PLANT SCIENCE TODAY
Vol 12(sp4): 1-10
https://doi.org/10.14719/pst.11991

eISSN 2348-1900

RESEARCH ARTICLE

Optimisation of growing environment and potting media for enhanced growth and flowering performance of kalanchoe (*Kalanchoe blossfeldiana* Poelln.)

R Varun Prasath[1], V A Sathiyamurthy[2*], D Keisar Lourdusamy[2], D Vijayalakshmi[3], P Malathi[4] & K P Ammu[4]

[1]Department of Floriculture and Landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore 641 003, India

[2]Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore 641 003, India

[3]Department of Plant Physiology, Tamil Nadu Agricultural University, Coimbatore 641 003, India

[4]Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, India

*Correspondence email - sathiyamurthyva@tnau.ac.in

Received: 26 September 2025; Accepted: 25 October 2025; Available online: Version 1.0: 01 December 2025

Cite this article: Varun PR, Sathiyamurthy VA, Keisar LD, Vijayalakshmi D, Malathi P, Ammu KP. Optimisation of growing environment and potting media for enhanced growth and flowering performance of kalanchoe (*Kalanchoe blossfeldiana* Poelln.). Plant Science Today. 2025; 12(sp4): 1-10. https://doi.org/10.14719/pst.11991

Abstract

Kalanchoe blossfeldiana Poelln. is an important ornamental plant that requires proper growing conditions to achieve good quality and high yields. This study investigated the effects of different growing environments and potting media on the growth, flowering and physiological health of *K. blossfeldiana*. The experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, over 90 days using a two-factor design with three replications. Two growing environments were evaluated: open field and shade-net house. Five different potting media were tested, each containing soil and coarse sand mixed with different organic materials: farmyard manure (FYM), leaf mould, vermicompost, rice husk and coir pith compost. Results showed that shade-net conditions significantly improved plant height (19.50 cm vs 17.89 cm), flower production (109 vs 97.27) and various physiological parameters compared to open field conditions. Among the potting media, coir pith compost consistently produced the best results, including the thickest leaves (1.64 mm), longest flower longevity (25.67 days) and superior root architecture. The combination of shade-net with coir pith compost produced the highest flower number (119.67), maximum plant growth (69.85 % biomass increase) and chlorophyll content (324.45 µg/g fresh weight). The present study demonstrates that cultivation of *K. blossfeldiana* under shade-net conditions supplemented with coir pith compost significantly enhances plant growth and quality, thereby improving its commercial value.

Keywords: coir pith compost; *Kalanchoe blossfeldiana*; ornamental cultivation; potting media; shade-net environment

Introduction

Kalanchoe blossfeldiana Poelln., commonly known as Flaming Katy or Christmas kalanchoe, is a valuable ornamental plant widely grown in nurseries and gardens (1). Originally from Madagascar, this plant was brought into commercial cultivation in 1932 by German botanist Robert Blossfeld (2). It has become popular worldwide due to its compact growth, bright, colourful flowers and long flowering period. The global ornamental plant market is growing rapidly. Within this market, succulents like *Kalanchoe* occupy an important position, driven by increasing interest in low-maintenance plants and urban gardening (3).

Kalanchoe blossfeldiana is valued for its small, compact structure and clusters of small, four-petaled flowers that last about six weeks. The flowers come in many colours, including red, orange, yellow, pink, white and peach. Plants typically flower twice a year (4). Recent plant breeding has created double-flowered varieties and novel leaf colours such as red-purple with higher anthocyanin content and variegated and maculated leaves, making the plant even more attractive (5). In Europe, the plant is also used as a cut flower, expanding its commercial uses (6). Despite its popularity, growing *K. blossfeldiana* commercially faces several challenges, such as inconsistent growing environments, pathogen and pest susceptibility and soil drainage issues. Many growers lack proper guidelines for choosing the right potting materials, managing growing environments and handling plant propagation. Poor growing conditions can cause faded flower colours and an increase in plant diseases, including root rot, powdery mildew and virus infections. Research shows that controlled growing environments can improve photosynthesis, reduce plant stress and increase overall plant quality (7). Similarly, the composition of potting media affects water retention, nutrient availability and root development, all of which directly impact plant health and appearance. This study investigates the effects of growing environment and potting media on *K. blossfeldiana* to optimise commercial cultivation.

Materials and Methods

Study location and design

This study was conducted from 2024 to 2025 at the Botanical Garden of Tamil Nadu Agricultural University (TNAU), Coimbatore, India. The experiment used a factorial completely randomised design (FCRD) with two main factors and three replications for each treatment combination (Table 1). During the experiment, shade-net environments had temperatures of 18-34 °C, light intensity of 37.7-52.2 klx and relative humidity of 45-85 %, while open field conditions had higher temperatures (20-37 °C), higher light (65-90 klx) and less stable humidity (50-92 %).

Plant material and setup

Healthy and uniform *K. blossfeldiana* plants were obtained from the Botanical Garden Nursery at TNAU, Coimbatore. Each plant was transplanted into individual pots (15 cm diameter) containing the assigned potting medium and labelled according to the treatment.

Plant management

Plants were watered 3-4 times per week using a watering can with a rose attachment. Watering frequency was adjusted based on soil moisture content checked at 1 cm depth. Every 10 days throughout the experiment, fungicides and bactericides were applied using the soil drenching method. Fungicide SAAF (containing 12 % carbendazim + 63 % mancozeb) was applied at 0.5 g per litre of water. Bactericide K-cycline (containing 90 % streptomycin + 10 % tetracycline) was applied at 0.3 g per litre of water.

Flowering and morphological growth parameters

Plant height was measured from the base to the tip of the tallest leaf using a ruler. Measurements were taken every 30 days for 90 days. Leaf thickness was measured using vernier callipers at the midpoint between the base and tip of mature leaves at 30-day intervals. The maximum horizontal spread of the plant was measured using a ruler at 30-day intervals. With respect to flowering, the total number of open flowers on selected plants (one plant per replication) was counted throughout the experimental period. The number of days from planting until the first flower opened was recorded for each treatment. The time from flower opening until more than 50 % of the flowers in the flower cluster wilted was measured as flower longevity (8).

At the end of the experiment, plants were carefully removed from pots for root examination. Roots were gently washed clean, photographed and analysed using RhizoVision Explorer software (version 2.0.3) to measure total root length, average diameter, number of root tips, volume and surface area (9).

Physiological measurements

Chlorophyll and carotenoid content

Photosynthetic pigments were analysed using spectrophotometric analysis (10). Fresh leaf samples of known weight were macerated in 80 % acetone, centrifuged at 3000-5000 g for 5 min and the supernatant was diluted to 20 mL final volume. Spectrophotometric readings were taken at wavelengths $A_{663\cdot2}$, $A_{646\cdot8}$, A_{470} and A_{710} nm.

Chlorophyll and carotenoids were calculated using the given formulae (Eqn. 1-4):

$$\text{Chlorophyll a } (\mu g/mL) = 12.25 \times (A_{663.2} - A_{710}) - 2.79 \times (A_{648.8} - A_{710}) \quad \text{(Eqn. 1)}$$

$$\text{Chlorophyll b } (\mu g/mL) = 21.50 \times (A_{646.8} - A_{710}) - 5.10 \times (A_{663.2} - A_{710}) \quad \text{(Eqn. 2)}$$

$$\text{Total Chlorophyll } (\mu g/mL) = (7.15 \times A_{663.2}) + (18.71 \times A_{646.8}) \quad \text{(Eqn. 3)}$$

$$\text{Total carotenoids } (\mu g/mL) = \frac{[1000 \times (A_{470} - A_{710}) - 1.82 \times \text{Chl a} - 85.02 \times \text{Chl b}]}{198} \quad \text{(Eqn. 4)}$$

Pigment concentrations were calculated using the following formula (Eqn. 5):

$$\text{Pigment } (\mu g/g\ FW) = \frac{C \times V}{W \times 1000} \quad \text{(Eqn. 5)}$$

Where, C = concentration (µg/mL), V = final extract volume (mL) and W = sample fresh weight (g).

