



Influence of paper mill biosolids-amended growing media on growth and flowering of chrysanthemum

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Abstract

The present study evaluated the influence of potting media formulated with paper mill biosolids (PMBS), carbonised rice husk and vermicompost (M1–M4), combined with three levels of vesicular-arbuscular mycorrhiza (VAM) inoculation (0, 15 and 30 g pot⁻¹), on the growth and flowering of pot chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. Givilando Pink. Media x VAM interaction significantly influenced vegetative growth, biomass and flowering, with M2V3 and M3V3 producing the highest number of branches (7.25 and 7.20), shoot dry weight (9.72 and 10.12 g), root dry weight (2.04 and 2.05 g) and flowers per plant (20.50 and 20.12, respectively); M3V3 also produced the largest flowers (4.90 cm). Independent of this interaction, leaf area and soil plant analysis development (SPAD) value was highest under the M2 and M3 media, while root colonisation (82.50 %) and dehydrogenase activity (71.00 µg TPF g⁻¹ soil hr⁻¹) were maximised at the 30 g pot⁻¹ VAM level. These results establish potting media containing 60–70 % PMBS with VAM inoculation at 30 g pot⁻¹ as a sustainable, locally available and effective alternative to red soil for pot chrysanthemum production, offering a practical route to valorise an underused paper-industry waste stream.

Keywords: carbonised rice husk; dehydrogenase activity; paper mill biosolids; pot chrysanthemum; potting media; root colonisation; soil plant analysis development; vesicular-arbuscular mycorrhiza

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1. Introduction

The Indian paper industry, valued at approximately US\$12 billion, is one of the fastest-growing paper markets in the world, with an annual production of nearly 25 million tonnes of paper and paperboard (1). The sector generates substantial quantities of solid waste, particularly paper mill biosolids (PMBS), which is produced during pulping, papermaking and wastewater treatment processes. Paper mills typically generate 40–50 kg of dry sludge per tonne of paper produced (2), resulting in an estimated annual generation of 1.0–1.25 million tonnes of PMBS in India. Disposal of this sludge through landfilling remains a common practice, leading to environmental concerns including land resource depletion, greenhouse gas emissions and the potential contamination of soil and groundwater (3). In recent years, increasing emphasis on sustainable waste management and circular bioeconomy principles has stimulated interest in the beneficial utilisation of industrial by-products (4). The PMBS contains appreciable amounts of organic matter and possesses favourable physical properties, including water-holding

capacity and porosity, making it a potential component of horticultural growing media (5).

Several studies have demonstrated the potential of PMBS as a sustainable component of horticultural growing media. Previous studies states that the incorporation of up to 30 % raw paper mill biosolids in pine bark-based substrates supported satisfactory growth of ornamental shrubs including cotoneaster, dogwood, forsythia and weigela (6). Subsequently, previous researchers found that replacing peat with raw paper mill biosolids at rates up to 40 % (v/v) improved rooting performance in several ornamental shrub species (7). Further studies observed that the inclusion of PMBS at levels up to 60 % enhanced growth and biomass production of container-grown ornamental shrubs such as *Cornus alba* L., *Forsythia × intermedia* Zabel, *Physocarpus opulifolius* (L.) Maxim. and *Weigela florida* (Bunge) A.DC. (8). The suitability of processed paper mill biosolids as a growing medium component has also been widely documented. Previous researchers recommended a substrate mixture consisting of composted paper mill biosolids and sand in

a 3 : 1 ratio for nursery crop production (9), while other studies reported that container media containing 50 % composted PMBS supported satisfactory plant growth (10). Similarly, previous researchers demonstrated that the incorporation of 50 % deinking paper sludge into coir-based media improved air-filled porosity, optimised water-holding capacity and significantly increased lettuce biomass production (11). Further research reported that paper sludge-amended substrates produced greater biomass in tomato and lettuce compared with conventional coir-based media, highlighting their potential as alternative growing substrates (12).

Beyond its use as a substrate component, paper mill biosolids have also been shown to improve soil quality and plant productivity. Earlier researchers reported that paper mill waste amendments increased soil organic carbon content, biological activity, aggregate stability and overall soil fertility (13). Moreover, earlier researchers demonstrated that the incorporation of paper-derived waste materials at levels up to 30 % in peat-based substrates maintained acceptable growth, flowering and marketability of ornamental crops such as marigold (*Tagetes erecta* L.) and petunia (*Petunia × hybrida* (Hook.) Regel) (14). Collectively, these studies indicate that paper mill biosolids possess considerable potential as a sustainable alternative to conventional growing media components, thereby contributing to waste valorisation and the development of environmentally sustainable horticultural production systems.

