volume 2. Crop production*. - Ball publishing, Batavia, Illinois, USA, pp. 736.

HANDRECK K.A., 1993 - *Properties of cocopeat dust and its use in the formulation of soilless potting media*. - Commun. Soil Sci. Plant Anal., 24(3-4): 349-363.

HLATSHWAYO M.S., WAHOME P.K., 2010 - *Effects of shading on growth, flowering and cut flower quality in carnation* (Dianthus caryophyllus*)*. - J. Agric. Sci., 6(2): 34-38.

KIRAN M., BALOCH J., WASEEM K., JILANI M. S., 2007 - *Effect of different growing media on the growth and development of* dahlia *(*Dahlia pinnata*) under the agro-climatic condition of Dera Ismail Khan*. - Pak. J. Agric. Sci., 10(22): 4140-4143.

KUMAR R., SHARMA S., PATHANIA V., 2013 - *Effect of shading and plant density on growth, yield and oil composition of clary sage (*Salvia sclarea *L.) in north western Himalaya*. - J. Essent. Oil Res., 25(1): 23-32.

LIU Y., DAWSON W., PRATI D., HAEUSER E., FENG Y., VAN KLEUNEN M., 2016 - *Does greater specific leaf area plasticity help plants to maintain a high performance when shaded?* - Ann. Bot., 118(7): 1329-1336.

LUGASSI-BEN-HAMO M., KITRON M., BUSTAN A., ZACCAI M., 2010 - *Effect of shade regime on flower development, yield and quality in Lisianthus.* - Sci. Hort., 124(2): 248-253.

MAPES C., XU Y., 2014 - *Photosynthesis, vegetative habit and culinary properties of sage (*Salvia officinalis*) in response to low-light conditions.* - Can. J. Plant Sci., 94(5): 881-889.

MARINA L.J., 2015 - *Cultivation of* dahlia*:* Review. - Cult. Trop., 36(1): 103-110.

MATHUR S., JAIN L., JAJOO A., 2018 - *Photosynthetic efficiency in sun and shade plants*. - Photosynthetica, 56: 354-365.

McCLAREN B., 2004 - *Encyclopedia of* dahlias. - Timber Press, Portland, Oregon, USA, pp. 212.

MENZEL J., 2016 - *Dahlias in Australia the winkie way*. - Bounty printing, Ringwood Victoria, Australia, pp. 126.

MUNIR M., JAMIL M., BALOCH J., KHATTAK K.R., 2004 - *Impact of light intensity on flowering time and plant quality of* Antirrhinum majus *L. cultivar chimes white*. - J. Zhejiang Univ. Sci., *A* 5: 400-405.

NELSON D.W., SOMMERS L.E., 1982 - *Total carbon, organic carbon and organic matter,* pp. 539-579. - In: PAGE A.L., R.H. MILLER, and D.R. KEENEY (eds.). *Methods of Soil Analysis. Part 2 Chemical and Microbiological Properties Agronomy*, 2nd edition, ASA-SSSA, Madison, Wisconsin, USA.

PAIK I., HUQ E., 2019 - *Plant photoreceptors: multi-functional sensory proteins and their signalling networks.* - Seminars Cell Devel. Biol., 92: 114-121.

REDDY K.M., KUMAR R., KIRAN S. B., 2023 - *Impact of climate change on tuber crops production and mitigation strategies*, pp. 167-184. - In: SOLANKEY S.S., and M. KUMARI (eds.) *Advances in research on vegetable production under a changing climat*e. Volume 2. Springer International Publishing, Cham, Switzerland, pp. 369.

RIAZ A., ARSHAD M., YOUNIS A., RAZA A., HAMEED M., 2008 - *Effect of different growing media on the growth and flowering of* Zinnia elegans cv. Blue Point. - Pak. J. Bot., 40(4):1579-1585.

RICHARDVILLE K., EGEL D., FLACHS A., JAISWAL A., PERKINS D., THOMPSON A., HOAGLAND L., 2022 - *Leaf mould compost reduces waste, improves soil and microbial properties, and increases tomato productivity.* - Urban Agric. Reg. Food Syst., 7(e1): 20022.

