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Evaluating Sustainable and Environment Friendly Growing Media Composition for Pot Mum (*Chrysanthemum morifolium* Ramat.)

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Abstract: The use of different growing media offers a valuable alternative to the conventional use of soil for quality flower production due to their good water holding capacity, aeration and nutrient status. The experiment was conducted in a Completely Randomised Design with three replications in the years 2021–2022 to study the influence of different compositions of growing media [Soil, Sand, Vermicompost, Cocopeat, Vermiculite, Perlite and Leaf mould] in different ratios on the growth and development of pot mum (*Chrysanthemum morifolium* Ramat.).The growing media compositions of cocopeat, vermicompost and leaf moulds improve the water retention and aeration of media. The results revealed vegetative growth with maximum plant height at first bud appearance, plant height at harvesting stage, number of primary branches per plant, number of secondary branches per plant, number of leaves per plant, leaf biomass, average fresh weight of leaf, dry weight of root and flowering parameters with maximum flower longevity, flower diameter, number of flowers per plant, number of ray florets, average fresh weight of flower, flower yield per plant and vase life of flower in case of media composition of Cocopeat + Vermicompost + Leaf mould (2:1:1) among all the growing media compositions. The combination of cocopeat with vermicompost and leaf mould (2:1:1 *v*/*v*/*v*) was found best for lighter media weight, better plant morphological development and sustained quality flower production of pot mum.

Keywords: flower; cocopeat; vermicompost; leaf mould; morphological development

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1. Introduction

Floriculture industry is becoming a diversified option with huge significance from an aesthetic, social, environmental and economical point of view. In recent years, it has emerged as a profitable agribusiness due to increasing demand for floricultural products on account of improved standards of living and growing consciousness among citizens to live in an environment friendly atmosphere [1]. World floriculture is largely an export-oriented agro industry that has shown a growth rate of 15% per annum. After cut flowers, ornamental plant production is the most important segment in floriculture, whose sales have increased by 3.3 and 2.7% for pot and garden plants, respectively [2,3].Chrysanthemum (*Chrysanthemum morifolium* Ramat.) is mostly used as cut flower, loose flower and pot plant. Cut flowers are used for making bouquets, flower arrangements and table arrangements while loose flowers are used for making veni, gajra, garland and offerings to God [4]. The demand for Chrysanthemum is increasing, especially during New Year, Christmas and Valentine's Day [5]. In addition, it is also used for pot mum, bedding, border plant and in hanging baskets [6].

Pot mums occupy an important place in the European, North American and Japanese floriculture trade and is a popular choice for beautification of living spaces, balconies and patios. Rapid urbanisation and changing lifestyles have increased the demand for potted plants in India [7]. Therefore, the need for a light-weight growing medium has become more desirable due to their portability and display during exhibitions and flower shows [8]. The various light-weight media, viz., cocopeat, farmyard manure, vermicompost, perlite, vermiculite, leaf-mould, etc., altered the physico-chemical characteristics of growing mixtures and affected the growth of potted ornamentals [9,10].

Containerised plant production presents two fundamental challenges for healthy root growth. First, unlike a normal soil profile, a container environment provides a very shallow layer of growing medium, which becomes quickly saturated during irrigation. Secondly, a small container volume provides limited capacity for water storage between irrigation events [11]. Essentially, an effective growing medium must have a physical structure that is capable of sustaining a favourable balance between air and water storage during and between irrigation events in order to prevent root asphyxia and drought stress. The inability of soil to provide this balance at such small volumes is a key driver in the development of soilless growing media [12]. Indeed, these media have been a pivotal innovation, allowing growers to carefully control water, air and nutrient supply to the plant roots whilst excluding soil borne pathogens [13]. Growing media must have a physical structure that creates an appropriate balance of air and water for healthy root development. This balance must be maintained over an entire crop production cycle, which can last from several weeks to more than a year. Growing medium structure is determined by the size, shape, texture and physical arrangement of the particles from which it is composed [12].