Despite the demonstrated potential of PMBS as a substrate component, its utilisation in ornamental horticulture remains limited. In the present study, carbonised rice husk was incorporated along with PMBS to improve the physical properties of the growing media, while vesicular-arbuscular mycorrhiza (VAM) was included to enhance nutrient uptake and overall plant growth. The integration of these materials was aimed at developing a sustainable and locally available growing substrate for ornamental plant production.

Although the availability of PMBS is geographically restricted, the East Godavari district of Andhra Pradesh, one of the major paper manufacturing regions in India, generates approximately 540 tonnes of paper mill sludge per day (15). Notably, the district is also home to the Kadiyam nursery cluster, one of the largest ornamental nursery hubs in India, which has a continuous demand for high-quality growing substrates. The utilisation of PMBS in nursery production therefore presents a unique opportunity to convert an industrial waste into a value-added resource while addressing the increasing need for sustainable and cost-effective growing media.

Accordingly, the present investigation was undertaken to evaluate the growth (plant height, number of leaves, number of branches, shoot and root dry weight), physiological (leaf area, soil plant analysis development (SPAD) value), root microbial (root colonisation percentage, dehydrogenase activity) and

flowering (number of flowers per plant, flower diameter) responses of pot chrysanthemum (*Chrysanthemum morifolium* Ramat.) cv. Givilando Pink to different substrate combinations comprising paper mill biosolids, carbonized rice husk and vermicompost, with and without VAM inoculation. The study aimed to identify suitable substrate formulations that could support sustainable ornamental plant production while promoting the beneficial utilisation of PMBS.

2. Materials and Methods

Location and experimental site

During November 2025 to February 2026, investigations were conducted at ICAR - Directorate of Floricultural Research (DFR) Regional Station situated in Vemagiri, East Godavari District of Andhra Pradesh. The experimental site is geographically located at 16.91° N latitude and 81.43° E longitude. The station is positioned within Agro-climatic Zone No. 11, which is characterised as the eastern coast plains and hills zone. The research was executed in a naturally ventilated polyhouse structure.

Media preparation

Media component source: PMBS was procured from Andhra Paper Ltd. mill situated at Kadiyam East Godavari district of Andhra Pradesh- 533 126; carbonised rice husk was prepared from rice husk procured from Rice mill in Kadiyam, East Godavari district of Andhra Pradesh. The rice husk was carbonised by using a steel drum method as described previously (16); vermicompost was procured from Garden world landscaping company Kadiyam, East Godavari district of Andhra Pradesh 533 126. The experiment was laid out in a two-factor factorial completely randomised design (FCRD), comprising VAM dose (V) and potting media combinations (M) as the experimental factors. Each treatment was replicated 3 times, with four pots maintained per replication. The VAM inoculum, supplied in a sterile vermiculite-based carrier medium, was procured from Tamil Nadu Agricultural University (TNAU), Coimbatore, India. The VAM factor consisted of three dose levels: V1 (0 g per pot), V2 (15 g per pot) and V3 (30 g per pot). The media factor comprised four different formulations: M1 (50 % PMBS + 30 % Carbonised rice husk + 20 % Vermicompost), M2 (60 % PMBS + 20 % Carbonised rice husk + 20 % Vermicompost), M3 (70 % PMBS + 10 % Carbonised rice husk + 20 % Vermicompost) and M4 (Red soil - control). All potting media formulations were prepared based on a pot volume of 2 L and were subsequently autoclaved for sterilisation at 121 °C and 15 psi for 20 min.

Planting material and management practices

A single rooted cutting of *C. morifolium* var. Givilando Pink, aged 30 days, was transplanted into each pot. Irrigation was administered at regular intervals in the morning hours during the entire crop development period using a rose cane (10 L capacity) applied in the early morning hours. Irrigation frequency and volume were

modulated in accordance with the moisture content of the growing medium, with precautions taken to prevent waterlogging conditions. Nutrient management involved three key components: a balanced water-soluble nitrogen, phosphorus and potassium (NPK) fertiliser (19 : 19 : 19) was supplied through fertigation at 3 g L⁻¹ three times per week and micronutrient mixture was applied as foliar spray at 5 g L⁻¹ at fortnightly interval. Prophylactic application of carbendazim at 1.5 g L⁻¹ of water was done at early plant growth stage prevent soil-borne fungal pathogens such as *Fusarium falciforme*.