SPAD chlorophyll meter readings were also recorded to supplement spectrophotometric analysis.

Plant biomass analysis

Initial plant samples were analyzed before transplanting to establish baseline measurements. After 90 days, entire plants were harvested and separated into root and shoot components. Fresh weights were recorded immediately, followed by oven-drying at 60 °C until constant weight to determine dry biomass. Biomass accumulation was calculated (Eqn. 6, 7):

$$\text{Biomass accumulation (g)} = \text{Final dry weight} - \text{Initial dry weight} \quad \text{(Eqn. 6)}$$

$$\text{Biomass accumulation (\%)} = \frac{\text{Final dry weight} - \text{Initial dry weight}}{\text{Initial dry weight}} \times 100 \quad \text{(Eqn. 7)}$$

Following this, the root-to-shoot ratio was calculated by the following formula at the end of the experimental period (Eqn. 8):

$$\text{Root : shoot ratio} = \frac{\text{Dry weight of root (g)}}{\text{Dry weight of shoot (g)}} \quad \text{(Eqn. 8)}$$

Relative water content (RWC)

Leaf samples were weighed to obtain fresh weight (FW), then rehydrated in distilled water for 2 hr to achieve turgid weight (TW) and finally oven-dried at 60 °C to obtain dry weight (DW) (11). Relative water content was calculated (Eqn. 9) as follows:

Table 1. Details of growing environments and potting media combinations used for treatments in the experiment

Factor E: Growing environments		Factor M: Potting media combinations	
E_1:	Open conditions	**M_1**:	Soil + Coarse sand + Farmyard manure (2:1:1)
E_2:	Shade-net	**M_2**:	Soil + Coarse sand + Leaf mould (2:1:1)
		M_3:	Soil + Coarse sand + Vermicompost (2:1:1)
		M_4:	Soil + Coarse sand + Rice husk (2:1:1)
		M_5:	Soil + Coarse sand + Coir pith compost (2:1:1)

$$\text{RWC (\%)} = \frac{\text{FW - DW}}{\text{TW - DW}} \times 100 \quad \text{(Eqn. 9)}$$

Plant health assessments

Survival rate was calculated as the percentage of living plants relative to the initial number at the end of 90 days (Eqn. 10). Root rot incidence was assessed by visual examination of root systems and calculated as the percentage of plants showing root rot symptoms (Eqn. 11).

$$\text{Survival rate (\%)} = \frac{\text{Number of living plants at 90 days}}{\text{Initial number of plants}} \times 100 \quad \text{(Eqn. 10)}$$

$$\text{Root rot incidence (\%)} = \frac{\text{Number of plants with visible root rot symptoms}}{\text{Total number of plants in treatment}} \times 100 \quad \text{(Eqn. 11)}$$

Soil analysis

Soil pH

A 1:2.5 soil-to-water suspension was prepared by mixing 20 g of air-dried, 2 mm-sieved media with 50 mL of distilled water. After 30 min of intermittent stirring, the pH meter (previously calibrated) electrodes-rinsed and dried-were immersed in the suspension and readings were recorded once stable.

Electrical conductivity (EC)

Using the same 1:2.5 suspension, EC was measured with a calibrated conductivity bridge, verified against saturated $CaSO_4$ (calcium sulphate) (≈ 2.2 dS m^{-1}) and 0.1 N KCl (potassium chloride) (≈ 1.41 dS m^{-1}) standards. The suspension was gently stirred and allowed to settle for 15 min. The electrodes were rinsed with distilled water and carefully immersed in the clear supernatant and EC was recorded with temperature compensation applied.

Water-holding capacity (WHC)

Saturated media samples were weighed (wet mass) after free-drainage (12). Samples were then oven-dried at 105 °C to constant weight (dry mass). Water-holding capacity was calculated as per the formula (Eqn. 12).

$$\text{WHC (\%)} = \frac{\text{Wet weight - Dry weight}}{\text{Dry weight}} \times 100 \quad \text{(Eqn. 12)}$$

Bulk density

20 g of oven-dry media was added to a 100 mL graduated cylinder; the initial volume (V_1) was noted. After slowly adding 50 mL distilled water to saturate pore spaces and standing for 30 min, the final volume (V_1+V_2) was recorded. Bulk density was calculated as per the formula (Eqn. 13):

$$\rho_b (\text{g cm}^{-3}) = \frac{W}{V_1} \quad \text{(Eqn. 13)}$$

Where, W = weight of dry soil (g) and V_1 = initial volume of soil (cm^3).

Particle density

Using the same saturated mixture, the soil-particle volume (V_3) was determined by subtracting pore volume (V_2) from initial media volume (V_1). Particle density was calculated using the given formula (Eqn. 14):

$$\rho_p (\text{g cm}^{-3}) = \frac{W}{(V_1 - V_{pore})} \quad \text{(Eqn. 14)}$$

Where, W = weight of dry soil (g), V_1 = initial volume of soil (cm^3), V_{pore} = pore space volume (cm^3).

Porosity

Porosity, the fraction of total volume occupied by pores, was determined by the formula (Eqn. 15):

$$\text{Porosity (\%)} = [1 - \frac{\rho_b}{\rho_p}] \times 100 \quad \text{(Eqn. 15)}$$

Using the previously calculated ρ_p and ρ_b.

Available nitrogen (N), phosphorus (P) and potassium (K)

Available N: 20 g of media was mixed with water, paraffin and glass beads in a distillation flask. After adding $KMnO_4$ (potassium permanganate) (0.32 %) and NaOH (sodium hydroxide) (2.5 %), the mixture was distilled; the distillate (100 mL) was titrated against 0.02 N H_2SO_4 (sulfuric acid) using boric acid–indicator solution. Nitrogen content was calculated from the titration volume (13). The following formula was used to calculate available N (Eqn. 16):

$$\text{Available N (mg/kg)} = 0.014 \text{ X } x \quad \text{(Eqn. 16)}$$

Where, x = titration value for the sample in mL.

Available P: 5 g of media was shaken with 50 mL of Olsen's reagent comprising 0.5 M $NaHCO_3$ (sodium bicarbonate) (pH 8.5) and activated carbon for 30 min (14). After filtration, 5 mL extract was reacted with ascorbic acid-molybdate reagent and absorbance at 660 nm was compared to a standard curve to yield P concentration (Eqn. 17).

$$\text{Available P (mg/kg)} = a \times 10 \quad \text{(Eqn. 17)}$$

Where, a = concentration of P in ppm or mg/L in extract.

Available K: 5 g of media was extracted with 25 mL neutral 1 N ammonium acetate. The mixture was shaken for 5 min and filtered. Filtrate K concentration was measured via flame photometry against standards (0-100 ppm) (15). The following formula is used to find available K (Eqn. 18).

$$\text{Available K (mg/kg)} = 5 \times X \quad \text{(Eqn. 18)}$$

Where, X = potassium concentration (ppm or mg/L) in the 1 N ammonium acetate extract, measured by flame photometer.

Statistical analysis

Data analysis was done using R software version 4.5.1. Assumptions of normality and homogeneity of variance were verified and analysis of variance (ANOVA) was performed for all measurements at a significance level of $\alpha = 0.05$. Post-hoc comparisons of treatment means were conducted using Least significant difference (LSD) and Tukeys' honestly significant difference (HSD) methods.

Results

Plant morphology and flowering

Plant height

Plant height at 90 days showed highly significant effects of growing environment, potting media and their interaction. Shade-net conditions (E_2) produced significantly taller plants (19.50 cm) compared to open field conditions (E_1, 17.89 cm). Among potting media, rice husk (M_4) and coir pith compost (M_5) were statistically on par and produced the tallest plants (19.80 cm each), followed by vermicompost (M_3, 18.90 cm). Leaf mould (M_2) and farmyard manure (FYM) (M_1) were on par at the lower end with 17.82 cm and 17.15 cm, respectively (Fig. 1). The interaction analysis revealed that E_2M_3 achieved maximum height (20.10 cm), while E_1M_1 produced minimum height (15.50 cm).

