PLANT SCIENCE TODAY
Vol 13(sp9): 1–13
https://doi.org/10.14719/pst.16637

eISSN 2348-1900
OPEN ACCESS

Research Article | Agriculture
2026, Volume 13, Issue sp9, pp. 1-13

Agro-industrial residues as sustainable potting media for growth and flowering of chrysanthemum (*Chrysanthemum morifolium* Ramat.)

Shilpa Shree K G[1]*, Tarak Nath Saha[2], Safeena S A[1], Naveen Kumar P[1] & Girish K S[2]

[1]ICAR-Indian Institute of Horticultural Research, Bengaluru 560 089, Karnataka, India

[2]ICAR-Directorate of Floricultural Research, Pune 411 036, Maharashtra, India

***Correspondence:** shilpa.kgs@gmail.com

Abstract

The effect of various agro-industrial residues as potting media on the growth and flowering of *Chrysanthemum morifolium* cv. 'Basanti' was evaluated in the present study during 2019, 2020 and 2021. Potting media combinations were prepared by separately mixing spent mushroom compost, burnt rice husk, bagasse, groundnut shells and soybean husk compost with cocopeat and perlite at a 1 : 1 : 1 (v/v/v) ratio. The experiments were laid out in a completely randomised design with 6 treatments and 4 replications. All the potting media combinations were analysed for initial chemical properties and nutrient content. Results revealed that spent mushroom compost : cocopeat : perlite (1 : 1 : 1) and soybean husk compost : cocopeat : perlite (1 : 1 : 1) were the most suited media for chrysanthemum plants. Average of 3 years data showed that chrysanthemum plants raised in soybean husk compost : cocopeat : perlite (1 : 1 : 1) exhibited significant increase in plant height (PH, 25.76 cm), plant spread (PS, 30.52 cm), secondary branches plant^{-1} (SB, 11.68), buds plant^{-1} (59.28) and flowers plant $^{-1}$ (56.12) compared to plants grown in control. Flower yield was significantly higher in chrysanthemum plants grown in media spent mushroom compost : cocopeat : perlite (1 : 1 : 1) (134 g plant^{-1}). Growth and flowering parameters were lowest in bagasse : cocopeat : perlite (1 : 1 : 1) and cocopeat : vermiculite : perlite (1 : 1 : 1) media. Multivariate analyses (principal component analysis (PCA) and correlation) also confirmed these results. Also, leaf nutrient content of chrysanthemum plants showed significant response to potting media combinations. Experimental results demonstrated that spent mushroom compost : cocopeat : perlite (1 : 1 : 1) and soybean husk compost : cocopeat : perlite (1 : 1 : 1) were most promising potting media combinations to produce potted chrysanthemum plants of cv. 'Basanti'. Their use as potting media enables sustainable recycling of agro-industrial residues.

Keywords: agro-industrial residues; flowering attributes; growth attributes; nutrient content of substrates; spent mushroom compost

Received: 08 July 2026. **Accepted:** 07 October 2026. **Available online:** Version 1.0: 20 November 2026.

Cite this article: Shilpa SKG, Tarak NS, Safeena SA, Naveen KP, Girish KS. Agro-industrial residues as sustainable potting media for growth and flowering of chrysanthemum (*Chrysanthemum morifolium* Ramat.). Plant Science Today. 2026; 13(sp9): 1-13. https://doi.org/10.14719/pst.16637

Introduction

The floriculture industry is growing into a versatile sector with substantial environmental and economic value. It has become a lucrative agribusiness driven by a rising demand for floricultural products because of increasing living standards and greater public desire for greener environments (1). In the floriculture industry, ornamental plant production comprising pot and garden plants is the second largest segment after cutting flowers with an increase in sales of 3.3 % and 2.7 % respectively (2, 3). Chrysanthemum (*Chrysanthemum morifolium* Ramat.) has multiple uses as cut flower, loose flower and pot plant. Pot mums are popular in international markets with high demand for decorating living spaces, seasonal gifting and commercial landscaping (4).

In potted plants production, potting media is one of the primary inputs and it represents the most significant expenditure constituting the second largest portion of total production costs after labour (5). A suitable growing media provides mechanical support for plants and maintains sufficient water-aeration balance essential for healthy plant development. Due to the limited volume of growing media in containerised production, inherently restricted root expansion and reduced gas exchange are common. To address these limitations, substrates are typically formulated as combinations of organic and inorganic constituents that optimise the physical and chemical properties required for better plant growth (6). Inorganic components of natural origin, such as sand and pumice and processed components such as perlite, vermiculite and rock wool, have become popular substrate components because of their contribution to enhancing substrate aeration and drainage. In addition, these inorganic materials are

suitable for reuse because of their long-term stability (7, 8). These properties make the inclusion of processed inorganic components crucial in substrate formulations, albeit in smaller fractions (9). Coir pith, compost, bark, vermicompost and wood fiber are among the organic materials already used commercially as peat alternatives (10). Several studies have reported cocopeat as a viable alternative substrate to peat for use in growing media (11, 12). In potted chrysanthemum, potting mixtures containing fibre materials, extruded bark and biochar at 30–50 % (v/v) have performed comparably to the peat based medium, demonstrating their potential as peat-reducing components (13). In potted ornamental sage, partial substitution of peat with wood fibre, coffee silverskin or brewers' spent grain at 20–40 % was reported to maintain the economic feasibility of production, further supporting the scope for agro-industrial residues in peat-reduced growing media (14). Utilising these organic substrates as alternatives to peat-based growing media has the potential to reduce the carbon footprint of the ornamental horticulture industry.

Agriculture and allied industries generate vast quantities of organic wastes, particularly in India, which is a significant producer of rice, sugarcane and mushrooms. Repurposing materials like spent mushroom compost, burnt rice husk, bagasse and ground nut shells as potting media for flower crops can reduce disposal issues while providing cost-effective, eco-friendly alternatives to peat-based substrates. Composting crop residues and using the resulting compost as growing media contributes to a circular economy by converting agricultural waste into a value-added substrate component, thereby recycling nutrients and reducing waste disposal. Considering the availability in terms of quantity, time and low cost, usage of many agro-industrial residues as growing media is gaining popularity. Soybean husk compost can be a valuable potting-media component because it is a leguminous, fibre-rich residue that, when composted, significantly contributes plant-available nutrients to the medium. It is reported that co-composting food waste with soybean meals at 20 % (w/w) produced compost with the highest macronutrient concentrations among tested additives (15). Previous studies have established the potential of spent mushroom compost (16), bagasse (17, 18), groundnut shell compost (19, 20) and rice husk ash (21) as components of growing media. These materials differ in their processing status and expected contribution to the potting medium. Spent mushroom compost and soybean husk compost were composted organic residues expected to contribute organic matter and plant nutrients (22, 23). In contrast, sugarcane bagasse and groundnut shells were uncomposed lignocellulosic residues expected to primarily modify physical properties such as pore space, aeration and water retention (24). Burnt rice husk is a thermally processed, silica-rich agricultural residue which might influence the physical properties, pH and electrical conductivity (EC) of substrate mixtures (25). However, information on comparative evaluation on the performance of these agro-industrial residues, when combined with cocopeat and perlite at a uniform ratio for potted chrysanthemum production is limited. Therefore, the present study evaluated agro-industrial residues such as spent mushroom compost, sugarcane bagasse, burnt rice husk, groundnut shells and soybean husk compost to determine their suitability as potting substrates for potted chrysanthemum production.

Materials and Methods

Experimental site and weather conditions

Pot experiments were carried out at ICAR-Directorate of Floricultural Research, Pune, India under open field conditions with different potting media combinations as treatments. The experiment was first conducted in 2019 (August–December) and repeated during the corresponding period in 2020 and 2021 for confirmation of results. The weather conditions during the cropping period differed over the 3 years. During 2019, the minimum and maximum air temperatures ranged from 16.42–21.66 °C and 28.91–31.36 °C, respectively, with minimum and maximum relative humidity of 54.00–76.15 % and 96.83–99.74 %. In 2019, the total rainfall was 530.5 mm received in 32 rainy days (26). In 2020, the minimum and maximum temperatures ranged from 12.10–22.20 °C and 24.70–31.60 °C, respectively, while the minimum and maximum relative humidity varied from 34.50–83.50 % and 79.00–99.20 %; a total of 585.0 mm rainfall was received over 34 rainy days (27). During 2021, the minimum and maximum temperatures ranged from 12.09–21.56 °C and 24.69–31.58 °C, respectively, with minimum relative humidity of 34.47–76.87 % and maximum relative humidity of 47.03–99.13 %; the rainfall received was 362.7 mm in 19 rainy days (28).