Observations recorded

Plant height (cm): Assessed by measuring the vertical distance from the soil surface to the apex of the main shoot using a 60 cm ruler at 60 days after planting (DAP). **Number of leaves:** fully mature and expanded leaves were counted on each plant at 60 DAP. **Number of branches:** Primary branch count was determined through visual inspection at 60 DAP. **Dry matter accumulation (g plant⁻¹):** At harvest, the entire aerial portion comprising stem, foliage and flowers was collected, oven-dried at 75 °C for 72 hr and weighed using an electronic balance to determine shoot dry weight in grams per plant. Plants were carefully uprooted and the roots were gently washed to remove adhering media without causing damage. The root samples were then oven-dried at 70 °C for 72 hr in a hot air oven, after which the dry weight was recorded.

Flowers per plant: The total count of fully opened flowers per plant was recorded at the full bloom stage. **Flower diameter:** Measured at full bloom stage using a 30 cm ruler. **Leaf area per plant (mm²):** Quantified by scanning leaves and analysing the images using a Biovis leaf area meter (Biovis Pvt. Ltd., India). The relative chlorophyll content (SPAD value) was non-destructively determined using a portable Konica Minolta SPAD-502 Plus meter. **Root colonisation (%):** Assessed employing the trypan blue staining method as described by Phillips JM and Hayman DS (17). **Dehydrogenase activity (µg TPF g⁻¹ soil h⁻¹):** Estimated using the triphenyl tetrazolium chloride (TTC) reduction method following Thalmann (18), with the spectrophotometric measurement of the resultant red colour intensity recorded at 485 nm using a UV-vis spectrophotometer.

Statistical analysis

The data were analysed using analysis of variance (ANOVA) and treatment means were separated using the least significant difference (LSD) test at the 5 % significance level ($p \leq 0.05$). Statistical analyses were performed using RAISINS software (version 1.2.0) (19).

3. Results

Vegetative traits

The potting media combinations (M), VAM inoculation (V) and their interaction significantly influenced the vegetative growth of chrysanthemum (Table 1). Among the media combinations, M3 recorded the highest plant

height (24.63 cm), whereas the control medium, M4, produced comparatively shorter plants. Among the VAM treatments, V3 resulted in the tallest plants (23.24 cm). A similar trend was observed for the number of branches per plant. The highest number of branches was recorded in M3 (6.47), which was statistically on par with M2 (6.44). Among the VAM treatments, V3 significantly increased the number of branches (6.80). The interaction between potting media and VAM inoculation was also significant, with M2 × V3 producing the highest number of branches (7.25), followed by M3 × V3 (7.20) and M1 × V3 (7.12). The number of leaves per plant was significantly affected by both media and VAM inoculation. M2 produced the highest number of leaves (20.08), which was statistically comparable to M3 (19.83). Among the VAM treatments, V3 recorded the highest number of leaves (21.31).

Biomass production

Potting media combinations and VAM inoculation significantly influenced biomass accumulation (Table 1). Among the media combinations, M3 recorded the highest shoot dry weight (8.75 g), followed by M2 (8.32 g). The V3 significantly increased shoot dry weight, recording 9.28 g. The interaction effect showed that M3 × V3 produced the highest shoot dry weight (10.12 g), followed by M2 × V3 (9.72 g). A similar trend was observed for root dry weight. M3 attained the highest root dry weight (1.66 g), while V3 resulted in the highest root dry weight (1.82 g). The combinations M3 × V3 (2.05 g) and M2 × V3 (2.04 g) recorded significantly greater root biomass than the remaining treatment combinations.

Soil plant analysis development values and leaf area

The SPAD value and leaf area were significantly influenced by both potting media and VAM inoculation (Table 2). Among the media combinations, M3 recorded the highest SPAD value (43.79), whereas M4 recorded the lowest value (40.95). Among the VAM treatments, V3 resulted in the highest SPAD value (44.00), while uninoculated plants (V1) recorded the lowest value (40.23). The interaction effect was significant, with M2 × V3 (60 % paper mill biosolids + 20 % carbonised rice husk + 20 % vermicompost + VAM at 30 g pot⁻¹) recording the highest SPAD value (45.85), whereas M1 × V1 recorded the lowest (38.84). Leaf area also varied significantly among treatments. M2 recorded the largest leaf area (58.79 mm²), whereas M4 produced the smallest leaf area (50.44 mm²). The VAM inoculation V3 significantly increased leaf area (63.72 mm²) compared with uninoculated plants (43.53 mm²). The interaction treatment M2 × V3 produced the maximum leaf area (68.13 mm²), while M4 × V1 recorded the minimum leaf area (40.89 mm²). were significantly influenced by VAM inoculation (Table 2) (Fig. 1). Root colonisation did not differ significantly among the potting media combinations. However, VAM inoculation markedly increased root colonisation, with V3 recording 77.50 % colonisation,