Leaf thickness

Leaf thickness at 90 days showed significant environmental effects, potting media effects and significant interaction effects. Shade-net conditions promoted significantly thicker leaves (1.56 mm) compared to open field (1.52 mm). Coir pith compost (M_5) produced the thickest leaves (1.64 mm), significantly superior to all other treatments. Vermicompost (M_3, 1.56 mm) was statistically on par with rice husk (M_4, 1.52 mm) and leaf mould (M_2, 1.51 mm), while FYM (M_1) produced the thinnest leaves (1.49 mm) (Fig. 2). The interaction demonstrated that E_2M_5 achieved maximum thickness (1.72 mm) compared to minimum thickness in E_1M_1 (1.47 mm).

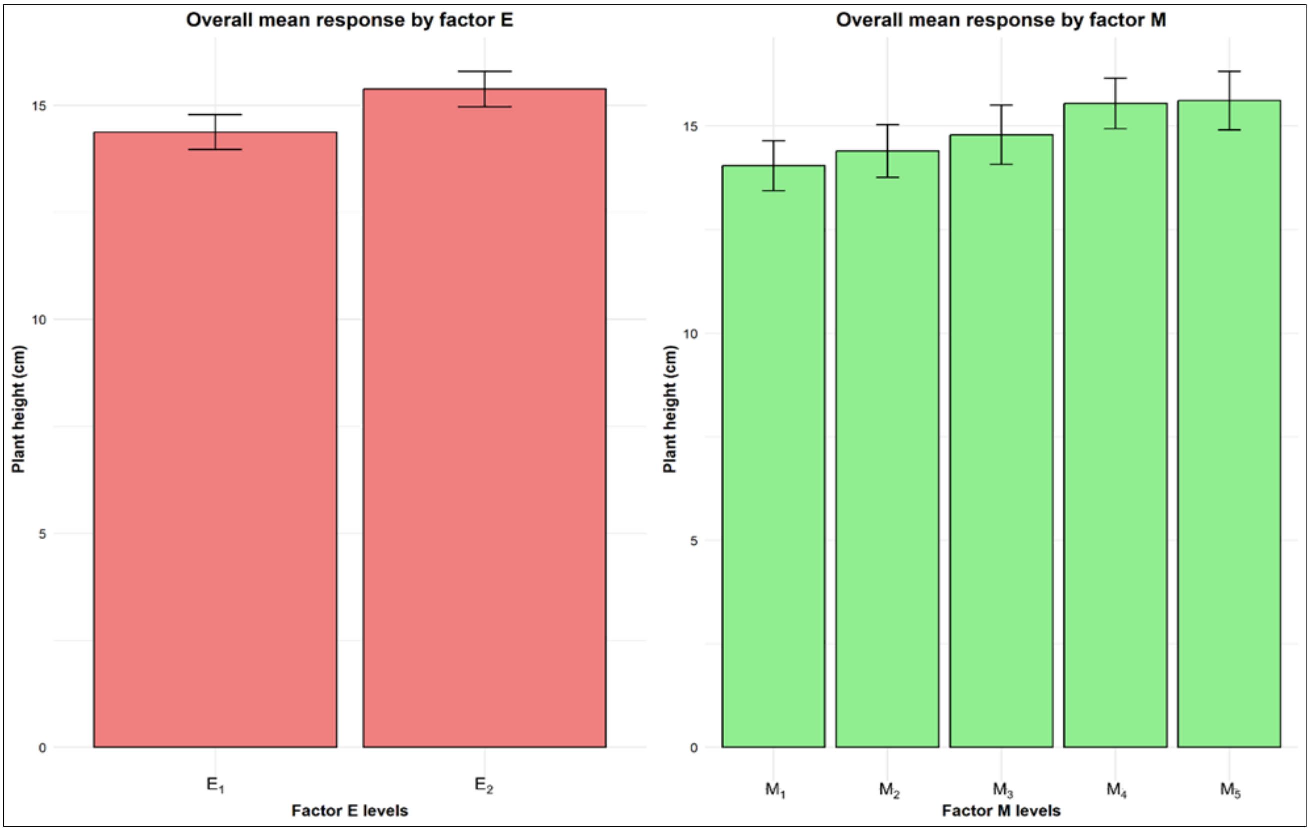

Fig. 1. Effect of growing environments and potting media on plant height in *K. blossfeldiana.*

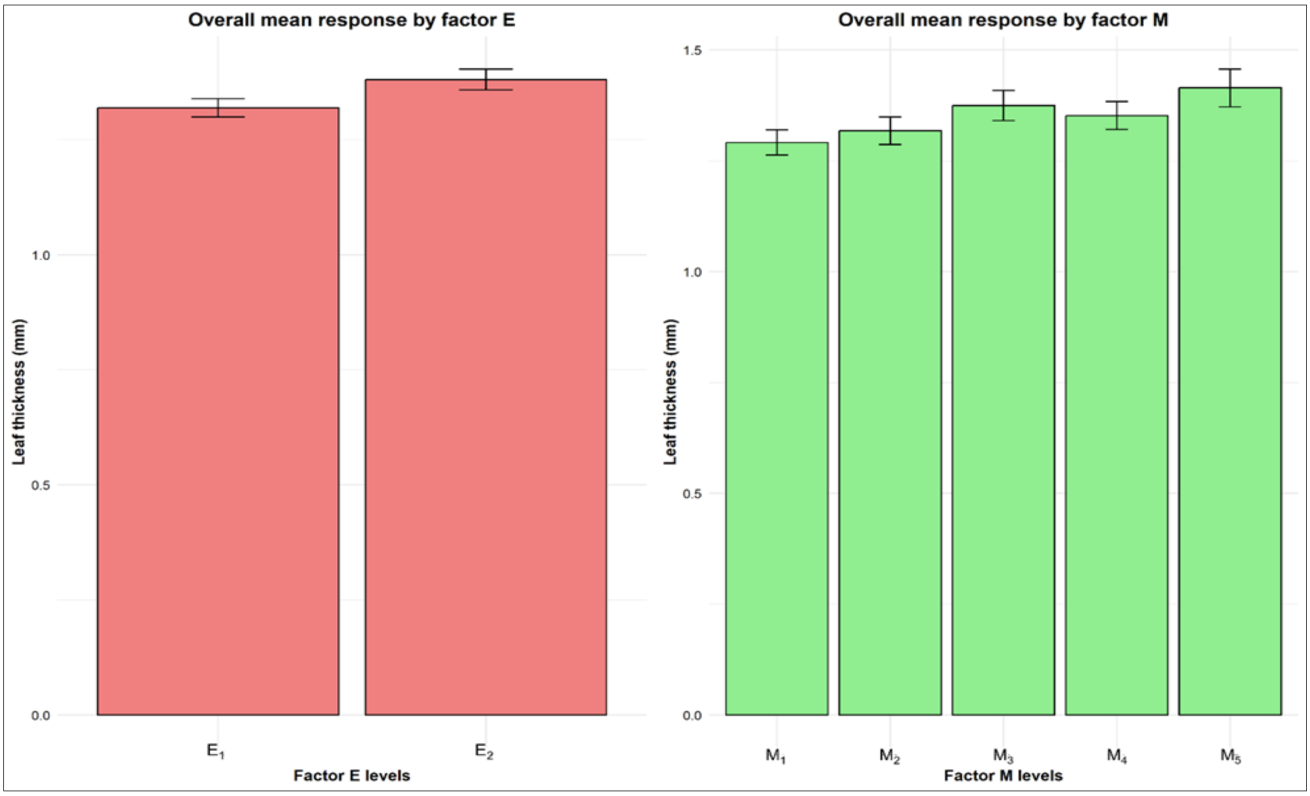

Fig. 2. Effect of growing environment and potting media on leaf thickness of *K. blossfeldiana.*

Plant width

Interestingly, plant width at 90 days showed contrasting responses with significant environmental effects, potting media effects and interactions. Open field plants developed significantly wider spread (19.19 cm) than shade-net plants (18.12 cm) (Fig. 3). Coir pith compost (M_5) promoted maximum width (20.62 cm), followed by vermicompost (M_3, 19.65 cm) and rice husk (M_4, 18.90 cm), which were statistically on par. Leaf mould (M_2, 17.83 cm) and FYM (M_1, 16.27 cm) formed progressively smaller width groups (Table S1). The interaction revealed E_2M_5 achieved maximum width (22.57 cm) while E_2M_1 showed minimum (14.83 cm).