Experimental treatments and plant materials

Different agro-industrial residues were mixed with cocopeat and perlite and the resulting potting media combinations were formulated as mentioned in Table 1.

Potting media components were mixed in volumetric proportions and filled into 10" plastic pots which have an approximate internal volume of 9.5 L. Each pot was filled with the respective treatment media to a consistent level, leaving a 2 cm headspace from the rim, resulting in an available media volume of approximately 9.0 L pot^{-1}. Media quantity was standardised by volume across all treatments to ensure uniform root zone space despite differences in bulk density. Pots were arranged in rows with 45 cm maintained between adjacent rows to prevent canopy overlapping.

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

Table 1. Potting media combinations used in the experiments

Potting media (PM)	
Potting media 1 (PM1)	Groundnut shell : Cocopeat : Perlite (1 : 1 : 1)
Potting media 2 (PM2)	Burnt rice husk : Cocopeat : Perlite (1 : 1 : 1)
Potting media 3 (PM3)	Bagasse : Cocopeat : Perlite (1 : 1 : 1)
Potting media 4 (PM4)	Soybean husk compost : Cocopeat : Perlite (1:1:1)
Potting media 5 (PM5)	Spent mushroom compost : Cocopeat : Perlite (1 : 1 : 1)
Potting media 6 (PM6)	Cocopeat : Vermiculite : Perlite (1 : 1 : 1)

Care was taken to ensure uniform filling of media by repeated tapping of pots 3–4 times so that uniform compaction was maintained. The PM6 comprising cocopeat : vermiculite : perlite at 1 : 1 : 1 (v/v/v) was treated as control (Table 1). In the study, aged spent mushroom compost of *Agaricus bisporus* was used. One month old, rooted cutting of chrysanthemum cv. Basanti was transplanted into each of these pots during August month of 2019, 2020 and 2021. Rooted cuttings were propagated in the nursery at ICAR-Directorate of Floricultural Research, Pune and uniform cuttings of similar size and vigour were selected for transplanting in each year of the study. Basanti is a spray type chrysanthemum variety suitable for pot plants with yellow colored anemone flower type. Manual irrigation was done on demand based on substrate moisture status. Water was applied to container capacity when the top 5–10 cm depth of the medium reached a near-dry state, determined by loss of dark colouration and absence of free moisture on the finger surface. Each potted plant was supplied with foliar nutrition (1 % of nitrogen (N) : phosphorous (P) : potassium (K) 19 : 19 : 19) once in 15 days starting from 30 days after planting until bud initiation stage.

Analysis of potting media for chemical properties

Potting media was analysed for basic chemical properties to evaluate the factors affecting the growth of chrysanthemum plants. Prior to planting in 2019, air-dried, single composite samples from each potting media combination were used to determine initial macro and micronutrient content. Since identical media components were used to formulate the treatment combinations for the subsequent 2020 and 2021 experimental trials, this 2019 baseline analysis was used as the initial nutrient profile for the entire study duration. pH (1 : 10 dilution), EC (1 : 10 dilution) and total P were assessed following standard methods (29) and total N content was estimated using the micro-Kjeldahl method (30). Total K content was estimated to be using flame photometer (29). Total sulphur was estimated by barium chloride turbidometric method (31). Total calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) were estimated by Atomic Absorption Spectroscopy (32).

Growth and flowering attributes observations

Plant growth observations namely plant height (PH, cm) at full bloom, number of primary and secondary branches per plant, average plant spread (PS, cm) at full bloom and number of buds per plant at colour break stage of bud were recorded. Flowers were harvested when they had attained full size and counted at each harvest. At each harvest fresh weight of flowers was recorded and flower yield per plant (g plant^{-1}) was computed by summing the weights obtained across all successive harvests in the year 2019 throughout the blooming period. Flower diameter (cm), shoot fresh weight (g plant^{-1}) and root fresh weight (g plant^{-1}) were recorded at final harvest. Shoot and root fresh weight were recorded only during 2019. Leaf samples were collected replication wise at the beginning of flowering and analysed for macro and micronutrients content during 2019 by following the same analytical methods used for analysing macro and micronutrients content of media combinations.

Experimental design and statistical analysis

For each potting media treatment 4 replicates were maintained and for each replication 7 plants were maintained. The experiments were laid out in a completely randomised design (CRD). Prior to analysis, a combined analysis of variance (ANOVA) was performed to test the year × teatment interaction. Because a significant interaction ($p \leq 0.05$) was observed, the data for each individual year (2019, 2020 and 2021) were subjected separately to ANOVA. Prior to ANOVA, normality of model residuals and homogeneity of variance among treatments were assessed separately for each response attribute and experimental year using the Shapiro–Wilk and Levene's tests, respectively, at $p = 0.05$. Where tests indicated deviations from ANOVA assumptions, the relevant datasets were examined further before final statistical inference. Critical difference (CD) values for main and interaction effects were calculated using OPSTAT web application developed by Department of Mathematics and Statistics, CCS Haryana Agricultural University, Hisar. Treatment means were separated using Duncan's multiple range test (DMRT) at $p \leq 0.05$. The relationship between parameters was analysed using Pearson coefficient. Principal component analysis was performed using GRAPES (General Rshiny based Analysis Platform Empowered by Statistics) web application developed by the Department of Agricultural Statistics, Kerala Agricultural University, India.

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

Results

Chemical properties of potting media

The chemical properties of potting media combinations have been presented in Table 2. pH of potting media combinations varied widely from slightly acidic (6.03) in PM3 (bagasse : cocopeat : perlite at 1 : 1 : 1) to moderately alkaline (8.28) in PM2 (burnt rice husk : cocopeat : perlite 1 : 1 : 1). Spent mushroom compost : cocopeat : perlite (1 : 1 : 1) (PM 5) was the most saline media (2.63 dS m^{-1}) among all the potting media combinations while PM6 had the lowest EC (0.45 dS m^{-1}). Maximum total N (1.48 %) and P (0.43 %) contents were determined in potting media combination PM4 (soybean husk compost : cocopeat : perlite at 1 : 1 : 1) while K (3.70 %) was maximum in PM6 (cocopeat : vermiculite : perlite 1 : 1 : 1). Among secondary and micronutrients Ca (2.63%), sulphur (S) (1.22 %), Mn (442 mg kg^{-1}), Zn (144 mg kg^{-1}) and Cu (94 mg kg^{-1}) were highest in PM5. Maximum iron content (2008 mg kg^{-1}) was determined in PM6.

Growth attributes

Growth parameters viz., PH, PS and number of branches recorded during three years of experimentation revealed statistically significant differences with respect to different potting media (Table 3). The maximum PH was recorded in PM4 which did not differ significantly from the mean height recorded in chrysanthemum plants grown in PM5 during 2019 and 2021. Average of three years data showed an increment of 117.38 %, 112.23 % and 66.67 % in PH in PM4, PM5 and PM1 (groundnut shell : cocopeat : perlite at 1 : 1 : 1) compared to plants grown in the control medium (PM6). Plant height was lowest in PM3. The spread of chrysanthemum plants was significantly influenced by potting media. In all 3 years, PM4 and PM5 were statistically at par with each other with respect to PS.

Significant effect on branch count was recorded due to potting media. Average of 3 years data showed that number of primary and secondary branches varied from 2.17 to 3.22 and 4.99 to 11.68 respectively (Table 3). However, data recorded on mean primary number of branches in 2020 and 2021 showed no statistically significant differences. Increase in secondary branches produced was 134.07 %, 129.46 % and 94.39 % in plants raised in PM5, PM4 and PM1 respectively compared to plants grown in PM6 which is control.

Significantly higher shoot and root fresh biomass were observed in plants raised in PM4 (43.55 and 16.49 g $plant^{-1}$) and PM5 (32.93 and 12.86 g $plant^{-1}$) (Fig. 1). Shoot and root fresh biomass were minimum in plants grown in substrate combination PM3 and PM6.

It is noteworthy that 'Basanti' has been categorised as a moderately salt-tolerant chrysanthemum variety (33), which explains its superior performance in the PM5 having an EC of 2.63 dS m^{-1}. Moreover, chrysanthemums and carnations are reported to tolerate salinity up to 6 dS m^{-1} (34). Therefore, an EC of 2.63 dS m^{-1} falls within the moderate salinity range that moderately salt tolerant cultivars can withstand without significant yield reduction, whereas salt-sensitive varieties would exhibit reduced growth and flower production under similar conditions.