whereas no colonisation was observed in uninoculated plants (V1). Among the interaction treatments, M3 × V3 recorded the highest root colonisation (82.50 %). Dehydrogenase activity was significantly affected by both potting media and VAM inoculation. Among the media combinations, M1 (50 % paper mill biosolids + 30 % carbonised rice husk + 20 % vermicompost) recorded the highest activity (63.00), while M3 (48.00) also

maintained higher activity than the control medium M4 (40.00). Among the VAM treatments, V3 recorded the highest dehydrogenase activity (59.75), followed by V2 (51.67), whereas V1 recorded the lowest activity (43.83). Although the interaction effect was not statistically significant, the treatment combination M1 × V3 numerically recorded the highest dehydrogenase activity (71.00).

Table 1. Effect of various media combinations and vesicular arbuscular mycorrhiza (VAM) inoculation on growth parameters in pot chrysanthemum

	Plant height (cm)	No. of leaves	Number of branches	Shoot dry weight (g)	Root dry weight (g)
VAM					
V1	20.74 ^b	15.94 ^c	5.21 ^c	7.03 ^c	0.95 ^c
V2	22.33 ^{ab}	18.92 ^b	5.87 ^b	7.94 ^b	1.21 ^b
V3	23.24 ^a	21.31 ^a	6.80 ^a	9.28 ^a	1.82 ^a
SE(m)	0.62	0.45	0.15	0.14	0.08
LSD ($p < 0.05$)	1.79	1.29	0.44	0.4	0.22
Media					
M1	20.33 ^b	17.33 ^b	5.71 ^b	7.71 ^b	1.19 ^b
M2	21.51 ^b	20.08 ^a	6.44 ^a	8.32 ^a	1.29 ^b
M3	24.63 ^a	19.83 ^a	6.47 ^a	8.75 ^a	1.66 ^a
M4	21.93 ^b	17.65 ^b	5.21 ^b	7.54 ^b	1.18 ^b
SE(m)	0.72	0.52	0.18	0.16	0.09
LSD ($p < 0.05$)	2.07	1.49	0.5	0.47	0.25
Interaction					
V1 × M1	19.25	15.12	5.00 ^{ef}	6.25 ^f	0.84 ^d
V1 × M2	19.50	16.62	5.32 ^{def}	7.25 ^{de}	0.93 ^d
V1 × M3	23.50	17.12	5.88 ^{cd}	7.88 ^{cd}	1.12 ^{cd}
V1 × M4	20.70	14.88	4.62 ^f	6.75 ^{ef}	0.92 ^d
V2 × M1	18.38	16.88	5.00 ^{ef}	7.62 ^{cd}	0.90 ^d
V2 × M2	21.65	20.88	6.75 ^{ab}	8.00 ^{cd}	0.89 ^d
V2 × M3	26.18	19.38	6.35 ^{bc}	8.25 ^c	1.81 ^{ab}
V2 × M4	23.12	18.58	5.38 ^{def}	7.88 ^{cd}	1.25 ^{cd}
V3 × M1	23.38	20.00	7.12 ^{ab}	9.25 ^b	1.81 ^{ab}
V3 × M2	23.38	22.75	7.25 ^a	9.72 ^{ab}	2.04 ^a
V3 × M3	24.23	23.00	7.20 ^{ab}	10.12 ^a	2.05 ^a
V3 × M4	21.98	19.50	5.62 ^{cde}	8.00 ^{cd}	1.38 ^{bc}
SE(m)	1.25	0.90	0.30	0.28	0.15
LSD ($p < 0.05$)	NS	NS	0.87	0.81	0.44

NS: not significant.

VAM Levels: V1 = 0g/pot, V2 = 15 g/pot, V3 = 30g/pot.

M1 = 50 % Paper mill biosolids + 30 % Carbonised rice husk + 20 % Vermicompost.

M2 = 60 % Paper mill biosolids + 20 % Carbonised rice husk + 20 % Vermicompost.

M3 = 70 % Paper mill biosolids + 10 % Carbonised rice husk + 20 % Vermicompost.

M4 = Red soil.