Flowering performance

Flower count exhibited highly significant environmental effects, potting media effects and marginal interaction effects ($p = 0.07$). Shade-net plants produced significantly more flowers (109.0) compared to open field plants (97.27). Coir pith compost (M_5) yielded the highest flower count (109.67), statistically on par with vermicompost (M_3, 106.50). Leaf mould (M_2, 102.50), rice husk (M_4, 99.33) and FYM (M_1, 97.67) formed progressively lower statistical groups (Table 2). The interaction showed E_2M_5 achieved maximum flower production (119.67) while E_1M_1 recorded minimum (93.67). Days to flowering showed significant environmental effects and potting media effects. Shade-net plants flowered later (81.07 days) than open field plants (79.67 days). Farmyard manure (M_1) induced late flowering (83.5 days), statistically on par with rice husk (M_4, 82.3 days). Leaf mould (M_2, 80.5 days) and vermicompost (M_3, 79.0 days) were intermediate, while coir pith compost (M_5) induced the earliest flowering (76.5 days) (Table 2). Flower longevity demonstrated highly significant environmental effects, potting media effects, but non-significant interactions. Shade-net conditions extended flower life significantly (24.40 days) compared to the open field (21.93 days). Coir pith compost (M_5) provided the longest flower longevity (25.67 days), significantly superior to all other treatments. Vermicompost (M_3, 24.17 days), rice husk (M_4, 23.0 days) and leaf mould (M_2, 22.17 days) formed intermediate groups, while FYM (M_1) provided the shortest longevity (20.83 days) (Table 2).

Root system development

Root system analysis showed significant differences among treatments. Coir pith compost consistently produced the most extensive root systems. The highest total root length was achieved with coir pith compost in both environments, with shade-net treatment (E_2M_5) recording 9084.25 mm and open field treatment (E_1M_5) achieving 9084.80 mm (Table 3). These values were much higher than FYM treatments, which recorded the lowest root lengths of 5170.80 mm (E_1M_1) and 5177.34 mm (E_2M_1). For the number of root tips, E_2M_5 exhibited the highest count (6,115), with E_1M_5 closely following at 5,641 (Fig. 4). Root volume measurements showed similar patterns, with coir pith compost treatments achieving volumes exceeding 19,000 mm^3 compared to approximately 8,900 mm^3 in FYM treatments. Root surface area followed the same trend, with maximum values of 27,282.74 mm^2 in shade-net coir pith treatment compared to minimum values around 23,260 mm^2 in FYM treatments. Detailed data is provided in Table 3.

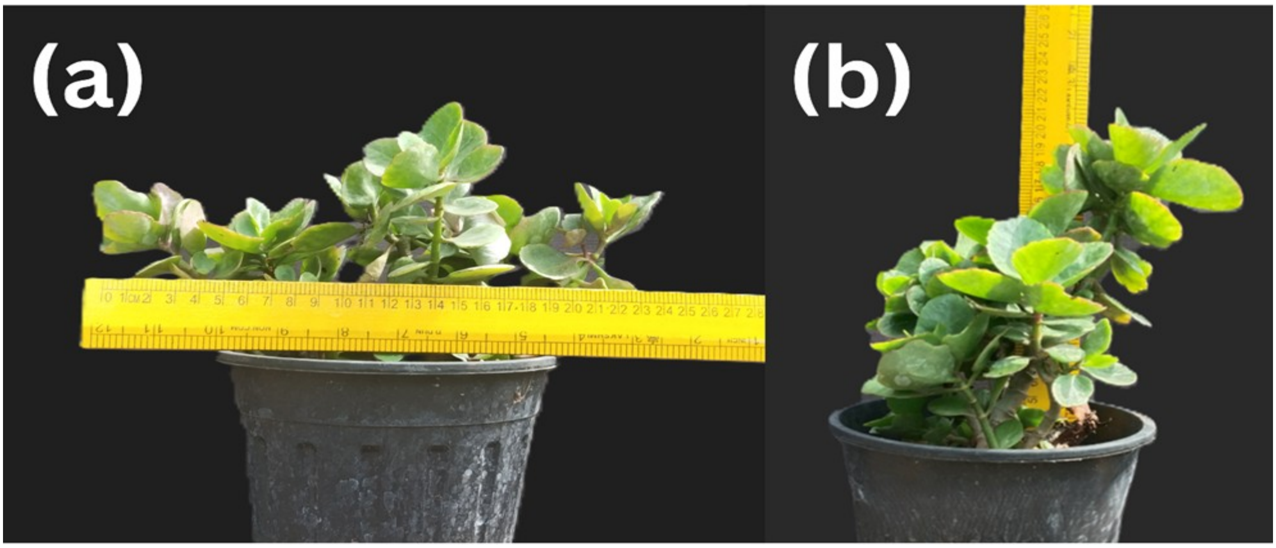

Fig. 3. Comparison of total plant width: **(a)** Open conditions, (**b**) Shade-net conditions.

Table 2. Effect of growing environment and potting media on flowering of *K. blossfeldiana*

	Number of flowers			Days to flowering			Flower longevity (days)		
	E_1	**E_2**	**Mean**	**E_1**	**E_2**	**Mean**	**E_1**	**E_2**	**Mean**
M_1	93.67	101.67	97.67^{d}	82.00	85.00	83.50^{a}	20.33	21.33	20.83^{d}
M_2	98.00	107.00	102.50^{bc}	80.33	80.67	80.50^{bc}	21.00	23.33	22.17^{cd}
M_3	100.33	112.67	106.50^{ab}	79.33	78.67	79.00^{c}	23.00	25.33	24.17^{b}
M_4	94.67	104.00	99.33^{cd}	80.67	84.00	82.33^{ab}	21.67	24.33	23.00^{bc}
M_5	99.67	119.67	109.67^{a}	76.00	77.00	76.50^{d}	23.67	27.67	25.67^{a}
Mean	97.27^{b}	109.00^{a}		79.67^{b}	81.07^{a}		21.93^{b}	24.40^{a}	
Factors	**E**	**M**	**E × M**	**E**	**M**	**E × M**	**E**	**M**	**E × M**
SE (d)	1.3824	2.1858	3.0912	0.6074	0.9603	1.3581	0.4269	0.6749	0.9545
CD	2.8837	4.5595	6.4481	1.2669	2.0032	2.833	0.8904	1.4079	1.9911

*Means followed by different letters differ significantly at $p \leq 0.05$ using the least significant difference (LSD) test.

E_1: Open conditions.; **E_2**: Shade-net; **M_1**: FYM mix; **M_2**: Leaf mould mix; **M_3**:Vermicompost mix; **M_4**:Rice husk mix; **M_5**: Coir pith compost mix.