The use of different growing media offers a valuable alternative to the conventional use of soil for quality flower production due to their good water holding capacity, aeration and nutrient status. Several studies advocated that it is much easier to handle soilless growing media and it is also good for growth and development of plants as compared to soil environment [14]. Diverse mineral substrates have distinctive traits which could have direct or indirect effects on plant growth and development. It was determined that growing media statistically affected morphological and reproductive attributes [15]. Diversified composition of growing media has a profound effect on physical, chemical and biological properties of the substrate. This diversified composition also alters the activities of microorganisms, which ultimately decreases the nitrogen losses and increases the cation exchange capacity [16,17]. When used in different ratios, compost or a combination of these materials work as great soil conditioners and have a major impact on plants growth and development and had significant effects on plant biomass [18], number of leaves [19], chlorophyll index [20], plant fresh and dry weight [21], greater availability of mineral nutrients to plants [22], plant heights and early flowering [23,24], number of primary and secondary branches [8,25,26], number of flowers per plant and flower diameter [26–30] number of leaves per plants [31–33], number of suckers per plants [34], vase life, root dry weight, flower longevity and flowering duration [19,26,35–37].

Therefore, keeping this in view, the study was conducted to evaluate the different compositions of growing media for sustainable pot mum production.

2. Materials and Methods

The experiment was carried out at the Department of Floriculture & Landscape Architecture, College of Horticulture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh, during the years 2021–2022. The terminal cuttings (5–7 cm) were taken from the healthy mother plants of pot mum (*Chrysanthemum morifolium* Ramat.) procured from CSIR-NBRI, Lucknow (India) in the year 2020. The terminal cuttings were treated with IBA (Indole Butyric Acid) @ 400 ppm and planted in sand for rooting in plug tray in the month of June and kept under shade. The rooted cuttings were transplanted individually in white plastic pots (8-inch diameter) filled with different growing media compositions in August 2021.Ten growing media combinations were selected and prepared as per treatment details after thoroughly mixing the various ingredients on a volume-by-volume basis. The growing media combination treatments (T) were:

T_1	Soil + Sand + FYM (Farm Yard Manure) [2:1:1 *v*/*v*/*v*]
T_2	Soil + Sand + Vermicompost (2:1:1 *v*/*v*/*v*)
T_3	Soil + Sand + Vermicompost + Cocopeat (2:1:1:1 *v*/*v*/*v*/*v*)
T_4	Cocopeat + Perlite + Vermicompost (2:1:1 *v*/*v*/*v*)
T_5	Cocopeat + Vermicompost + Vermiculite (2:1:1 *v*/*v*/*v*)
T_6	Cocopeat + Perlite + Leaf mould (2:1:1 *v*/*v*/*v*)
T_7	Cocopeat + Vermicompost + Leaf mould (2:1:1 *v*/*v*/*v*)
T_8	Soil + Leaf mould + Sand (2:1:1 *v*/*v*/*v*)
T_9	Cocopeat + FYM (Farm Yard Manure) +Sand +Vermicompost (2:1:0.5:0.5 *v*/*v*/*v*/*v*)
T_{10}	Soil (control)

The cocopeat bricks were saturated by keeping them in water overnight in the container. The saturated bricks were beaten with a wooden rod to ensure homogenous mixture without any clod or foreign particles. The media mixtures were prepared in different ratios as per treatments and filled in plastic pots. Plastic pots of similar diameter (8 inch) and weight (0.195 kg) were used in the experiment. Proper care was taken for uniform filling of media mixtures into all pots by tapping to maintain equal compaction levels. The pots were saturated with water immediately after filling to ensure settling down of media mixtures. One rooted cutting of *Chrysanthemum* was allowed to grow and develop until maturity. First, the pinching operation was conducted by removing the terminal bud 30 days after transplanting. The second pinching operation was conducted 25 days after first pinching to encourage more side shoots.

The water-soluble fertiliser NPK (20:20:20) @ 3g/liter was applied 1 month after transplanting and then at 2-week interval until the flowering stage was reached. Weeding was performed manually with hand hoe and plants were inspected daily. The pots were irrigated once a week during the months of December to February and twice a week during March to April (due to temperature fluctuations) with 5 cm of irrigation water. The mean temperature during the course of experiment varied from 5 to 34 °C.