Flowering attributes

Data for flowering attributes revealed significant differences among the potting media treatments for number of buds per plant, number of flowers per plant and flower diameter (Table 4). Chrysanthemum plants grown in PM5 and PM4 recorded significantly higher number of buds and flowers per plant in all 3 years of experimentation. Lowest flower count per plant was recorded in PM6 (16.62) and PM3 (18.33). Average of 3 years data showed that flower diameter differed significantly among potting media treatments. Maximum flower diameter was observed in PM5 (4.26 cm) and PM4 (4.25 cm). Consequent to higher number of flowers per plant, significantly higher flower yield was recorded in chrysanthemum plants grown in potting media PM5 (134 g $plant^{-1}$) and PM4 (122 g $plant^{-1}$) (Fig. 1). Flower yield was minimum in plants raised on PM3 (23.89 g $plant^{-1}$).

Leaf macro and micronutrient content

The leaf nutrient content of chrysanthemum plants at the beginning of flowering responded significantly to the potting substrate combinations (Table 5). Significantly higher content of N (2.64%), P (0.69 %) and K (3.98 %) in leaf tissue were recorded in plants grown in PM4, PM5 and PM6 respectively. The lowest content of nitrogen was recorded in plants grown in PM3, P and K were lowest in plants grown in PM2. Among secondary nutrients, sulphur content in leaf tissues showed no statistically significant differences while highest content of Ca (1.52 %) and Mg (0.35 %) were determined in plants grown in PM5 and PM4 respectively. Calcium and Mg contents were lowest in plants grown in PM3.

Among micronutrients, highest Mn content was obtained in plants grown in PM5 (152 mg kg^{-1}) followed by PM6 (116 mg kg^{-1}). Significantly higher content of zinc (217 mg kg^{-1}) and copper (2265 mg kg^{-1}) were also noted in plants grown in PM5. However, no statistically significant differences were observed in the iron content of leaf tissues in plants due to different potting substrate combinations.

Discussion

Growth attributes

Enhanced plant growth observed in PM5 and PM4 compared to other media combinations could be attributed primarily to higher nutrient content (Table 2). Composition and nutritional status of the potting medium are important to produce good quality flowering plants (35). Nitrogen is a constituent of chlorophyll, amino acids, proteins and nucleic acids and therefore promotes leaf area development, photosynthetic capacity and biomass accumulation, whereas P is integral to nucleic acids, membrane phospholipids and ATP-mediated energy transfer, supporting root growth,

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

photosynthesis and carbohydrate metabolism (36, 37). In chrysanthemum, optimum nutrient supply increased PH, leaf fresh weight, root dry weight, stem dry weight and leaf dry weight, indicating that adequate nutrient availability promotes vegetative growth and biomass partitioning (38). Hence, soybean husk compost and spent mushroom compost could enhance PH, spread, branching and biomass by supplying essential nutrients and supporting sustained nutrient availability.

Prior research aligns with these findings, for example, enhanced growth of ornamental plants was reported when pruning wastes compost was mixed with spent mushroom compost (39) and better growth of pistachio seedlings was reported in growing media containing adequate nutrients (40). The improvement was attributed to the inherent nutrient richness of spent mushroom substrate due to mixing of poultry manure and calcium sulphate ($CaSO_4$) (41).

Our results are also in conformity with the study which reported improved PH, leaf area, fresh weight, dry weight and index of seedling quality in tomato and cucumber when spent mushroom compost was used as a growing medium component along with vermiculite and perlite (42). Higher dry matter accumulation in shoot and root is an indication of better utilisation of nutrients by chrysanthemum plants (43). Spent mushroom compost and soybean husk compost are a rich source of Ca, S, N, P (Table 2) and the ability of spent mushroom compost to bind mineral particles together to improve aeration and water-holding capacity is documented (44).

Table 2. Chemical properties and nutrient content of potting substrate combinations

Treatments	pH	EC (dS m^{-1})	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
PM1	7.87	0.91	0.99	0.11	0.60	1.01	0.45	0.29	1680	136	37	86
PM2	8.28	0.75	0.25	0.04	0.45	2.24	0.38	0.23	1572	130	39	19
PM3	6.03	1.92	0.62	0.11	0.48	0.67	0.42	0.12	1726	124	44	21
PM4	7.13	1.37	1.48	0.43	0.85	1.43	0.80	0.34	1814	402	116	18
PM5	7.34	2.63	1.09	0.33	0.83	2.63	0.69	1.22	1788	442	144	94
PM6	7.18	0.45	0.74	0.09	3.70	1.38	0.83	0.57	2008	372	86	82

PM1–PM6: potting media treatments; pH: potential of hydrogen; EC: electrical conductivity; N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; S: sulphur; Fe: iron; Mn: manganese; Zn: zinc; Cu: copper. *Data values represent initial baseline chemical properties determined from a single composite sample from each potting media combination prior to planting.

Table 3. Effect of different potting media on growth attributes of chrysanthemum cv. Basanti

Treatments	Plant height (cm)				Plant spread (cm)				Number of primary Branches per plant				Number of secondary branches per plant			
	2019	2020	2021	Mean (3 years)	2019	2020	2021	Mean (3 years)	2019	2020	2021	Mean (3 years)	2019	2020	2021	Mean (3 years)
PM1	21.26^{b}	18.9^{abc}	19.08^{b}	19.75	26.33^{b}	20.43^{c}	25.43^{b}	24.06	3.65^{ab}	2.10	2.54	2.76	14.24^{a}	7.60^{b}	7.24^{b}	9.69
PM2	14.48^{c}	14.10^{bc}	13.29^{c}	13.96	14.93^{c}	14.62^{d}	15.24^{c}	14.93	3.01^{bc}	2.05	2.34	2.47	6.19^{b}	4.89^{c}	7.72^{b}	6.27
PM3	11.92^{d}	12.45^{c}	11.19^{c}	11.85	7.71^{d}	8.67^{e}	7.29^{d}	7.89	2.50^{c}	2.00	2.01	2.17	4.05^{b}	4.75^{c}	7.22^{b}	5.34
PM4	27.89^{a}	24.30^{ab}	25.10^{a}	25.76	32.33^{a}	28.33^{b}	30.90^{a}	30.52	4.19^{a}	2.38	3.05	3.21	13.29^{a}	11.22^{a}	10.53^{a}	11.68
PM5	24.30^{a}	26.66^{a}	24.48^{a}	25.15	27.90^{b}	32.00^{a}	27.48^{b}	29.13	3.91^{ab}	2.43	3.33	3.22	12.52^{a}	9.70^{a}	12.12^{a}	11.45
PM6	12.81^{d}	12.65^{c}	13.19^{c}	12.88	8.24^{d}	8.14^{e}	7.81^{d}	8.06	2.26^{c}	2.00	3.26	2.51	4.33^{b}	4.36^{c}	6.28^{b}	4.99
CV (%)	5.84	13.69	10.55		6.79	9.12	8.37		14.68	12.40	11.70		12.54	13.20	14.40	
CD ($p \leq 0.05$)																
Year (Y)	1.075				NS				0.402				0.672			
Treatments (T)	5.846				6.49				NS				4.424			
Y × T	2.242				4.309				1.05				2.482			

*Values followed by the same letter(s) in a column are not significantly different at $p \leq 0.05$ according to Duncan's Multiple Range Test. CV: coefficient of variation (%), CD: critical difference at 5 % level of significance. NS indicates that treatment effects were non-significant ($p > 0.05$). Values in the "Mean (3 years)" column are arithmetic means calculated from the corresponding treatment means recorded during the three experimental years.

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

Differences in chrysanthemum growth among the potting media combinations may be related to the contrasting chemical and physical functions of the tested agro-industrial residues. The composted substrates, namely spent mushroom compost and soybean husk compost, likely contributed to enhanced nutrient supply and organic matter mediated nutrient retention. Spent mushroom substrate has been reported to possess higher organic matter, water-holding capacity and EC (22). Conversely, the unprocessed lignocellulosic materials, sugarcane bagasse and groundnut shells, would be expected to contribute principally to pore continuity and aeration, but their comparatively high carbon (C) : N ratio may restrict immediate nutrient availability if used without adequate composting or supplementary fertilisation (24).