Table 3. Root growth parameters of *K. blossfeldiana* under different environments and media

		Total root length (mm)	Average diameter (mm)	No. of root tips	Volume (mm^3)	Surface area (mm^2)
	M_1	5170.8009	0.7811	1776	8862.955	23258.03
	M_2	7475.8641	0.9449	3394	15438.31	24202.30
E_1	**M_3**	8435.3231	1.1853	5577	18651.58	24621.53
	M_4	7309.8421	0.8059	2849	9144.86	24083.63
	M_5	9084.7961	1.5329	5641	19365.12	26304.16
	M_1	5177.3351	0.8797	2163	9076.051	23292.48
	M_2	7477.1239	1.0841	3985	16013.41	24595.90
E_2	**M_3**	8436.3349	1.3911	5590	19123.41	25789.78
	M_4	7315.2419	1.0139	3372	10509.98	24177.16
	M_5	9084.2479	1.6541	6115	19699.50	27282.74

E_1: Open conditions.; **E_2**: Shade-net; **M_1**: FYM mix; **M_2**: Leaf mould mix; **M_3**:Vermicompost mix; **M_4**:Rice husk mix; **M_5**: Coir pith compost mix.

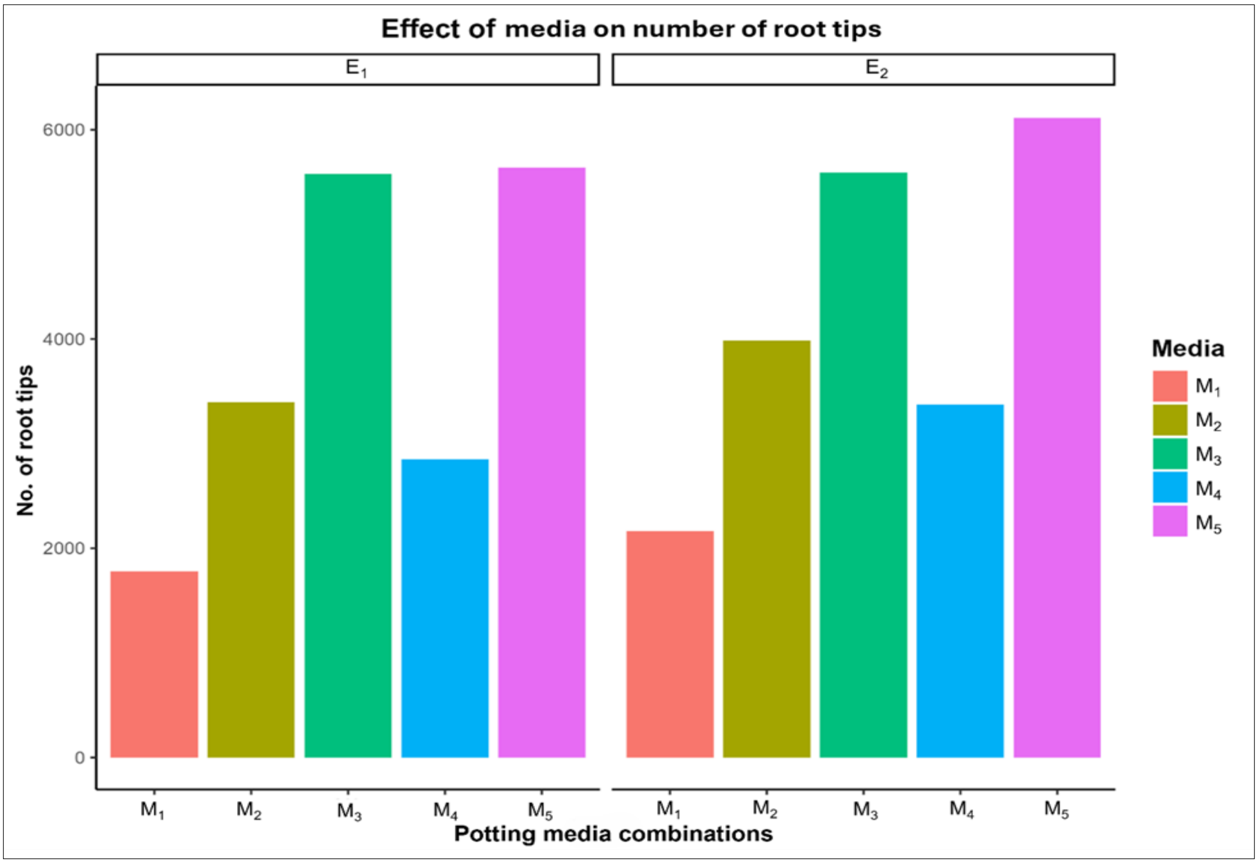

Fig. 4. Effect of growing environment and potting media on root tips of *K. blossfeldiana.*

Physiological parameters

Chlorophyll and pigment content

Analysis of plant pigments showed significant benefits of shade-net cultivation. Chlorophyll a content was much higher in shade-net plants (192.81 µg/g fresh weight) compared to open field plants (163.75 µg/g fresh weight). Chlorophyll b and total chlorophyll followed similar patterns, with shade-net plants recording 88.30 µg/g and 281.11 µg/g, respectively, compared to 81.47 µg/g and 245.22 µg/g in open field conditions (Table S2).

Among potting media, coir pith compost consistently promoted the highest pigment levels, achieving chlorophyll a levels of 214.58 µg/g and total chlorophyll of 305.49 µg/g. In contrast, FYM supported the lowest pigment levels across all measurements. The combination of shade-net and coir pith compost produced exceptional pigment concentrations, with chlorophyll a reaching 229.90 µg/g and total chlorophyll achieving 324.45 µg/g (Table 4). Chlorophyll index demonstrated highly significant environmental effects, potting media effects. Shade-net plants recorded significantly higher SPAD values (45.16) compared to open field plants (40.29). Among potting media, coir pith compost (M_5) achieved the highest SPAD readings (47.02), significantly exceeding all other treatments. Vermicompost (M_3, 44.45) and leaf mould (M_2, 43.30) were statistically on par and formed the second group. Rice husk (M_4, 40.35) and FYM (M_1, 38.52) were statistically similar at the lower end (Table 4).

Carotenoid content

Carotenoid accumulation showed highly significant environmental effects and potting media effects. Shade-net conditions promoted higher carotenoid levels (52.52 µg/g FW) than open field (46.47 µg/g FW). Coir pith compost (M_5) yielded maximum carotenoids (56.39 µg/g FW), significantly exceeding all other treatments (Table 4). The interaction between shade-net and coir pith compost (E_2M_5) achieved peak chlorophyll a (229.90 µg/g FW), chlorophyll b (94.55 µg/g FW), total chlorophyll (324.45 µg/g FW) and carotenoid content (59.88 µg/g FW), representing substantial increases over minimum values recorded in open field FYM treatments.

Table 4. Effect of growing environment and potting media on chlorophyll, carotenoids and SPAD index of *K. blossfeldiana*

	Total chlorophyll (µg/g)			Total carotenoids (µg/g)			SPAD index		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean
M_1	208.57	232.68	220.62^d	40.81	44.70	42.76^e	36.65	40.38	38.52^c
M_2	242.77	286.41	264.59^b	46.01	53.13	49.57^c	40.09	46.51	43.30^b
M_3	262.98	303.39	283.18^b	49.04	56.00	52.52^b	41.65	47.25	44.45^b
M_4	225.26	258.66	241.96^c	43.61	48.87	46.24^d	38.85	41.84	40.34^c
M_5	286.54	324.45	305.50^a	52.91	59.88	56.39^a	44.22	49.82	47.02^a
Mean	245.22^b	281.12^a		46.47^b	52.52^a		40.29^b	45.16^a	
Factors	**E**	**M**	**E × M**	**E**	**M**	**E × M**	**E**	**M**	**E × M**
SE (d)	5.9803	9.4557	13.3723	0.6593	1.0425	1.4743	0.7461	1.1797	1.6684
CD	12.4747	19.7242	27.8942	1.3753	2.1745	3.0752	1.5564	2.4609	3.4802

*Means followed by different letters differ significantly at $p \leq 0.05$ using LSD test.