The air-dried growth media was used for estimation of pH (1:2 media: water suspension) using pH meter and electrical conductivity (1:2 media: water suspension) using EC meter [38]. Organic carbon (%) was determined by wet digestion method [39], total nitrogen (%) by the Kjeldahl method [40] and total phosphorus determined by spectrophotometer [41]. Total K, Ca, Mg, Na was estimated by Flame Photometer [42]. Diethylene triamine penta acetic acid(DTPA) extractable Zn, Fe, Cu and Mn were determined in media samples by Atomic Absorption Spectroscopy [43].The water holding capacity (WHC) was determined with the help of Keen's box method [44].Vegetative parameters, viz., plant height at first bud appearance (cm),plant height at harvesting stage(cm),number of primary branches per plant, number of secondary branches per plant, number of leaves per plant, leaf biomass, internodal length (cm), stem diameter (cm), plant spread, average fresh weight of leaf(g), number of suckers per plant, pot weight (kg), root spread (cm), root length(cm) and dry weight of roots(g) and floral parameter, i.e., days taken to first flower bud initiation, days taken to first flower bud opening, days taken for full blooming, flowering duration (days), flower longevity, flower diameter(cm), number of flowers per plant, number of ray florets, average fresh weight of flower(g), flower peduncle length (cm), flower yield per plant (g) and vase life (days)were recorded during crop period.

Statistical Analysis

The experiment was conducted as per treatment in Completely Randomised Design (CRD) with three replications and five pots per replication. The data was analysed using analysis of variance (ANOVA) to calculate least square difference (LSD, p = 0.05) and Tukey's HSD (Honest significant difference) test using statistical package for the social sciences (SPSS) program.

3. Results

3.1. Physico-Chemical Analysis of Media Composition

The physico-chemical characteristics, viz., organic carbon, bulk density (BD), water holding capacity (WHC), pH and macro and micronutrients, were greatly different among different treatments (Table 1). The media compositions comprising T_5 (Cocopeat + Vermicompost + Vermiculite 2:1:1) recorded the highest WHC (210%), followed by the media composition T_7 (Cocopeat + Vermicompost + Leaf mould 2:1:1) having 205% WHC. The minimum WHC was noticed in soil-based media composition T_{10} (Soil only) and T_8 (Soil + Leaf mould + Sand 2:1:1). The highest bulk density (1.10g/cc) was observed in T_{10} (soil) while the lowest (0.22g/cc) was observed in T_4(Cocopeat + Perlite + Vermicompost 2:1:1), followed by T_5, T_6 and T_7. Total organic carbon was highest (7.442) in T_9 (Cocopeat + FYM + Sand), followed by T_6 (Cocopeat + Perlite +Leaf mould 2:1:1) having 6.640% organic carbon content. The total nitrogen, phosphorous and potash were higher (359.91, 3615 and 2212.24 ppm) in T_7 (Cocopeat + Vermicompost + Leaf mould 2:1:1), followed by T_9 (Cocopeat + FYM + Sand) and T6 (Cocopeat + Perlite + Leaf mould 2:1:1). Minimum total nitrogen and phosphorous (152.96 and 500) was recorded in T_{10} (soil only). Analysis of media composition revealed that exchangeable Ca, Mg, Na, Fe, Zn, Mn, Cu and EC were in higher content in growing media comprised of cocopeat and vermicompost compositions (Table 1).

Table 1. Physico-chemical properties of growing media.

Treatments	Organic Carbon (%)	Bulk Density (g/cc)	WHC (%)	pH	EC (dSm^{-1})	Ex. Na (ppm)	Total N (ppm)	Total P (ppm)	Ex. K (ppm)	Ex Ca (%)	Ex. Mg (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
T_1	2.442	1.02	55	7.567	0.312	83.60	165.88	780	556.57	0.380	0.060	19.030	9.250	35.690	4.880
T_2	2.400	0.88	75	7.508	0.525	134.75	209.66	1820	646.79	0.440	0.120	21.530	17.880	66.250	1.460
T_3	1.460	0.70	95	7.640	0.439	195.80	202.58	1035	907.97	0.400	0.070	19.150	26.380	84.310	1.400
T_4	4.200	0.22	80	6.867	1.940	11.30	337.64	3240	8,821.03	0.360	0.250	61.310	14.750	88.630	3.760
T_5	6.500	0.26	210	6.965	1.281	900.89	309.29	2620	4,433.51	0.320	0.170	52.310	24.190	77.630	9.490
T_6	6.640	0.30	185	7.498	0.364	31.62	271.53	3940	135.52	0.030	0.010	26.190	2.440	139.250	1.110
T_7	5.530	0.34	205	7.171	1.350	402.60	359.91	3615	2212.24	0.390	0.090	52.880	14.880	68.560	4.710
T_8	2.740	0.96	50	7.958	0.248	53.32	190.20	900	180.69	0.480	0.150	16.940	1.260	31.380	4.680