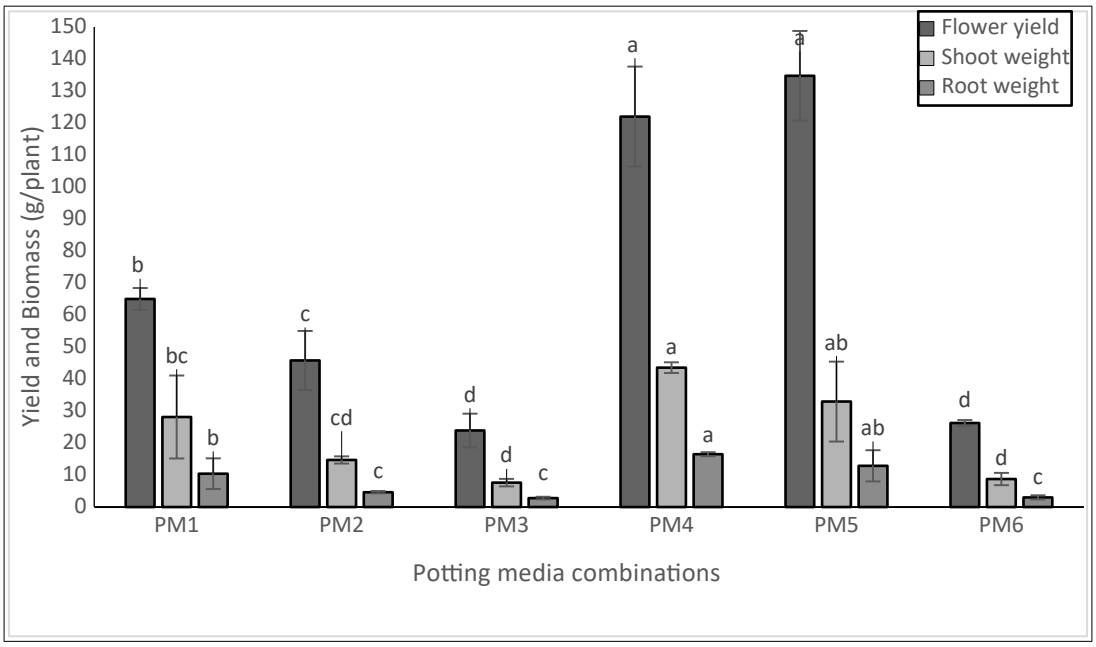


Fig. 1. Effect of different potting media treatments on flower yield, shoot fresh weight and root fresh weight. Vertical bars represent the standard error of replication means. Means followed by the same lowercase letters within the same parameter cluster are not significantly different ($p \leq 0.05$) according to Duncan's multiple range test (DMRT).

Table 4. Effect of different potting media on flowering attributes of chrysanthemum cv. Basanti

Treatments	Number of buds per plant				Number of flowers per plant				Flower diameter (cm)			
	2019	2020	2021	Mean (3 years)	2019	2020	2021	Mean (3 years)	2019	2020	2021	Mean (3 years)
PM1	38.34^{b}	31.38^{b}	30.33^{b}	33.35	32.67^{c}	25.71^{c}	24.66^{c}	27.68	3.92^{ab}	4.08^{a}	3.83	3.94
PM2	35.52^{b}	28.06^{b}	25.33^{bc}	29.64	29.86^{c}	22.39^{c}	19.67^{cd}	23.97	3.54^{b}	3.54^{b}	4.27	3.78
PM3	20.07^{c}	23.54^{b}	20.67^{cd}	21.43	15.43^{d}	18.9^{c}	16.03^{d}	16.79	3.52^{b}	3.53^{b}	4.17	3.74
PM4	67.82^{a}	57.35^{a}	52.67^{a}	59.28	64.67^{a}	54.2^{a}	49.49^{b}	56.12	4.29^{a}	4.22^{a}	4.23	4.25
PM5	58.62^{a}	46.1^{a}	59.67^{a}	54.80	55.81^{b}	43.29^{b}	56.86^{a}	51.99	4.21^{a}	4.23^{a}	4.33	4.26
PM6	20.04^{c}	20.28^{b}	16.67^{d}	19.00	16.48^{d}	16.71^{c}	13.10^{d}	15.43	3.53^{b}	3.52^{b}	4.20	3.75
CV (%)	7.95	11.7	10.5		7.42	15.5	13.01		7.34	6.4	6.83	
CD ($p \leq 0.05$)												
Year (Y)	2.74				0.71				0.21			
Treatment (T)	10.31				6.37				NS			
Y × T	10.40				2.24				0.61			

*Values followed by the same letter(s) in a column are not significantly different at $p \leq 0.05$ according to Duncan's Multiple Range Test. CV: coefficient of variation (%), CD: critical difference at 5 % level of significance. NS indicates that treatment effects were non-significant ($p > 0.05$). Values in the "Mean (3 years)" column are arithmetic means calculated from the corresponding treatment means recorded during the three experimental years.

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

Table 5. Leaf nutrient content of chrysanthemum plants grown in different potting media

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
PM1	2.50^{ab}	0.29^{d}	1.58^{e}	1.02^{cd}	0.31^{bc}	0.28	637.5	104.5^{cd}	77.5^{e}	1296^{c}
PM2	2.31^{bc}	0.14^{e}	1.50^{e}	1.48^{a}	0.39^{a}	0.32	632.0	98.0^{d}	63.0^{f}	1265^{c}
PM3	2.10^{c}	0.48^{c}	2.30^{c}	0.83^{d}	0.28^{cd}	0.30	638.0	105.0^{cd}	88.0^{d}	1274^{c}
PM4	2.64^{a}	0.52^{b}	1.95^{d}	1.29^{ab}	0.35^{ab}	0.25	628.5	109.0^{bc}	181.5^{b}	1107^{d}
PM5	2.53^{ab}	0.69^{a}	2.65^{b}	1.52^{a}	0.25^{d}	0.31	630.0	152.0^{a}	217.0^{a}	2265^{a}
PM6	2.40^{ab}	0.28^{d}	3.98^{a}	1.18^{bc}	0.34^{b}	0.25	644.0	116.0^{b}	113.0^{c}	2068^{b}
SEm±	0.09	0.01	0.05	0.09	0.02	NS	NS	3.01	1.96	54.04
CD at $p \leq 0.05$	0.28	0.02	0.15	0.28	0.07			9.50	6.16	170.29
CV (%)	6.37	3.3	3.44	7.54	8.90	7.30	8.30	4.57	2.74	6.05

PM1–PM6: potting media treatments; N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; S: sulphur; Fe: iron; Mn: manganese; Zn: zinc; Cu: copper; SEm(±): standard error of mean; CV: coefficient of variation (%);CD: critical difference at 5 % level of significance. NS indicates that treatment effects were non-significant ($p > 0.05$). *Values present replicated means of four independent determinations. Values followed by the same letter(s) in a column are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

Although physical properties such as bulk density, total porosity, water-holding capacity and air-filled porosity were not measured in the present study, published data indicate that the tested residue types can substantially alter these characteristics in growing media mixtures. For spent mushroom compost, a bulk density of 0.41 g cm^{-3}, water-holding capacity of 65.04 %, total pore space of 73.13 % and air-filled porosity of 8.03 % has been reported and when spent mushroom compost was combined with peat and perlite, these values varied from 0.15 to 0.29 g cm^{-3}, 71.41 to 75.41 %, 78.07 to 87.06 % and 6.64 to 11.64 %, respectively, depending on the mixture composition (45). For rice husk ash, a bulk density of 0.20 g cm^{-3}, total porosity of 67.02 %, water holding porosity of 45.26 % and aeration porosity of 22.10 % have been reported (25), confirming its potential contribution as a lightweight, porous component in soilless media. Direct published information on the physical properties of soybean husk compost as a potting-medium component is limited. Therefore, values reported for other mature agro-industrial composts may be used as comparative benchmarks. For example, composts produced from different agri-food residues showed bulk density of 0.14 –0.20 g cm^{-3}, total porosity of 89–92% and volumetric water-holding capacity of 56–62%; these values indicate that mature composts can provide a low-density and highly porous fraction in potting media mixtures (46). The favourable performance of composted substrates : cocopeat : perlite combinations (PM4 and PM5) may therefore have resulted from a balanced combination of nutrient availability supplied by compost, moisture retention supplied principally by cocopeat and root-zone aeration maintained by perlite.