E_1: Open conditions; **E_2**: Shade-net; **M_1**: FYM mix; **M_2**: Leaf mould mix; **M_3**:Vermicompost mix; **M_4**:Rice husk mix; **M_5**: Coir pith compost mix.

Plant biomass gain

Plant biomass accumulation showed highly significant environmental effects, potting media effects. Shade-net conditions promoted significantly greater biomass accumulation (88.84 %) compared to open field conditions (80.53 %). Coir pith compost (M_5) produced maximum biomass accumulation (93.84 %), significantly superior to all other treatments. Vermicompost (M_3, 88.63 %) ranked second, followed by leaf mould (M_2, 84.69 %) and rice husk (M_4, 80.32 %), while FYM (M_1) achieved the lowest accumulation (75.93 %). The interaction showed E_2M_5 achieved maximum biomass accumulation (98.96 %) while E_1M_1 recorded minimum (73.39 %), representing a 35 % difference (Table 5).

Relative water content (RWC)

Relative water content, which reflects the hydration status and water balance of plant tissues, revealed highly significant environmental and potting media effects. Shade-net plants maintained superior water status (91.61 %) compared to open field plants (89.43 %). Coir pith compost (M_5) supported the highest RWC (92.66 %), significantly exceeding all other treatments except vermicompost (M_3, 91.08 %). Leaf mould (M_2, 90.64 %) and rice husk (M_4, 89.65 %) were intermediate, while FYM (M_1) recorded the lowest RWC (88.56 %) (Table 5). This is likely due to high water holding capacity (55.05 %) and high porosity (70.00 %) in coir pith compost, in contrast to lower water holding capacity (35.67 %) and comparatively low porosity (61.75 %) in FYM mix.

Root-to-shoot ratio

Root-to-shoot ratio (R:S) showed highly significant effects of both growing environment and potting media. Plants grown in the open field (E_1) exhibited significantly higher R:S ratio (0.555) compared to those grown under shade-net conditions (E_2), which had a ratio of 0.499. This indicates a greater relative investment in root biomass under open field growing conditions, potentially as a stress response to environmental factors. Among potting media, FYM (M_1) led to the highest root-to-shoot ratio (0.580), followed by rice husk (M_4, 0.547) and leaf mould (M_2, 0.526). Coir pith compost (M_5, 0.503) and vermicompost (M_3, 0.480) produced the lowest R:S ratios, reflecting a more balanced biomass allocation favouring shoot growth (Table 5).

Plant survival and rot incidence

Survival rate analysis showed significant environmental effects, highly significant potting media effects and marginal interaction effects (p = 0.07). Shade-net conditions supported slightly higher survival rates (95.60 %) compared to open field (94.22 %). Coir pith compost (M_5) and vermicompost (M_3) were statistically on par with the highest survival rates (97.32 % and 96.52 % respectively). Leaf mould (M_2, 94.90 %) was intermediate, while FYM (M_1, 93.47 %) showed the lowest survival rate (Table 6). The interaction revealed E_1M_5 achieved maximum survival (97.64 %) while E_1M_4 recorded minimum (91.46 %). Root rot analysis demonstrated highly significant environmental effects, potting media effects. Interestingly, shade-net conditions showed slightly higher root rot incidence (8.09 %) compared to open field (7.10 %), likely due to higher humidity levels. Among potting media, FYM (M_1) and leaf mould (M_2) were statistically on par with the highest root rot incidence (8.68 % and 8.17 % respectively). Vermicompost (M_3, 7.55 %) and coir pith compost (M_5, 7.28 %) showed intermediate susceptibility, while rice husk (M_4) demonstrated the lowest incidence (6.29 %) (Table 6).

Table 5. Effect of growing environment and potting media on physiological parameters of *K. blossfeldiana*

	Plant biomass gain (%)			Root to shoot ratio			Relative water content (%)		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean
M_1	44.86 (0.73)	49.92 (0.78)	47.39 (0.76)^d	0.62	0.54	0.58^a	87.81 (1.21)	89.32 (1.24)	88.56 (1.23)^d
M_2	51.40 (0.80)	60.79 (0.89)	56.09 (0.85)^{bc}	0.55	0.50	0.53^{bc}	89.29 (1.24)	91.98 (1.28)	90.64 (1.26)^{bc}
M_3	55.19 (0.84)	64.71 (0.94)	59.95 (0.89)^b	0.50	0.46	0.48^{cd}	89.86 (1.25)	92.30 (1.29)	91.08 (1.27)^b
M_4	48.30 (0.77)	55.25 (0.84)	51.77 (0.80)^{cd}	0.58	0.51	0.55^{ab}	88.70 (1.23)	90.60 (1.26)	89.65 (1.24)^{cd}
M_5	60.06 (0.89)	69.85 (0.99)	64.96 (0.94)^a	0.53	0.47	0.50^d	91.50 (1.28)	93.82 (1.32)	92.66 (1.30)^a
Mean	51.96 (0.81)^b	60.11 (0.89)^a		0.56^a	0.50^b		89.43 (1.24)^b	91.61 (1.28)^a	
Factors	**E**	**M**	**E × M**	**E**	**M**	**E × M**	**E**	**M**	**E × M**
SE (d)	0.0143	0.0225	0.0319	0.0101	0.0159	0.0225	0.067	0.0106	0.015
CD	0.0297	0.047	0.0665	0.021	0.0332	0.0469	0.014	0.0221	0.0312

*Means followed by different letters differ significantly at $p \leq 0.05$ using the LSD test. Values in parentheses are transformed values.

E_1: Open conditions; **E_2**: Shade-net; **M_1**: FYM mix; **M_2**: Leaf mould mix; **M_3**: Vermicompost mix; **M_4**: Rice husk mix; **M_5**: Coir pith compost mix.

Table 6. Effect of growing environment and potting media on survival rate and root rot incidence of *K. blossfeldiana*

	Survival rate (%)			Root rot incidence (%)		
	E_1	E_2	Mean	E_1	E_2	Mean
M_1	92.43 (1.29)	94.52 (1.34)	93.47 (1.31)^c	8.29 (0.29)	9.06 (0.31)	8.68 (0.30)^a
M_2	94.01 (1.32)	95.80 (1.37)	94.90 (1.34)^b	7.49 (0.28)	8.86 (0.30)	8.17 (0.29)^a
M_3	95.58 (1.36)	97.47 (1.41)	96.52 (1.39)^a	7.00 (0.27)	8.10 (0.29)	7.55 (0.28)^b
M_4	91.45 (1.27)	93.24 (1.31)	92.34 (1.29)^c	6.03 (0.25)	6.55 (0.26)	6.29 (0.25)^c
M_5	97.64 (1.42)	97.00 (1.40)	97.32 (1.41)^a	6.71 (0.26)	7.86 (0.28)	7.28 (0.27)^b
Mean	94.22 (1.33)^b	95.60 (1.36)^a		7.10 (0.27)^b	8.09 (0.29)^a	
Factors	**E**	**M**	**E × M**	**E**	**M**	**E × M**
SE (d)	0.0081	0.0128	0.0182	0.0029	0.0046	0.0065
CD	0.0169	0.0268	0.0379	0.0061	0.0096	0.0135

*Means followed by different letters differ significantly at $p \leq 0.05$ using the LSD test. Values in parentheses are transformed values.

E_1: Open conditions; **E_2**: Shade-net; **M_1**: FYM mix; **M_2**: Leaf mould mix; **M_3**: Vermicompost mix; **M_4**: Rice husk mix; **M_5**: Coir pith compost mix.