Table 1. *Cont.*

Treatments	Organic Carbon (%)	Bulk Density (g/cc)	WHC (%)	pH	EC (dSm^{-1})	Ex. Na (ppm)	Total N (ppm)	Total P (ppm)	Ex. K (ppm)	Ex Ca (%)	Ex. Mg (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
T_9	7.442	0.53	120	7.512	0.849	355.30	215.06	4070	3,796.16	0.270	0.100	32.990	1.800	58.130	0.980
T_{10}	0.750	1.10	50	7.953	0.374	376.20	152.96	500	247.62	0.430	0.030	10.190	2.660	36.380	1.800

WHC: Water Holding Capacity, EC: Electrical Conductivity, Ex. Na: Exchangeable Sodium, N: Nitrogen, P: Phosphorus, Ex. K: Exchangeable Potassium, Ex. Ca: Exchangeable Calcium, Ex. Mg: Exchangeable Magnesium, Fe: Iron, Zn: Zinc, Mn: Manganese, Cu: Copper. T_1 Soil + Sand + FYM (2:1:1 *v*/*v*/*v*), T_2 Soil + Sand + Vermicompost (2:1:1 *v*/*v*/*v*), T_3 Soil + Sand + Vermicompost + Cocopeat (2:1:1:1 *v*/*v*/*v*/*v*), T_4 Cocopeat + Perlite + Vermicompost (2:1:1 *v*/*v*/*v*), T_5 Cocopeat + Vermicompost + Vermiculite (2:1:1 *v*/*v*/*v*), T_6 Cocopeat + Perlite + Leaf mould (2:1:1 *v*/*v*/*v*), T_7 Cocopeat + Vermicompost + Leaf mould (2:1:1 *v*/*v*/*v*), T_8 Soil + Leaf mould + Sand (2:1:1 *v*/*v*/*v*), T_9 Cocopeat + FYM + Sand + Vermicompost (2:1:0.5:0.5 *v*/*v*/*v*/*v*), T_{10} Soil (control).

3.2. Vegetative Parameters

The different media compositions significantly ($p<0.05$) influenced plant height at first bud appearance (2.38) and at harvesting stage (3.83), number of primary (1.42) and secondary branches per plant (3.01), number of leaves per plant (21.67), leaf biomass (45.91), internodal length (0.11), stem diameter (0.10), plant spread (4.57), average fresh weight of leaf (0.01), number of suckers per plant(6.49), pot weight (0.55), root spread (0.31), root length (1.33) and dry weight of roots (0.42). The maximum plant height at first bud appearance (30.72 cm) and at harvesting stage (41.95 cm) was recorded in treatmentT7 while minimum plant height at first bud appearance (24.79 cm) andat harvesting stage (32.40 cm) was recorded in treatment T6 andT8, respectively. The number of primary branches per plant was observed to be highest in treatment T7(15.33), followed by T5and T9 (12.67). However, the minimum number of primary branches per plant found inT6 (8.34). The number of leaves per plant and leaf biomass was significantly better in treatment T7 (424.89 and 306.50 g, respectively), followed by T5 (358.89 and 247.42 g, respectively). The internodal length was reported to be at its maximum in treatment T4 (2.52 cm) while minimum internodal length was observed in T6 (1.91 cm). The maximum stem diameter was recorded in T9 (0.90 cm),followed by media composition T7 (0.85 cm) and T10 (0.85 cm), while minimum stem diameter was recorded in T6 (0.56 cm). Plants with maximum spread were found in T9 (47.21 cm), followed by T7 (46.93) (Table 2).

Table 2. Mean performance of *Chrysanthemum* for various vegetative parameters.