Flowering attributes

Higher number of buds and flowers recorded in PM5 and PM4 could be attributed to better growth parameters recorded in these treatment combinations. Enhanced growth parameters contribute to the synthesis of additional plant metabolites leading to increased flower production (47, 48). This direct correlation between enhanced flower yield due to increased growth parameters has been previously documented in other floriculture crops like carnation (49). In addition to ornamental plants, the nutrient supplying capacity of spent mushroom substrate and its effect on yield increase is well established in vegetable crops as well. A 38 % increase in yield of sweetcorn cob and 82–96 % in cabbage yield was reported due to various levels of spent mushroom substrate applications when inorganic fertiliser was not used (50). These findings emphasise the high fertiliser value and yield promoting efficacy of the spent mushroom substrate.

The higher flower yield observed in PM5 may be partly associated with the higher concentrations of Ca, S, Zn and Mn in the medium, which could have contributed to enhanced flowering and flower yield. Calcium plays an important role in maintaining cell-wall structure, membrane stability and functions as a key intracellular signal, thereby contributing to plant growth and reproductive development (51). In hydroponically grown chrysanthemum, it has been reported that plants receiving an adequate Ca supply produced bigger inflorescences compared to the ones supplied with lower levels of Ca (52). Zinc serves as a cofactor for numerous enzymes involved in photosynthetic activity, carbohydrate metabolism, reproductive development and most critically, auxin biosynthesis (53) which directly influences flowering attributes in plants (54). This enzymatic activation is supported by S, which drives the synthesis of essential amino acids and chlorophyll, preventing premature foliar senescence and maintaining the photosynthetic capacity needed to sustain heavy floral flushes (55). Significantly improved flowering and yield attributes such as single flower weight, flower yield per plant and flower yield per square meter has been reported in *C. morifolium* cv. Mayur 5 due to foliar application of Zn and Fe (56). Adequate Mn supply is also important during reproductive development and Mn

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

imbalance can adversely affect flowering, carbohydrate metabolism and reproductive tissue function (57). In chrysanthemum, application of micronutrients including Mn has been reported to improve flowering and flower yield, although the highest response was obtained with a combined micronutrient treatment rather than Mn alone (58). These results provide direct evidence that adequate Ca, S, Zn and Mn nutrition can contribute to enhanced flower yield in chrysanthemum.

The superior growth and flowering obtained with spent mushroom compost containing media is consistent with recent studies showing that composted spent mushroom substrate, used at low to moderate proportions in peat-based mixtures, can improve vegetative growth and flowering of ornamental crops such as *Celosia cristata* L., *Torenia fournieri* Linden ex E.Fourn. (59), snapdragon, scarlet sage (60) and it has worked well in soilless media for greenhouse potted basil production as a partial substitute for peat (61). The benefits may be due to its residual nutrient content, organic matter and favourable water-retention characteristics. But, blending at appropriate proportions is essential because spent mushroom compost can increase soluble salt concentration of substrate as evidenced in the present study as well. Nutrient rich compost based potting media containing soybean husk compost or spent mushroom compost can enhance chrysanthemum growth when used at a balanced proportion with materials such as cocopeat and perlite, because they simultaneously supply mineral nutrients and improve the root-zone environment.

Correlation analysis underscored the key role of nutrient content of potting media on growth and flowering parameters of chrysanthemum observed in the present study (Table 6). A highly significant and positive correlation was observed between N, P, Ca, Mn, Zn content of potting substrate combinations and PH, PS, primary branches (PB), secondary branches (SB) and number of flowers per plant. Principal component analysis (PCA) revealed distinctive responses in growth and flowering parameters of chrysanthemum to potting substrate combinations (Fig. 2). The PCA biplot clearly positioned PM4, PM5 and PM1 in association with growth and flower attributes supporting their superior performance. PM4 showed strong associations with flower yield, number of buds and flower per plant. PM5 and PM1 clustered closely with PH, PS, PB, SB and flower diameter.

Growth and flowering were comparatively lower in 2020 than in 2019, which coincided with distinct differences in prevailing weather conditions that year. The cropping period of 2020 (August–December) received the highest total rainfall (585.0 mm) and number of rainy days (34) among the 3 years, with rainfall particularly concentrated in September–October (454.6 mm) when the crop was in its active vegetative and flower bud initiation phase. Maximum relative humidity during this period reached 98.5–99.2 %, conditions conducive to waterlogging stress, nutrient leaching from the potting media and increased incidence of humidity favoured diseases like botrytis blight, septoria leafspot (62, 63, 64) all of which can reduce photosynthetic efficiency, thereby likely limiting the photosynthates availability required for vegetative and reproductive growth (65). In addition, minimum temperatures during November–December 2020 (12.10–12.60 °C) were markedly lower than in 2019 (16.42–16.93 °C) and fell below the optimum night temperature range of 15–17 °C reported for chrysanthemum flower bud initiation, below which bud initiation and development are retarded (66, 67), which may have further reduced bud and flower production. Although the year × treatment interaction was significant, it was quantitative rather than qualitative, since the best-performing potting media remained the same (PM4 and PM5) across all 3 years, with the interaction reflecting weather-driven differences in the magnitude, rather than the ranking of treatment response.

Leaf macro and micronutrient content

Leaf nutrient content of chrysanthemum plants indicated a significant difference due to different potting substrate combinations except S and Fe. High nutrient concentration in leaf tissues of plants grown in PM4 and PM5 could be linked to the fertility status of potting media. High nutrient content and favourable physico-chemical conditions of potting substrate combinations can aid in better nutrient uptake and nutrient utilisation resulting in improved shoot growth and leaf nutrient content in chrysanthemum (43). Agro-industrial composts contribute organic matter and plant nutrients and can alter potting medium bulk density, porosity, water-holding capacity, pH, EC and nutrient availability (24). Experimental evidence reports that varying proportions of organic residues in a potting medium can change pH, EC, macro and micronutrient concentrations, with corresponding changes in plant nutrient content and growth (68). In addition to nutrient content, physico-chemical properties of substrate combinations also influence plant growth. Substrate bulk density and particle size distribution are directly related to aeration and drainage and influence plant growth (69, 70). A well aerated medium can support root function and plant growth by influencing nutrient availability (71). Improved macronutrient contents in ornamental plants with the use of spent mushroom compost was well established (60). Spent mushroom compost of *Agaricus bisporus* up to 75 % v/v along with peat resulted in good growth of courgette and pepper seedlings and was found to positively affect nutrient contents of the seedlings (72). Maximum concentrations of Fe, Zn, Mn and Cu were reported in eggplant seedlings grown in fresh spent mushroom compost (73).

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

Table 6. Correlation matrix showing the relationship between growth attributes of chrysanthemum and chemical properties of potting media combinations

	PH	PS	PB	SB	FN	pH	EC	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
PH	1																
PS	0.970**	1															
PB	0.967**	0.938**	1														
SB	0.969**	0.986**	0.936**	1													
FN	0.986**	0.980**	0.961**	0.985**	1												
pH	0.213^{NS}	0.239^{NS}	0.190$^{N}_{S}$	0.229^{NS}	0.196^{NS}	1											
EC	0.568*	0.430^{NS}	0.513$^{N}_{S}$	0.433^{NS}	0.493^{NS}	-0.085$^{N}_{S}$	1										
N	0.749**	0.669*	0.782**	0.663*	0.722**	-0.235$^{N}_{S}$	0.533^{NS}	1									
P	0.891**	0.794**	0.911**	0.772**	0.855**	0.191^{NS}	0.617*	0.791**	1								
K	-0.107$^{N}_{S}$	-0.210$^{N}_{S}$	0.047$^{N}_{S}$	-0.201$^{N}_{S}$	-0.150$^{N}_{S}$	0.070^{NS}	-0.022$^{N}_{S}$	0.172$^{N}_{S}$	0.126$^{N}_{S}$	1							
Ca	0.765**	0.671*	0.817**	0.659*	0.751**	0.173^{NS}	0.425^{NS}	0.701**	0.933**	0.130^{NS}	1						
Mg	0.569*	0.432^{NS}	0.649*	0.436^{NS}	0.536^{NS}	-0.044$^{N}_{S}$	0.419^{NS}	0.764**	0.771**	0.617*	0.776**	1					
S	0.656*	0.535^{NS}	0.773**	0.560*	0.607*	0.200^{NS}	0.501^{NS}	0.631*	0.779**	0.466^{NS}	0.771**	0.754**	1				
Fe	0.314^{NS}	0.168^{NS}	0.381$^{N}_{S}$	0.182^{NS}	0.274^{NS}	-0.318$^{N}_{S}$	0.480^{NS}	0.699**	0.520$^{N}_{S}$	0.539^{NS}	0.534$^{N}_{S}$	0.841**	0.527$^{N}_{S}$	1			
Mn	0.788**	0.688**	0.875**	0.688**	0.769**	-0.007$^{N}_{S}$	0.485^{NS}	0.811**	0.926**	0.293^{NS}	0.934**	0.863**	0.864**	0.619*	1		
Zn	0.766**	0.659*	0.834**	0.651*	0.731**	-0.232$^{N}_{S}$	0.678*	0.842**	0.858**	0.227^{NS}	0.782**	0.778**	0.805**	0.666*	0.911**	1	
Cu	0.323^{NS}	0.166^{NS}	0.322$^{N}_{S}$	0.200^{NS}	0.194^{NS}	0.289^{NS}	0.462^{NS}	0.246$^{N}_{S}$	0.385$^{N}_{S}$	0.364^{NS}	0.334$^{N}_{S}$	0.395^{NS}	0.663*	0.358$^{N}_{S}$	0.363^{NS}	0.390$^{N}_{S}$	1

PH: plant height; PS: plant spread; PB: primary branches; SB: secondary branches; FN: flower number per plant; pH: potential of hydrogen; EC: electrical conductivity; N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; S: sulphur; Fe: iron; Mn: manganese; Zn: zinc; Cu: copper; NS: not significant; *p* * 0.05: significant at the 5 % level; *p* ** 0.01: significant at the 1 % level.