Soil media properties

Potting media varied significantly in several key physical and chemical properties. pH ranged from slightly acidic in coir pith compost (6.83) to slightly alkaline in leaf mould (7.80). Electrical conductivity was highest in coir pith compost (0.82 dS/m), indicating greater soluble salts compared to other media. Water holding capacity was also highest in coir pith compost (55.05 %), while FYM recorded the lowest (35.67 %). Porosity followed a similar pattern, with coir pith compost showing the greatest porosity (70.00 %) and leaf mould the lowest (55.00 %). Bulk density ranged from 0.841 to 1.00 g cm^{-3}. Available nitrogen was highest in vermicompost (165.00 mg/kg) and available phosphorus and potassium were highest in coir pith compost (81.70 and 932.50 mg/kg, respectively). The detailed properties measured are provided (Table 7).

Table 7. Soil parameters of *K. blossfeldiana* potting media

Parameters	M_1	M_2	M_3	M_4	M_5
pH	7.59	7.80	7.20	7.57	6.83
EC (dS/m)	0.26	0.18	0.35	0.21	0.82
Water holding capacity (%)	35.67	29.60	42.50	32.95	55.05
Bulk density (g/cm^3)	0.85	0.90	0.95	0.841	1.00
Particle density (g/cm^3)	2.20	2.00	2.40	2.53	3.33
Porosity (%)	61.75	55.00	60.40	66.74	70.00
Available N (mg/kg)	102.20	123.20	165.00	138.60	86.80
Available P (mg/kg)	20.54	20.67	40.98	37.52	81.70
Available K (mg/kg)	280.00	220.00	350.00	107.50	932.50

M_1: FYM mix; **M_2**: Leaf mould mix; **M_3**: Vermicompost mix; **M_4**: Rice husk mix; **M_5**: Coir pith compost mix.

Discussion

The present investigation provides comprehensive insights into the optimisation of *K. blossfeldiana* cultivation through systematic evaluation of environmental conditions and potting media. The findings demonstrate clear advantages of controlled shade-net environments combined with organic-rich substrates, particularly coir pith compost, for enhancing ornamental quality and commercial viability.

Environmental effects on plant performance

The superior performance of *K. blossfeldiana* under shade-net conditions compared to open field cultivation reflects the species' evolutionary adaptation to partially shaded habitats. The 8.6 % increase in plant height under shade-net conditions aligns with previous research, which demonstrated that controlled photoperiod and reduced light stress enhance auxin-mediated stem elongation in ornamental succulents (16). The moderated light intensity (50 % shade) appears to optimise the balance between photosynthetic light capture and photoprotection, consistent with previous findings indicating that controlled shading reduces photooxidative damage while promoting chloroplast biogenesis (17).

The enhanced flowering performance under shade-net conditions, with 12 % higher flower production, supports earlier studies that reported that diffused light and moderated temperatures reduce heat-induced flower abortion in ornamental plants (18). The extended flower longevity (24.40 vs 21.93 days) under controlled conditions is particularly significant for commercial ornamental production, as it extends the marketing window and enhances consumer value. This finding corroborates previous studies, which proved that prolonged floral persistence reduces ethylene sensitivity in controlled environments (19). Interestingly, the earlier flowering initiation under open field conditions (79.67 vs 81.07 days) suggests a stress-induced reproductive response, consistent with the adaptive mechanisms described in previous research (20). This phenomenon reflects the plants' evolutionary strategy to accelerate reproduction when environmental conditions become challenging, though at the expense of overall plant quality and flower longevity.

Potting media effects and substrate optimisation

The consistent superiority of coir pith compost across morphological, physiological and flowering parameters can be attributed to its exceptional physical and chemical properties. With 70 % porosity and 55.05 % water holding capacity, coir pith compost provides an optimal balance between aeration and moisture retention, creating ideal rhizosphere conditions for *K. blossfeldiana*. These findings align with previous research, which demonstrated enhanced nutrient availability and root functionality in coir-based growing media for ornamental crops (21, 22). The exceptional potassium availability in coir pith compost (932.5 mg/kg) likely contributes significantly to its superior performance, particularly regarding flower longevity and overall plant quality. High potassium levels support enhanced membrane stability, improved water relations and extended flowering periods, as documented in *Helianthus annuus* (23). This nutritional advantage explains the 23 % longer flower duration achieved with coir pith compost compared to FYM.

The consistently poor performance of FYM across most parameters, despite its lower cost, reflects its limitations in providing optimal physical structure for succulent cultivation. The lower porosity and suboptimal water-holding characteristics of FYM -based media likely restricted root development and nutrient uptake, consistent with earlier findings which emphasised the importance of substrate decomposition status and physical properties in ornamental plant production (24).

Root system architecture and development

The dramatic differences in root system development among treatments underscore the critical importance of substrate selection in succulent cultivation. Coir pith compost consistently produced the most extensive root systems, with total root length exceeding 9000 mm compared to approximately 5200 mm in FYM treatments. This 75 % improvement in root development translates directly to enhanced nutrient and water uptake capacity, supporting superior above-ground performance. This root growth morphology was also supported by superior biomass gain of coir pith compost (93.84 %) in comparison to FYM potting mix (75.93 %). The superior root development in coir pith compost correlates with high porosity and optimal moisture conditions stimulate root branching and elongation in succulent species (25). The enhanced root surface area and volume in optimal treatments provide the foundation for sustained vegetative growth and flowering performance.

Physiological responses and adaptive mechanisms

The enhanced chlorophyll content under shade-net conditions (18 % increase in chlorophyll a) reflects optimised photosynthetic apparatus development under moderated light stress. This finding supports research that states that controlled environments enhance chloroplast biogenesis by mitigating photooxidative stress (26). The concurrent increase in carotenoid content (13 % higher under shade-net) indicates improved photoprotective capacity, consistent with previous trials on carotenoid metabolism regulation in *Kalanchoe* species (2). The superior biomass accumulation of dry weight under optimal conditions (69.85 % increase with shade-net and coir pith compost) highlights the critical role of controlled environments in optimising Crassulacean acid metabolism (CAM). Research indicates that environmental stability allows CAM plants to balance CO_2 fixation efficiency with water conservation more effectively (27). The contrasting root-to-shoot allocation patterns between environments provide insights into plant adaptive strategies. The higher root-to-shoot ratio under open field conditions (0.56) and FYM media (0.58) indicates compensatory root investment under environmental stress (28). This adaptive mechanism enhances resource acquisition capacity under limiting conditions but may compromise the shoot growth. In the FYM potting mix, the likely reduced nutrient content may physiologically induce greater root allocation as plants invest more in roots to improve resource capture, while shoot growth is relatively limited to balance overall growth (Table 7).

Disease resistance and plant health

The slight increase in root rot incidence under shade-net conditions (8.1 % vs 7.1 %) reflects the trade-off between optimal growth conditions and disease pressure (29). The higher humidity levels under controlled conditions, while beneficial for plant growth, create more favourable conditions for pathogen development. However, the overall low incidence rates across all treatments indicate successful disease management protocols. The superior disease resistance of rice husk medium (6.29 % root rot incidence) may be attributed to its physical properties and potential antimicrobial compounds, though this requires further investigation. The higher susceptibility of FYM treatments (8.68 % incidence) may reflect substrate decomposition status and organic matter quality, emphasising the importance of compost maturity in disease suppression (30).

Conclusion

This study demonstrates that under the conditions of this experiment, controlled shade-net cultivation combined with coir pith compost potting medium significantly enhances growth, flowering, physiological health and overall quality of *K. blossfeldiana*. Shade-net conditions improved plant height, leaf development, flower production, bloom longevity, water content and photosynthetic pigments. Coir pith compost provided optimal physical and chemical substrate properties fostering vigorous and healthy growth. Overall, the combination of shade-net cultivation and coir pith compost resulted in maximum flower production, longest flowering duration, highest biomass accumulation and superior chlorophyll content, highlighting its potential for practical and commercial cultivation. Future research should evaluate the suitability of the tested media and environment for other ornamental cacti and succulents, optimize improved environmental control for flowering in *K. blossfeldiana* and advance understanding of the molecular mechanisms underlying flowering in *K. blossfeldiana* and other CAM plants.