Treatment	Plant Height at First Bud Appear-ance(cm)	Plant Height at Harvesting Stage (cm)	Number of Primary Branches per Plant	Number of Secondary Branches per Plant	Number of Leaves per Plant	Leaf Biomass (g)	Internodal Length (cm)	Stem Diameter (cm)	Plant Spread (cm)
T_1	28.04	35.30	9.55	20.22	216.56	132.83	2.33	0.82	40.32
T_2	28.27	37.55	10.447	20.78	251.00	179.15	2.31	0.78	40.10
T_3	30.70	39.50	11.89	25.89	300.89	210.05	2.43	0.82	41.34
T_4	28.64	38.58	11.78	26.66	319.78	227.61	2.52	0.74	44.43
T_5	29.81	40.17	12.67	28.11	358.89	247.42	2.51	0.77	45.31
T_6	24.79	32.63	8.34	19.00	158.56	90.78	1.91	0.56	32.35
T_7	30.72	41.95	15.33	33.00	424.89	306.50	2.43	0.85	46.93
T_8	26.60	32.40	10.56	22.00	235.67	160.15	2.33	0.84	40.83
T_9	30.41	41.37	12.67	28.34	347.78	228.03	2.29	0.90	47.21
T_{10}	26.99	35.34	10.22	21.78	197.00	134.21	2.20	0.85	36.64
SE	1.38	2.23	0.83	0.82	36.52	26.76	0.06	0.05	2.66
C.D.@5%	2.38	3.83	1.42	3.01	21.67	45.91	0.11	0.10	4.57
HSD@5%	3.93	6.32	2.35	2.34	106.16	75.72	0.18	0.15	7.54

T_1 Soil + Sand + FYM (2:1:1 *v*/*v*/*v*), T_2 Soil + Sand + Vermicompost (2:1:1 *v*/*v*/*v*), T_3 Soil + Sand + Vermicompost + Cocopeat (2:1:1:1 *v*/*v*/*v*/*v*), T_4 Cocopeat + Perlite + Vermicompost (2:1:1 *v*/*v*/*v*), T_5 Cocopeat + Vermicompost + Vermiculite (2:1:1 *v*/*v*/*v*), T_6 Cocopeat + Perlite + Leaf mould (2:1:1 *v*/*v*/*v*), T_7 Cocopeat + Vermicompost + Leaf mould (2:1:1 *v*/*v*/*v*), T_8 Soil + Leaf mould + Sand (2:1:1 *v*/*v*/*v*), T_9 Cocopeat + FYM + Sand + Vermicompost (2:1:0.5:0.5 *v*/*v*/*v*/*v*), T_{10} Soil (control). SE: Standard error, CD: Critical difference, HSD: Honestly significant difference.

The maximum average fresh weight of leaf was recorded in T7 (0.71 g), followed by T3 (0.70 g) and T4 (0.70 g), while minimum average fresh weight of leaf was found in T6 (0.57 g). The maximum number of suckers per plant was recorded in treatment T6 (27.22), followed by T9 (25.11). However, the minimum suckers per plant were recorded in T10 (15.67). The maximum pot weight was recorded in treatment T10 (6.42 kg), followed by treatment T8 (5.58 kg), while minimum pot weight was found in T4 (2.97 kg). Plants with maximum root spread were observed in T1 (19.95cm), followed by T7 (19.76cm), while minimum root spread was found in T10 (11.07 cm). The maximum root length was recorded in T10 (23.21cm), followed by T4 (20.17 cm), while minimum root length was recorded in T5 (16.43 cm) (Table 3, Supplementary Materials Figure S1). The dry weight of roots was found to be at its maximum in T7 (52.82g), followed by T3 (49.32 g), while the minimum dry weight of roots in potting media composition was found in T6 (8.83 g) (Table 3).

Table 3. Mean performance of *Chrysanthemum* for leaf weight, number of suckers and roots characteristics.

Treatment	Average Fresh Weight of Leaf (g)	Number of Suckers per Plant	Pot Weight (kg)	Root Spread (cm)	Root Length (cm)	Dry Weight of Roots (g)
T_1	0.61	22.66	5.24	19.95	19.24	31.19
T_2	0.68	18.56	5.10	17.18	19.98	42.22
T_3	0.70	20.44	3.81	18.90	17.29	49.32
T_4	0.70	20.89	2.97	18.31	20.17	45.69
T_5	0.69	21.11	3.33	18.29	16.43	44.09
T_6	0.57	27.22	3.54	12.09	18.03	8.83
T_7	0.71	17.67	3.01	19.76	17.89	52.82
T_8	0.68	20.22	5.58	18.19	17.18	38.61
T_9	0.66	25.11	3.59	18.94	17.19	31.95
T_{10}	0.68	15.67	6.42	11.07	23.21	10.01
SE	0	3.78	0.31	0.17	0.77	0.24
C.D. @5%	0.01	6.49	0.55	0.31	1.33	0.42
HSD@5%	0	10.70	0.90	0.51	2.19	0.70