Table 2. Effect of various media combinations and vesicular arbuscular mycorrhiza (VAM) inoculation on leaf area, soil plant analysis development (SPAD) values and microbial activity in pot chrysanthemum

	Leaf area (mm ²)	SPAD	Root colonisation (%)	Dehydrogenase activity (µg TPF g ⁻¹ soil h ⁻¹)
VAM				
V1	43.53 ^c	40.23 ^b	0.00 ^c	43.83 ^c
V2	56.51 ^b	42.93 ^a	63.75 ^b	51.67 ^b
V3	63.72 ^a	44.00 ^a	77.50 ^a	59.75 ^a
SE(m)	0.99	0.61	1.50	0.27
LSD ($p < 0.05$)	2.85	1.74	4.31	0.79
Media				
M1	52.22 ^b	41.52 ^{bc}	46.67	63.00 ^a
M2	58.79 ^a	43.29 ^{ab}	46.67	56.00 ^b
M3	56.90 ^a	43.79 ^a	49.17	48.00 ^c
M4	50.44 ^b	40.95 ^c	45.83	40.00 ^d
SE(m)	1.15	0.70	1.73	0.32
LSD ($p < 0.05$)	3.29	2.01	NS	0.91
Interaction				
V1 × M1	40.39	38.84	0.00	55.30
V1 × M2	45.78	40.30	0.00	47.70
V1 × M3	47.08	41.60	0.00	40.00
V1 × M4	40.89	40.20	0.00	32.30
V2 × M1	55.35	42.98	65.00	62.70
V2 × M2	62.46	43.73	62.50	56.00
V2 × M3	58.05	43.58	65.00	48.30
V2 × M4	50.17	41.45	62.50	39.70
V3 × M1	60.93	42.76	75.00	71.00
V3 × M2	68.13	45.85	77.50	64.30
V3 × M3	65.59	46.19	82.50	55.70
V3 × M4	60.24	41.20	75.00	48.00
SE(m)	1.99	1.21	3.00	0.55
LSD ($p < 0.05$)	NS	NS	NS	NS

NS: not significant; TPF: triphenyl formazan.

VAM Levels: V1 = 0g/pot, V2 = 15g/pot, V3 = 30g/pot.

M1 = 50 % Paper mill biosolids + 30 % Carbonised rice husk + 20 % Vermicompost.

M2 = 60 % Paper mill biosolids + 20 % Carbonised rice husk + 20 % Vermicompost.

M3 = 70 % Paper mill biosolids + 10 % Carbonised rice husk + 20 % Vermicompost.

M4 = Red soil.

Flowering traits

Flowering performance was significantly influenced by both potting media combinations and VAM inoculation (Fig. 1 and 2). Among the media combinations, M3 recorded the highest number of flowers per plant (17.91) and the largest flower diameter (4.81 cm). Among the VAM treatments, V3 produced the highest number of flowers (18.69 per plant) and flower

diameter (4.58 cm), whereas uninoculated plants (V1) recorded the lowest values (12.75 flowers per plant and 4.34 cm flower diameter). The interaction treatment M3 × V3 proved to be the most effective, producing the highest number of flowers (20.50 per plant) and the largest flower diameter (4.90 cm), while M4 × V1 recorded the lowest flowering performance (9.75 flowers per plant and 4.15 cm flower diameter).