Conclusion

The present investigation demonstrated that composted agro-industrial residues, such as spent mushroom compost and soybean husk compost can be effectively utilised as potting media substrates in combination with cocopeat and perlite at 1 : 1 : 1 (v/v/v) ratio for the production of potted chrysanthemum plants of cv. 'Basanti'. From a commercial perspective, these findings provide chrysanthemum growers with a scientific basis for evaluating locally available recycled organic residues as partial components of potting media, with the potential to reduce dependence on non-renewable peat resources. Their incorporation offers a feasible approach for successful potted chrysanthemum production while promoting nutrient recycling within the circular economy of ornamental horticulture.

However, these substrates can be heterogeneous in their chemical properties and nutrient composition depending on their source origin and storage conditions. Also, their commercial availability relative to production requirement remains insecure. In addition, spent mushroom compost has higher salt content which limits its application for salt sensitive crops. Therefore, investigations into pre-treatment washing or leaching techniques will be crucial to safely managing the elevated salt content of spent mushroom compost. In case of transformed residue such as compost, slight change in composting duration, environmental conditions and composting efficiency may result in significant differences in the properties of compost even when prepared from a single material origin. Therefore, it is essential to conduct initial quantitative assessment of the chemical properties of the substrates and standardise mixing ratio of agro residues to maintain suitable growing conditions for target crops. Future research should focus on optimising long term storage protocols to address material heterogeneity and evaluating performance across diverse climatic conditions.

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

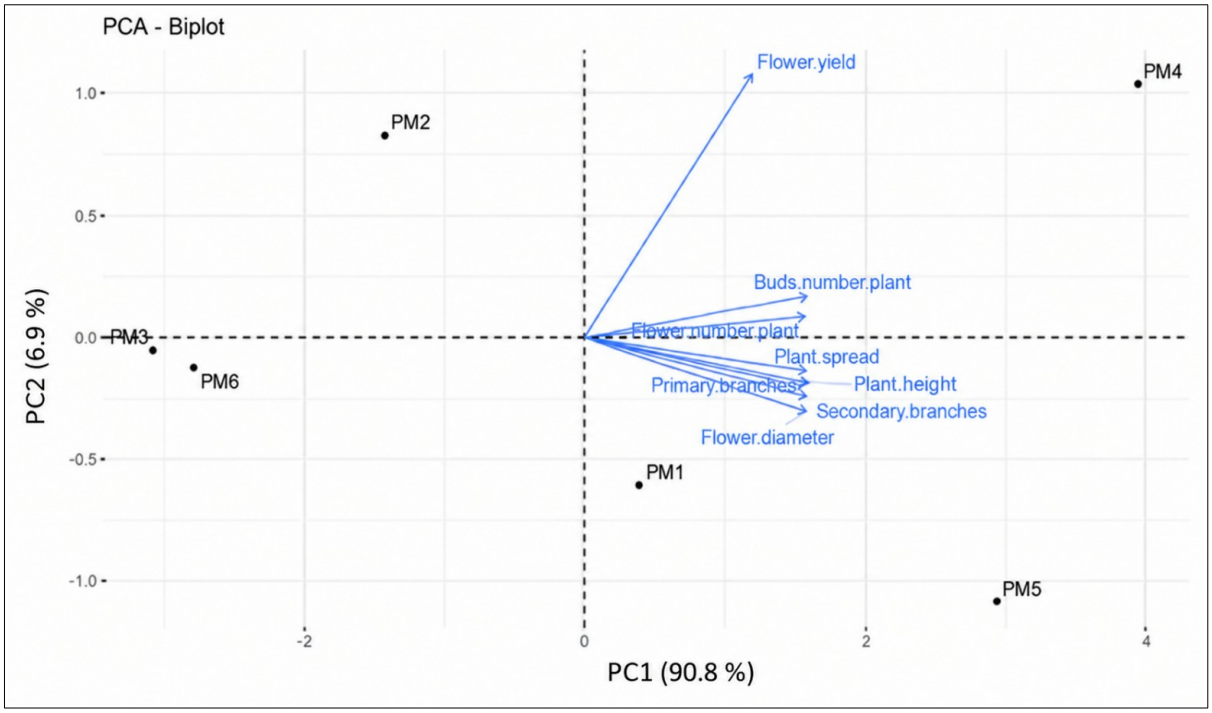


Fig. 2. Principal component analysis (PCA) biplot of chrysanthemum cv. Basanti showing multivariate relationships among growth traits, flowering traits and potting media combinations. Potting media treatments (PM1–PM6) are represented by solid black dots, while plant trait variables are denoted by directional blue vector lines. The proximity between black dots indicates similarities among treatment combinations and the direction of blue lines reflects the loading strength and correlation of specific plant attributes across the principal components.

Acknowledgements

The authors acknowledge Indian Council of Agricultural Research, New Delhi for financial support and ICAR-Directorate of Floricultural Research, Pune for institutional support in conducting this research work.

Authors' contributions

SSKG contributed to conceptualisation, investigation, analysis and interpretation of data and writing the original draft. TNS contributed to supervision of the experimentation and validation. SSA contributed to revising the manuscript for important intellectual content. NKP contributed to revising the manuscript for important intellectual content. GKS contributed to supervision of the experimentation. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests 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 have used Perplexity for references formatting, improving scientific wording and clarifying statistical reporting. 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. Vahoniya D, Panigrahy SR, Patel D, Patel J. Status of floriculture in India: with special focus to marketing. Int J Pure Appl Biosci. 2018;6(2):1434–8. https://doi.org/10.18782/2320-7051.6487
2. Kachru RP. Agro-processing industries in India: growth, status and prospects. Indones J Agric Sci. 2010;13(2):114–26.
3. Royal Flora Holland. Annual report 2019. Aalsmeer (NL): Coöperatie Royal Flora Holland UA; 2020. Royal Flora Holland
4. Singh AK, Singh R, Kumar R, Gupta AK, Kumar H, Rai A, et al. Evaluating sustainable and environment friendly growing media composition for pot mum (*Chrysanthemum morifolium* Ramat.). Sustainability. 2023;15(1):536. https://doi.org/10.3390/su15010536
5. Pascual JA, Ceglie F, Tuzel Y, Koller M, Koren A, Günay A, et al. Organic substrate for transplant production in organic nurseries: a review. Agron Sustain Dev. 2018;38(3):35. https://doi.org/10.1007/s13593-018-0508-4

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

6. Barrett GE, Alexander PD, Robinson JS, Bragg NC. Achieving environmentally sustainable growing media for soilless plant cultivation systems: a review. Sci Hortic. 2016;212:220–34. https://doi.org/10.1016/j.scienta.2016.09.030

7. Gruda NS. Advances in soilless culture and growing media in today's horticulture—an editorial. Agronomy. 2022;12(11):2773. https://doi.org/10.3390/agronomy12112773

8. Kaudal BB, Chen D, Madhavan DB, Downie A, Weatherley A. An examination of physical and chemical properties of urban biochar for use as growing media substrate. Biomass Bioenergy.2016;84:49–58. https://doi.org/10.1016/j.biombioe.2015.11.012

9. Gruda NS, Hirschler O, Stuart J. Peat reduction in horticulture: an overview of Europe. Acta Hortic. 2024;1391:545–60. https://doi.org/10.17660/ActaHortic.2024.1391.75