Acknowledgements

The authors gratefully acknowledge the valuable comments and constructive suggestions provided by the reviewers. The funding for research was provided through "Strengthening of Tamil Nadu Agricultural University Botanical Garden" under a grant-in-aid from the Government of Tamil Nadu.

Authors' contributions

RVP conceived the study, conducted the experiments, performed the primary analysis and drafted the manuscript. VAS guided the research, reviewed the methodology and critically revised the manuscript. DKL suggested methodological improvements, helped with experimental procedures and reviewed the manuscript. DV and PM provided research guidance and experimental procedures and reviewed the manuscript. KPA helped with the organisation of data and preparation of tables. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process:

During the preparation of this work, the authors used ChatGPT, version GPT-4 to assist with reference formatting, language editing and minor sentence improvements. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

1. García L, Pérez M, Rivero L, Rodríguez M, MarianaLa O, Padrón Y, et al. Protocol for *Kalanchoe blossfeldiana* Poelln. macropropagation. Biotecnología Vegetal. 2020;20:129-34.
2. Nascimento LB dos S, Casanova LM, Costa SS. Bioactive compounds from *Kalanchoe* genus potentially useful for the development of new drugs. Life. 2023;13:646. https://doi.org/10.3390/life13030646
3. Ilangaweera LAS, Naramada SEMH, Sajith NTM, Aashiq MNM, Hinas MNA. IOT based smart plant growing and caring platform for urban environments. In: 2024 9th International Conference on Information Technology Research (ICITR). IEEE; 2024. p. 1-6.
4. Góraj-Koniarska J, Stochmal A, Oleszek W, Mołdoch J, Saniewski M. Elicitation of anthocyanin production in roots of *Kalanchoe blossfeldiana* by methyl jasmonate. Acta Biologica Cracoviensia S Botanica. 2015;57:141-8. https://doi.org/10.1515/abcsb-2015-0007
5. Kahraman MU, Mendi YY, Karabıyık Ş, Lütken HV, Favero BT. *Kalanchoë* breeding: past, present and future. Ornamental Hortic. 2022;28:19-35. https://doi.org/10.1590/2447-536x.v28i1.2403
6. Bejaouı R, Özdemir G, Ellialtioğlu Ş. *In vitro* or *ex vitro* rooting and acclimatization of *Kalanchoe blossfeldiana* Poelln. shoots propagated by tissue culture technique. Turk J Agric Nat Sci. 2023;10:843-53. https://doi.org/10.30910/turkjans.1288919
7. Dhivya M, Sankaranarayanan R, Kumar GD. Physiological efficiency of succulents under different growing environments in tropical condition. Asian J Hortic. 2016;11(1):176-9.
8. Leonard RT, Nell TA. Effects of production and postproduction factors on longevity and quality of *Kalanchoe*. Acta Hortic. 2000;518:121-4. https://doi.org/10.17660/ActaHortic.2000.518.15
9. Seethepalli A, Dhakal K, Griffiths M, Guo H, Freschet GT, York LM. Rhizovision explorer: open-source software for root image analysis and measurement standardization. AoB Plants. 2021;13. https://doi.org/10.1093/aobpla/plab056
10. Lichtenthaler HK, Wellburn AR. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochem Soc Trans. 1983;11:591-2. https://doi.org/10.1042/bst0110591
11. González L, González-Vilar M. Determination of relative water content. In: Reigosa RMJ, editor. Handbook of Plant Ecophysiology Techniques. Dordrecht: Springer; 2001. p. 1-6. https://doi.org/10.1007/0-306-48057-3_14
12. Nelson JT, Adjuik TA, Moore EB, VanLoocke AD, Ramirez Reyes A, McDaniel MD. A simple, affordable, do-it-yourself method for measuring soil maximum water holding capacity. Commun Soil Sci Plant Anal. 2024;55:1190-204. https://doi.org/10.1080/00103624.2023.2296988
13. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Curr Sci. 1956;25:259-60.
14. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular 939. 1954.
15. Stanford G, English L. Use of the flame photometer in rapid soil tests for K and Ca. Agron J. 1949;41(9):446-7.
16. Yang J, Song J, Jeong BR. Low-intensity blue light supplemented during photoperiod in controlled environment induces flowering and antioxidant production in *Kalanchoe*. Antioxidants. 2022;11:811. https://doi.org/10.3390/antiox11050811
17. Kujawa A, Kornas J, Hanrieder N, González Rodríguez S, Hristov L, Fernández Solas Á, et al. Tomato yield under different shading levels in an agrivoltaic greenhouse in southern Spain. Agri Engineering. 2025;7:178. https://doi.org/10.3390/agriengineering7060178
18. Karban R, Rutkowski D, Murray NA. Flowers that self-shade reduce heat stress and pollen limitation. Am J Bot. 2023;110. https://doi.org/10.1002/ajb2.16109
19. Poonsri W. Effect of modified and controlled atmosphere storage on enzyme activity and senescence of *Dendrobium* orchids. Heliyon. 2020;6:e05070. https://doi.org/10.1016/j.heliyon.2020.e05070
20. Kazan K, Lyons R. The link between flowering time and stress tolerance. J Exp Bot. 2016;67:47-60. https://doi.org/10.1093/jxb/erv441
21. Fernando JAKM, Amarasinghe ADUS. Drying kinetics and mathematical modeling of hot air drying of coconut coir pith. Springerplus. 2016;5:807. https://doi.org/10.1186/s40064-016-2387-y
22. Chromkaew Y, Kaeomuangmoon T, Mawan N, Mukjang N, Khongdee N. Is coconut coir dust an efficient biofertilizer carrier for promoting coffee seedling growth and nutrient uptake? Peer J. 2023;11:e15530. https://doi.org/10.7717/peerj.15530
23. Elbohy NFSI. Impact of pre-harvest nitrogen and potassium fertilizers rate on growth and longevity and some chemical constituents of sunflower (*Helianthus annuus* L.) cut flowers. Middle East J Agric Res. 2017;6:1536-44.
24. Sendhilvel V, Rohini R, Manoranjitham SK. Suppression of seedling diseases of silk cotton (*Bombax ceiba*) and *Eucalyptus tereticornis* by *Pleurotus sajorcaju* decomposed coir pith and plant growth promoting rhizobacteria (PGPR) based potting media. Plant Sci Today. 2025;12. https://doi.org/10.14719/pst.6502
25. Chen J, Wu S, Dong F, Li J, Zeng L, Tang J, Gu D. Mechanism underlying the shading-induced chlorophyll accumulation in tea leaves. Front Plant Sci. 2021;12. https://doi.org/10.3389/fpls.2021.779819
26. van der Kooi CJ, Reich M, Löw M, De Kok LJ, Tausz M. Growth and yield stimulation under elevated CO_2 and drought: a meta-analysis on crops. Environ Exp Bot. 2016;122:150-7. https://doi.org/10.1016/j.envexpbot.2015.10.004
27. Nejad TS. Effect of drought stress on shoot/root ratio. World Acad Sci Eng Technol. 2011;81:598-600.
28. Rosas U, Zhou RW, Castillo G, Collazo-Ortega M. Developmental reaction norms for water stressed seedlings of succulent cacti. PLoS One. 2012;7:e33936. https://doi.org/10.1371/journal.pone.0033936
29. Madriz-Ordeñana K, Jørgensen HJL, Balan A, Sørensen DM, Nielsen KL, Thordal-Christensen H. Prevalence of soil-borne diseases in *Kalanchoe blossfeldiana* reveals a complex of pathogenic and opportunistic fungi. Plant Dis. 2019;103:2634-44. https://doi.org/10.1094/PDIS-12-18-2252-RE
30. De Corato U. Disease-suppressive compost enhances natural soil suppressiveness against soil-borne plant pathogens: a critical review. Rhizosphere. 2020;13:100192. https://doi.org/10.1016/j.rhisph.2020.100192

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.