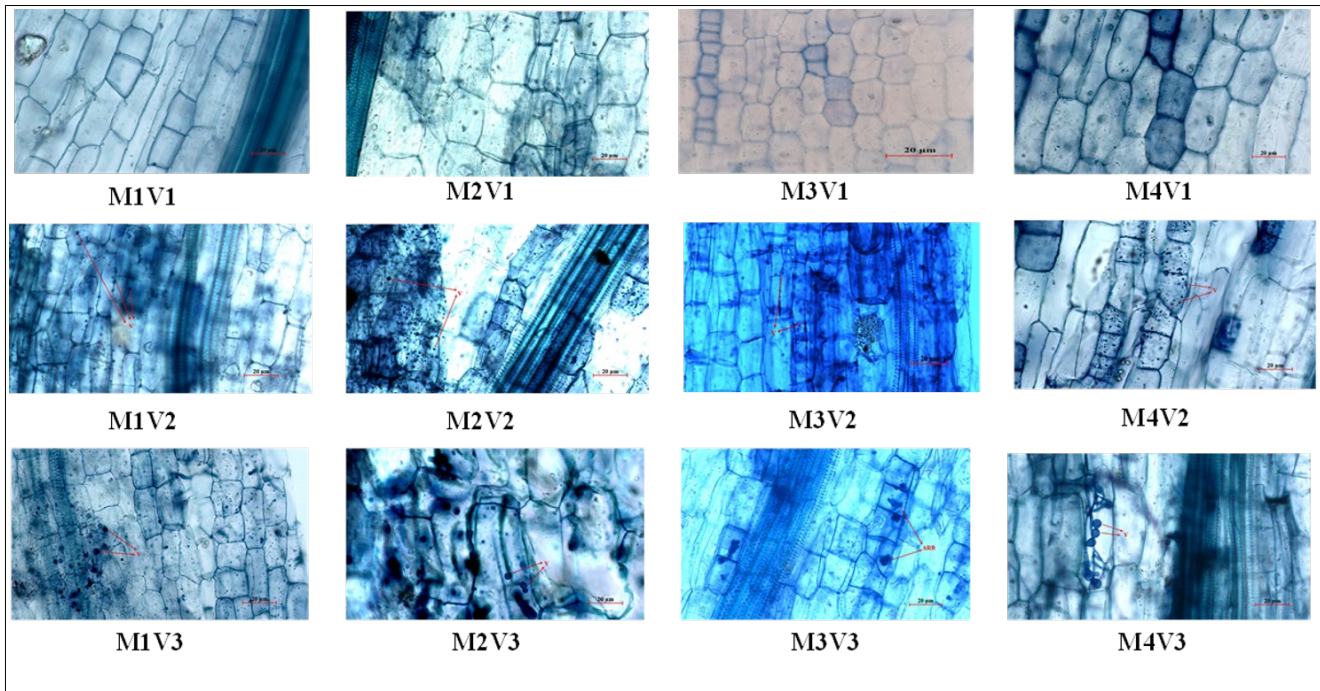


Fig. 1. Microscopic examination of stained root samples revealed the presence of distinctive arbuscular mycorrhizal structures, including vesicles and arbuscules, in all vesicular arbuscular mycorrhiza (VAM)-inoculated treatments (V2 and V3), whereas these fungal structures were completely absent in the uninoculated control (V1, 0 g per pot).

V: vesicles; ARB: arbuscules.

VAM levels: V1 = 0 g/pot, V2 = 15 g/pot, V3 = 30 g/pot.

Media levels: M1: 50 % Paper mill biosolids + 30 % Carbonised rice husk + 20 % Vermicompost; M2: 60 % Paper mill biosolids + 20 % Carbonised rice husk + 20 % Vermicompost; M3: 70 % Paper mill biosolids + 10 % Carbonised rice husk + 20 % Vermicompost; M4: Red soil.

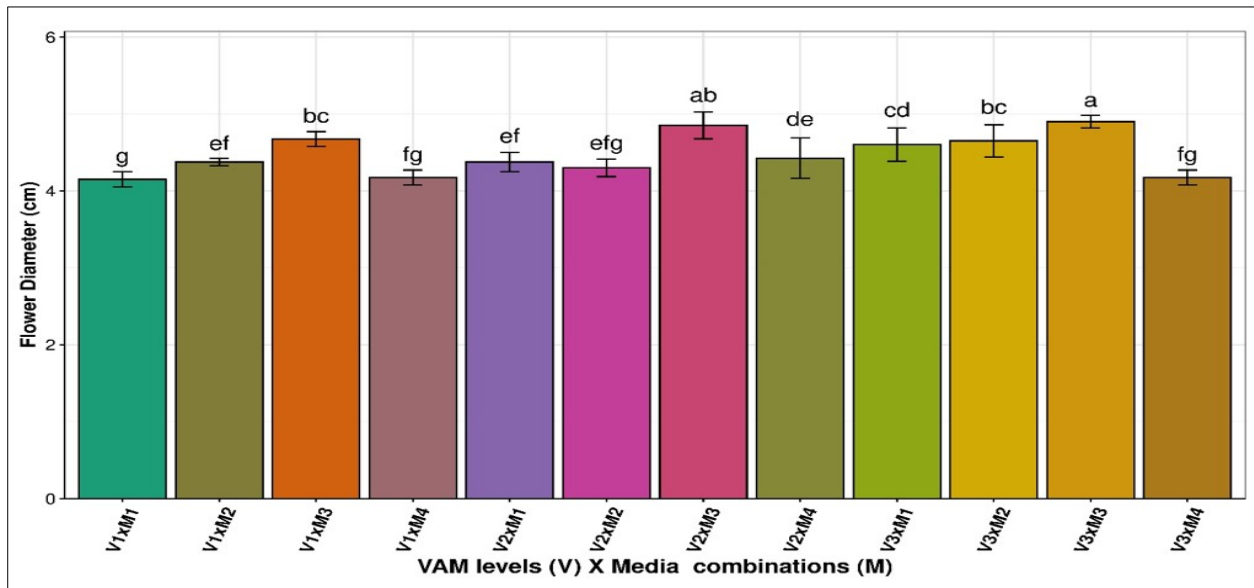


Fig. 2. Effect of Various media combinations and vesicular arbuscular mycorrhiza (VAM) inoculation on flower diameter (cm) in pot chrysanthemum.