ROMER J., 2008 - *Growing dahlias*. -Instructional Technology Center, Iowa State University, Ames, IA, USA.

SALISBURY F.B., ROSS C.W., 1991 - *Plant physiology*. - Wadsworth Publishing Company, Belmont, California, USA, pp. 682.

SCHULZ V.S., MUNZV, STOLZENBURG K., HARTUNG J., WEISENBURGER S., GRAEFF-HÖNNINGERV S., 2019 - *Impact of different shading levels on growth, yield and quality of potato (*Solanum tuberosum *L.)*. - Agron., 9(6): 330.

SINGH A.K., KUMAR R., TOMAR K.S., GUPTA A.K., KUMAR H., PATEL R., 2023 - *Influence of potting media composition on quality flower production of petunia* (Petunia hybrida). - J. Plant Nutr., 46(13): 3101-3108.

SINGH A.K., SINGH R., KUMAR R., GUPTA A. K., KUMAR H., RAI A., KANAWJIA A., TOMAR K.S., PANDEY G., SINGH B., KUMAR S., DWIVEDI S.V., KUMAR S., PATHANIA K., OJHA G., SINGH A., 2022 - *Evaluating sustainable and environment friendly growing media composition for pot mum* (Chrysanthemum morifolium *Ramat.)*. - Sustainability, 15(1): 536.

SUBBIAH B.V., ASIJA C.L., 1956 - *A rapid procedure for the estimation of available nitrogen in soils*. - Curr. Sci., 25: 259-260.

TARIQ U., REHMAN S.U., KHAN M.A., YOUNIS A., YASEEN M., AHSAN M., 2012 - *Agricultural and municipal waste as potting media components for the growth and flowering of* dahlia *hortensis* 'Figaro'. - Turk. J. Bot., 36(4): 378-385.

THAKUR M., BHATT V., KUMAR R., 2019 - *Effect of shade level and mulch type on growth, yield and essential oil composition of damask rose (*Rosa damascene *Mill.) under mid hill conditions of Western Himalayas*. - PLoS ONE, 14(4):e0214672.

VALLADARES F., NIINEMETS Ü., 2008 - *Shade tolerance, a key plant feature of complex nature and consequences*. - Annu. Rev. Ecol. Evol. Syst., 39: 237-257.

WANG Y., GUO Q., JIN M., 2009 - *Effects of light intensity on growth and photosynthetic characteristics of Chrysanthemum morifolium*. - Zhongguo Zhong Yo Za Zhi, 34: 1633-1635.

WAZIR J.S., SHARMA Y.D., DHIMAN S.R., 2009 - *Performance of potted Alstroemeria (*Alstroemeria hybrida *L.) in different growing media under wet temperate conditions*. - J. Ornam. Hortic., 12(3): 167-174.

YAZICI K., GUNES S., 2018 - *The effects of shading treatments on the plant growth rate of some varieties of aster flowers (*Dahlia *spp.) in the ecologic conditions of Tokat (Turkey).* - Appl. Ecol. Environ. Sci., 16(5): 7191-7202.

YOUNIS A., ANJUM S., RIAZ A., HAMEED M., TARIQ U., AHSAN M., 2014 - *Production of quality* dahlia *(*Dahlia variabilis *cv. Redskin) flowers by efficient nutrients management running title: Plant nutrition impacts on dahlia quality.* - Am.-Eurasian J. Agric. Environ. Sci., 14(2): 137-142.

ZERVOUDAKIS G., SALAHAS G., KASPIRIS G., KONSTANTOPOULOU E., 2012 - *Influence of light intensity on growth and physiological characteristics of common sage (*Salvia officinalis *L.).* - Braz. Arch. Biol. Technol., 55: 89-95.

ZHAO D., HAO Z., TAO J., 2012 - *Effects of shade on plant growth and flower quality in the herbaceous peony* (Paeonia lactiflora *Pall.).* - Plant Physiol. Biochem., 61: 187-196.