10. Gruda NS. Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. Agronomy. 2019;9(6):298. https://doi.org/10.3390/agronomy9060298

11. Evans MR, Stamps RH. Growth of bedding plants in sphagnum peat and coir dust-based substrates. J Environ Hortic. 1996;14(4):187–90. https://doi.org/10.24266/0738-2898-14.4.187

12. De Kreij C, Van Leeuwen GJL. Growth of pot plants in treated coir dust as compared to peat. Commun Soil Sci Plant Anal. 2001;32(13–14):2255–65. https://doi.org/10.1081/CSS-120000281

13. Nguyen VTH, Eveleens-Clark B, Vogelsang J, Blok C. Circular growing media-growth trials in potted chrysanthemum: practical conditions trials (2023 and 2024) at WUR research station. Report no. WPR-1452. Wageningen (The Netherlands): Wageningen Plant Research; 2025. https://doi.org/10.18174/696674

14. Massa D, Sdao AE, De Lucia B, De Boni A, Ottomano Palmisano G, Roma R. Peat partial replacement: life cycle assessment and eco-efficiency in potted ornamental sage cultivation. Sustainability. 2025;17(24):11238. https://doi.org/10.3390/su172411238

15. Iewkittiyakorn J, Savisai T, Khunthongkaew P, Chungsiriporn J. Nutrient enrichment of food waste compost using agricultural residues. Asia Pac J Sci Technol. 2026;31(2):APST–31. https://doi.org/10.22299/apst.2026.280165

16. Ghasemi S, Kalateh Jari S, Diyanat M. Effects of spent mushroom compost and *Sargassum* on growth and physiology of *Philodendron* 'Prince of Orange'. N Z J Crop Hortic Sci. 2026;54:e70140. https://doi.org/10.1002/nzc2.70140

17. Najarian A, Souri MK. Influence of sugar cane compost as potting media on vegetative growth and some biochemical parameters of *Pelargonium* × *hortorum*. J Plant Nutr. 2020;43:2680–4. https://doi.org/10.1080/01904167.2020.1783305

18. Thiessen M, Fields JS, Abdi D, Beasley J. Sugarcane bagasse is an effective soilless substrate amendment in quick-turn *Osteospermum* production. HortScience. 2023;58:1170–7. https://doi.org/10.21273/HORTSCI17286-23

19. Omidi J, Abdolmohammadi S, Hatamzadeh A, Mahboub Khomami A. Application of peanut shell composts in replacement with peat on growth indices and physical and chemical properties of violet growth media (*Viola* spp.) in outdoor. Front Environ Microbiol. 2017;3(5):68–72. https://doi.org/10.11648/j.fem.20170305.11

20. Khomami AM, Padasht MN, Lahiji AA, Mahtab F. Reuse of peanut shells and *Azolla* mixes as a peat alternative in growth medium of *Dieffenbachia amoena* 'Tropic Snow'. Int J Recycl Org Waste Agric. 2019;8:151–7. https://doi.org/10.1007/s40093-018-0241-7

21. Rashidha CK, Sankar M, Sreelatha U, Anupama TV, Prameela P. Standardization of soilless growth media for raising potted ornamental foliage plants for export purpose. J Trop Agric. 2021;59(1):118–23.

22. Çatal S, Pekşen A. Physical, chemical and biological properties of spent mushroom substrates of different mushroom species. Acta Hortic. 2020;1287:353–60. https://doi.org/10.17660/ActaHortic.2020.1287.45

23. Yagüe MR, González-Pérez JA, Almendros G, Lobo MC. Assessing the potential agronomic value of spent mushroom substrates: evaluating their suitability to contribute to soil carbon storage. Sustainability. 2025;17(16):7335. https://doi.org/10.3390/su17167335

24. Agarwal P, Saha S, Hariprasad P. Agro-industrial-residues as potting media: physicochemical and biological characters and their influence on plant growth. Biomass Convers Biorefin. 2023;13:9601–24. https://doi.org/10.1007/s13399-021-01998-6

25. Li M, Ning X, Gao T, Fazry S, Othman BA, Najm AAK, et al. Rice husk ash based growing media impact on cucumber and melon growth and quality. Sci Rep. 2024;14:5147. https://doi.org/10.1038/s41598-024-55622-4

26. ICAR-National Research Centre for Grapes. Annual report 2019. Pune: ICAR-National Research Centre for Grapes; 2019. p.145.

27. ICAR-National Research Centre for Grapes. Annual report 2020. Pune: ICAR-National Research Centre for Grapes; 2020. p. 164.

28. ICAR-National Research Centre for Grapes. Annual report 2021. Pune: ICAR-National Research Centre for Grapes; 2021. p. 156.

29. Jackson ML. Soil chemical analysis. New Delhi: Prentice-Hall of India Pvt. Ltd.; 1973. p. 498.

30. Bremner JM, Mulvaney CS. Nitrogen—total. In: Page AL, Miller RH, Keeney DR, editors. Methods of soil analysis: part 2. Chemical and microbiological properties. 2nd ed. Madison (WI): American Society of Agronomy; 1982. p. 595–624. https://doi.org/10.2134/agronmonogr9.2.2ed.c31

31. Chesnin L, Yien CH. Turbidimetric determination of available sulfates. Soil Sci Soc Am J. 1951;15(C):149–51. https://doi.org/10.2136/sssaj1951.036159950015000C0032x

32. Baker DE, Suhr NH. Atomic absorption and flame emission spectrometry. In: Page AL, Miller RH, Keeney DR, editors. Methods of soil analysis: part 2. Chemical and microbiological properties. 2nd ed. Madison (WI): American Society of Agronomy; 1982.

33. Rai H, Raju DVS, Prasad KV, Singh M, Kumar G, Pandey RN, et al. Evaluation of *Chrysanthemum morifolium* varieties for salinity tolerance under hydroponic system. Indian J Agric Sci.2017;87(7):870–7. https://doi.org/10.56093/ijas.v87i7.71806

34. Zapryanova N, Atanassova B. Effects of salt stress on growth and flowering of ornamental annual species. Biotechnol Biotechnol Equip. 2009;23(1):177–9. https://doi.org/10.1080/13102818.2009.10818394

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.

https://doi.org/10.14719/pst.16637

35. Khan S, Ali G, Gola AS, Kakar A, Zehri AQ, Khan SA. Effect of different growing media on the growth of marigold flower under agro climatic condition of Quetta. Int J Acad Multidiscip Res. 2020;4(5):159–63.

36. Hawkesford MJ, de Kok LJ, Haneklaus S, Kopriva S. Functions of macronutrients. In: Rengel Z, Cakmak I, White PJ, editors. Marschner's mineral nutrition of plants. 4th ed. Academic Press; 2023. https://doi.org/10.1016/B978-0-12-819773-8.00004-2

37. Kumar S, Kumar S, Mohapatra T. Interaction between macro- and micro-nutrients in plants. Front Plant Sci. 2021;12:665583. https://doi.org/10.3389/fpls.2021.665583

38. Fang X, Yang Y, Zhao Z, Zhou Y, Liao Y, Guan Z, et al. Optimum nitrogen, phosphorous, and potassium fertilizer application increased chrysanthemum growth and quality by reinforcing the soil microbial community and nutrient cycling function. Plants. 2023;12(23):4062. https://doi.org/10.3390/plants12234062

39. Benito M, Masaguer A, De Antonio R, Moliner A. Use of pruning waste compost as a component in soilless growing media. Bioresour Technol. 2005;96:597–603. https://doi.org/10.1016/j.biortech.2004.06.006

40. Mahmoud TSM, Nabila EK, Rayy MSA. Effect of planting dates and different growing media on seed germination and growth of pistachio seedlings. Bull Natl Res Cent. 2019;43:133. https://doi.org/10.1186/s42269-019-0176-9

41. Mwangi RW, Mustafa M, Kappel N, Csambalik L, Szabó A. Practical applications of spent mushroom compost in cultivation and disease control of selected vegetables species. J Mater Cycles Waste Manag. 2024;26:1918–33. https://doi.org/10.1007/s10163-024-01969-9

42. Zhang RH, Duan ZQ, Li ZG. Use of spent mushroom substrate as growing media for tomato and cucumber seedlings. Pedosphere. 2012;22(3):333–42. https://doi.org/10.1016/S1002-0160(12)60020-0