VAM levels: V1 = 0 g/pot, V2 = 15 g/pot, V3 = 30 g/pot

Media combinations- M1: 50 % Paper mill biosolids+ 30 % Carbonised rice husk + 20 % Vermicompost; M2: 60 % Paper mill biosolids + 20 % Carbonised rice husk + 20 % Vermicompost; M3: 70 % Paper mill biosolids + 10 % Carbonised rice husk + 20 % Vermicompost; M4: Red soil.

4. Discussion

Vegetative traits

In the present study the media composition M3 and M2 have produced vegetatively superior plants with better plant height, highest number of leaves per plant, more branches per plant and high SPAD readings, high shoot and root biomass. The results are in concurrence with earlier studies where reported better plant height, superior leaves with the application of 50 % of potting substrate composed of paper mill waste along with other components for marigold, petunia and matthiola (20). Similarly another studies reported increased biomass accumulation in *Festuca rubra*, *Agropyron trachycaulum* and *Medicago sativa* (21) and increased shoot biomass accumulation in *Pinus taeda* L. upon paper mill biosolids application directly to soil (22). The improved vegetative traits in plants grown in M2 and M3 media can be attributed to better nutrient availability with high organic matter (23–26) and improved physical characters of media such as water holding capacity (27), bulk density (28, 29), cation exchange capacity (CEC) (30), ideal pH (31). Additionally in our study the plants received 10–20 % carbonised rice husk along with 20 % vermicompost in combination of 60–70 % PMBS further added to the positive effect of PMBS on improving the physicochemical properties of media (32, 33). As the carbonised rice husk has a higher carbon content and is lighter in weight; moreover, it is well understood

fact that carbonised rice husk improves nutrient availability (34–36). Further the high microbial activity and better root colonisation (Fig. 1) was observed in plants inoculated with VAM at 30 g pot⁻¹ (V3) this had a positive influence on growth traits as VAM improves nutrient availability by P solubilisation and higher water uptake (35, 37).

Flower traits

The superior flower traits observed in media combination that have 60–70 % PMBS and 10–20 % carbonised rice husk may be attributed to significant vegetative growth and physiological status of the plant (Fig. 3). Plants grown in M3 media combination followed by M2 in combination with V3 produced significantly more flowers per plant with larger flower diameter (Fig. 4). The superior vegetative attribute like higher number of branches and number of leaves per plant combined with high leaf area together provided a larger photosynthetically active canopy and higher SPAD values recorded in these treatments indicate improved chlorophyll content and N status, reflecting enhanced nutrient uptake. The combined effect of adequate nutrient supply with high photosynthetic capacity greater biomass assimilation promoted the flower bud development and improved flower quality. Present findings are consistent with those of previous researchers where they reported flowers per plant had strong positive correlation with plant height, number of branches and leaf number (38, 39).



Fig. 3. Effect of different media combinations (M) and varied levels of vesicular arbuscular mycorrhiza (VAM) on flowering of pot chrysanthemum cv. Givilando Pink.

VAM levels: V1 = 0 g/pot, V2 = 15g/pot, V3 = 30 g/pot.

Media levels: M1: 50 % Paper mill biosolids + 30 % Carbonised rice husk + 20 % Vermicompost; M2: 60 % Paper mill biosolids + 20 % Carbonised rice husk + 20 % Vermicompost; M3: 70 % Paper mill biosolids + 10 % Carbonised rice husk + 20 % Vermicompost; M4: Red soil.