43. Dutt M, Sonawane PC. Nutrient uptake in chrysanthemum grown on various substrates. Indian J Hortic. 2006;63(1):66–9.

44. Jasińska A. Spent mushroom compost (SMC)—retrieved added value product closing loop in agricultural production. Acta Agrar Debreceniensis. 2018;150:185–202. https://doi.org/10.34101/actaagrar/150/1715

45. Di Gioia F, De Bellis P, Mininni C, Santamaria P, Serio F. Organic waste compost and spent mushroom compost as potential growing media components for the sustainable production of microgreens. Front Plant Sci. 2023;14:1229157. https://doi.org/10.3389/fpls.2023.1229157

46. Altieri R, Spaccini R, Pane C, Manganiello G, Cangemi S, Verrillo M, et al. Process and quality evaluation of different improved composts made with a smart laboratory pilot plant. Heliyon.2024;10(10):e31059. https://doi.org/10.1016/j.heliyon.2024.e31059

47. Chauhan AP, Patel RB, Chawla SL, Parameshwari C, Dishaben KP. Effect of nitrogen and phosphorus on growth, quality and flower production of golden rod (*Solidago canadensis* L.) cv. Local. J Ornamental Hortic. 2018;21(1–2):13–16. https://doi.org/10.5958/2249-880X.2018.00003.5

48. Adhikari P, Mishra K, Marasini S, Neupane RC, Shrestha AK, Shrestha J. Effect of nitrogen doses on growth and yield of marigold (*Tagetes erecta* L.) in subtropical climate of Nepal. Fundam Appl Agric. 2020;5(3):414–20. https://doi.org/10.5455/faa.114705

49. Chan AP. Mineral nutritional studies on carnation: effect of N, P, K, Ca and temperature on flower production. Proc Amer Soc Hortic Sci. 1959;72:473.

50. Stewart DPC, Cameron KC, Cornforth IS. Effects of spent mushroom substrate on soil chemical conditions and plant growth in an intensive horticultural system: a comparison with inorganic fertiliser. Aust J Soil Res. 1998;36:185–98. https://doi.org/10.1071/S97034

51. Wdowiak A, Podgórska A, Szal B. Calcium in plants: an important element of cell physiology and structure, signaling, and stress responses. Acta Physiol Plant. 2024;46:108. https://doi.org/10.1007/s11738-024-03733

52. Kageyama Y, Shima K, Konishi K. Effect of calcium levels in culture solution on growth and cut flower quality of chrysanthemum. J Jpn Soc Hortic Sci. 1995;64(1):169–76. https://doi.org/10.2503/jjshs.64.169

53. Mandal AK, Kumar J, Dey JK, Chhetri A, Das S, Kumar V, et al. Zinc in soil-plant-human systems: a synthesis of its fate, essential roles, and health implications. Scientifica. 2026;2026:2944933. https://doi.org/10.1155/sci5/2944933

54. Ravishankar LV, Puranik N, Lekkala VVV, Lomada D, Reddy MC, Maurya AK. ZnO nanoparticles: advancing agricultural sustainability. Plants. 2025;14(15):2430. https://doi.org/10.3390/plants14152430

55. Narayan OP, Kumar P, Yadav B, Dua M, Johri AK. Sulfur nutrition and its role in plant growth and development. Plant Signal Behav. 2023;18(1):2030082. https://doi.org/10.1080/15592324.2022.2030082

56. Vanlalruati V, Sindhu SS, Anand P, Kumar G. Effect of micronutrients (Fe and Zn) on flowering and yield attributes of chrysanthemum (*Chrysanthemum morifolium*) cv. Mayur 5. Indian J Agric Sci. 2019;89(8):1282–6. https://doi.org/10.56093/ijas.v89i8.92846

57. Pessoa CC, Luís IC, Daccak DF, Legoinha PA, Ramalho JC, Lidon FC, et al. Mn's key roles in plant ecophysiology: a comprehensive review for unstressed and stress conditions. Agronomy.2026;16(7):709. https://doi.org/10.3390/agronomy16070709

58. Annasamy K, Karuppapiah P. Effect of micronutrients on flowering and yield attributes of chrysanthemum (*Dendrathemum grandiflora* Tzeuleu) cv. CO 1. Int J Plant Soil Sci. 2024;36(2):48–52. https://doi.org/10.9734/ijpss/2024/v36i24362

59. Chen JT, Lin MJ, Chen CC, Chu CW, Wu JY, Dai TE. Development and application of mushroom cultivation waste recycling technology on flower cultivation. Acta Hortic. 2022;1355:351–6. https://doi.org/10.17660/ActaHortic.2022.1355.44

60. Zhao Z, Zhang L. Spent mushroom substrate and medical stone modified composted green waste as growth media for ornamental plant *Antirrhinum majus* L. and *Salvia splendens*. Sci Hortic. 2023;313:111929. https://doi.org/10.1016/j.scienta.2023.111929

61. Johnson T, Di Gioia F. Spent mushroom compost as an alternative to peat-based soilless media for greenhouse potted basil production. Acta Hortic. 2025;1426:317–24. https://doi.org/10.17660/ActaHortic.2025.1426.44

62. Chandel S, Chandel V. Correlation of disease with meteorological factors and management of Septoria leaf spot of chrysanthemum (*Chrysanthemum grandiflorum*). Indian J Agric Sci. 2010;80(1):54–8. https://doi.org/10.56093/ijas.v80i1.2809

63. Bika R, Baysal-Gurel F, Jennings C. *Botrytis cinerea* management in ornamental production: a continuous battle.

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.
https://doi.org/10.14719/pst.16637

Can J Plant Pathol. 2021;43(3):345–65. https://doi.org/10.1080/07060661.2020.1807409

64. Shohrat N, Yenjerappa ST, Amaresh YS, Aswathanarayana DS, Sathyanarayana Rao, Hugar A. Survey for the Septoria leaf spot of chrysanthemum in Northern parts of Karnataka. Pharma Innov J. 2022;11(9S):3273–7.

65. Zhou J, Jiang X, Agathokleous E, Lu X, Yang Z, Li R. High temperature inhibits photosynthesis of chrysanthemum (*Chrysanthemum morifolium* Ramat.) seedlings more than relative humidity. Front Plant Sci. 2023;14:1272013. https://doi.org/10.3389/fpls.2023.1272013

66. Munir M. Application of photo-thermal models to quantify flowering time and development response of chrysanthemum (*Chrysanthemum* × *morifolium* Ramat.). J Appl Hortic. 2023;25(3):230–7. https://doi.org/10.37855/jah.2023.v25i03.41

67. Hu Q, Yin M, Gao Z, Zhang Z, Zhu Y, Hu R, et al. Late flowering in chrysanthemum induced by low ambient temperature is mediated by flowering locus C-like. J Exp Bot. 2025;76(8):2192–206. https://doi.org/10.1093/jxb/eraf019

68. Alam T, Ikram M, Chaudhry AN, Subhan CM, Alotaibi KD, Haq ZU, et al. Utilization of organic-residues as potting media: physico-chemical characteristics and their influence on vegetable production. PLoS One. 2024;19(6):e0302135. https://doi.org/10.1371/journal.pone.0302135

69. Ansorena Miner J. Sustratos: propiedades y caracterización. Madrid: Mundi-Prensa; 1994. p. 172 .

70. Kämpf AN. Produção comercial de plantas ornamentais. Guaíba: Agropecuária; 2000. p.254.

71. Lowery B, Hickey WJ, Arshad MAC, Lal R. Soil water parameters and soil quality. In: Doran JW, Jones AJ, editors. Methods for assessing soil quality. SSSA Special Publication 49. Madison (WI): Soil Science Society of America; 1996. p. 143–55. https://doi.org/10.2136/sssaspecpub49.c8

72. Medina E, Paredes C, Pérez-Murcia MD, Bustamante MA, Moral R. Spent mushroom substrates as component of growing media for germination and growth of horticultural plants. Bioresour Technol. 2009;100:4227–32. https://doi.org/10.1016/j.biortech.2009.03.055

73. Sönmez İ, Kalkan H, Demir H. Effects of spent mushroom compost on seedling quality and nutrient contents of eggplant (*Solanum melongena*) grown in different growing media. Acta Hortic.2016;1142:403–8. https://doi.org/10.17660/ActaHortic.2016.1142.61

Additional information

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

Reprints & permissions information: 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: See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting.

Copyright: © The Author(s). This is an open-access article distributed under the Creative Commons Attribution License CC BY 4.0.

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

© The Author(s) 2026. Creative Commons CC BY 4.0. Published by Horizon e-Publishing Group.

https://doi.org/10.14719/pst.16637