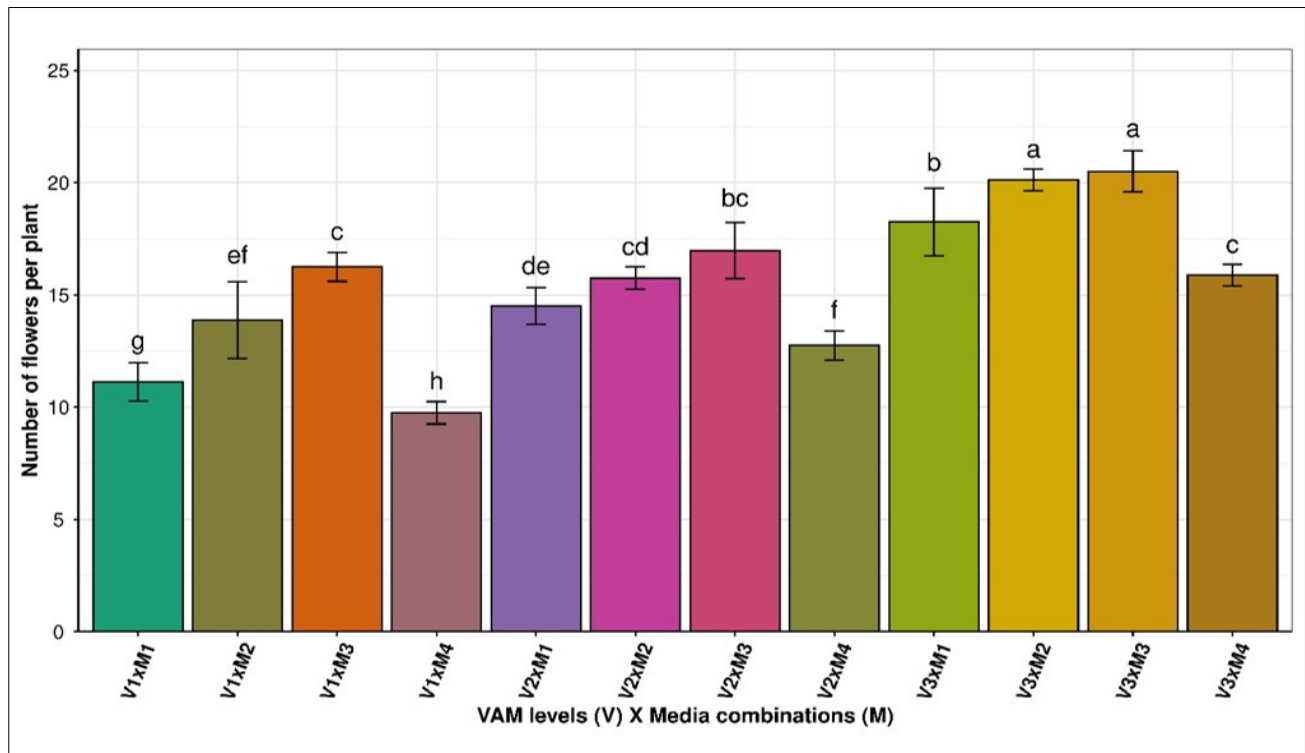


Fig. 4. Effect of Various media combinations and vesicular arbuscular mycorrhiza (VAM) inoculation on number of flowers per plant in pot chrysanthemum.

VAM levels: V1 = 0 g/pot, V2 = 15 g/pot, V3 = 30 g/pot

Media combinations- M1: 50 % Paper mill biosolids + 30 % Carbonised rice husk + 20 % Vermicompost; M2: 60 % Paper mill biosolids + 20 % Carbonised rice husk + 20 % Vermicompost; M3: 70 % Paper mill biosolids + 10 % Carbonised rice husk + 20 % Vermicompost; M4: Red soil.

5. Conclusion

The present study demonstrated that the pot chrysanthemums (*Chrysanthemum morifolium*) cv. Givilando Pink can be successfully grown in substrates containing 60–70 % paper mill biosolids (PMBS), 10–20 % carbonised rice husk and 20 % vermicompost, particularly when supplemented with vesicular-arbuscular mycorrhiza (VAM) at 30 g pot⁻¹. This substrate combination enhanced vegetative growth, flowering and overall plant quality, indicating its potential as a sustainable alternative to conventional growing media. Further detailed studies are necessary to understand nutrient dynamics, nutrient uptake patterns, microbial interactions in plants grown in PMBS in combination with carbonised rice husk and VAM inoculation under different production systems.

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Authors' contributions

TS contributed to investigation, data collection, formal analysis and writing original draft. DVSR contributed to conceptualisation, supervision and editing. AS and RG contributed to conceptualisation and supervision. LM contributed to conceptualisation, investigation, resource mobilisation and final manuscript preparation. MBR contributed to research design, physical and chemical analysis and supervision. AE contributed to data collection, statistical analysis and investigation. USM contributed to laboratory supervision and microbial activity analysis. ST contributed to root colonisation analysis, microscopic evaluation and result interpretation. 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



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