T_1 Soil + Sand + FYM (2:1:1 *v/v/v*), T_2 Soil + Sand + Vermicompost (2:1:1 *v/v/v*), T_3 Soil + Sand + Vermicompost + Cocopeat (2:1:1:1 *v/v/v/v*), T_4 Cocopeat + Perlite + Vermicompost (2:1:1 *v/v/v*), T_5 Cocopeat + Vermicompost + Vermiculite (2:1:1 *v/v/v*), T_6 Cocopeat + Perlite + Leaf mould (2:1:1 *v/v/v*), T_7 Cocopeat + Vermicompost + Leaf mould (2:1:1 *v/v/v*), T_8 Soil + Leaf mould + Sand (2:1:1 *v/v/v*), T_9 Cocopeat + FYM + Sand + Vermicompost (2:1:0.5:0.5 *v/v/v/v*), T_{10} Soil (control). SE: Standard error, CD: Critical difference, HSD: Honestly significant difference.

3.3. Flowering Parameters

The different media compositions significantly influenced ($p < 0.05$) days taken to first flower bud initiation (1.04), first flower opening (1.30), full blooming (3.05), flowering duration (1.11), flower longevity (0.39), flower diameter (0.25), number of flowers per plant (27.86), number of ray florets (7.53), average fresh weight of flower (0.15), flower peduncle length (0.24), flower yield per plant (49.77) and vase life (0.88).The earliest first flower bud initiation was recorded in treatment T1 (66.67 days), followed by T2 (66.89 days), whereas late first flower bud initiation was recorded in T8 (70 days). The first flower bud opening was recorded earliest in T10 (95.33 days), followed by T8 (98.45 days). However, delayed opening of first flower was observed in T5 (101.78 days). The minimum number of days for full blooming was recorded in T10 (110.33 days), followed by treatment T9 (117 days), whereas late blooming was recorded in T6 (122 days). Flowering duration was recorded maximum in treatment T6 (55.89 days), followed by T7 (54.22 days), while minimum flowering duration was found in T3 (49.22 days). Maximum flower longevity was recorded in treatment T7 (33.78 days), followed by T9 (30.78 days), while minimum flower longevity was found in treatment T10 (21.78 days). Flowers with maximum diameter were recorded inT7 (4.97 cm), followed by T5 (4.95 cm), while minimum flower diameter was recorded in treatment T10 (4.19 cm).The maximum number of flowers per plant was recorded in T7 (214.11), followed by treatment T9 (169.78). However, the minimum number of flowers was observed in T6 (96.00). The number of ray florets was recorded maximum in T7 (260.67), followed by T3 (259.89), while the minimum number of ray florets was found in T1 (236.44). The maximum average fresh weight of flower was recorded in treatment T7 (7.13 g), followed by T5 (6.87 g), and minimum average fresh weight of flower was observed in T10 (4.52 g). The maximum flower peduncle length was observed in treatment T5 (5.70 cm), followed by T3 (5.50 cm), while minimum peduncle length was observed in T10 (4.52 cm). The maximum flower yield per plant was recorded in T7 (519.67g), followed by T5 (324.59 g), while minimum flower yield per plant was recorded in T6 (167.53 g). Vase life was recordedat itsmaximum in treatment T7 (24.44 days), followed by T8 (23.33 days), while minimum vase life was observed in T9 (15.11 days) (Table 4, Supplementary Materials Figure S2).

Table 4. Mean performance of *Chrysanthemum* for various flowering parameters.

Treatment	Days Taken to First Flower Bud Initiation	Days Taken to First Flower Opening	Days Taken for Full Blooming	Flowering Duration (Days)	Flower Longevity (Days)	Flower Diameter (cm)	Number of Flowers per Plant	Number of Ray Florets	Average Fresh Weight of Flower (g)	Flower Peduncle Length (cm)	Flower Yield per Plant (g)	Vase Life (Days)
T_1	66.67	99.22	118.00	50.33	25.11	4.40	113.78	236.44	4.86	4.86	188.25	20.78
T_2	66.89	100.00	118.00	49.55	23.78	4.57	149.78	241.22	4.78	4.78	238.70	20.22
T_3	67.33	99.78	118.44	49.22	25.56	4.71	165.33	259.89	5.50	5.50	302.93	20.22
T_4	68.00	98.89	119.33	53.00	27.33	4.73	151.00	258.33	5.19	5.19	257.47	23.22
T_5	67.00	101.78	118.89	51.66	24.67	4.95	143.55	257.44	6.87	5.70	324.59	21.78
T_6	67.67	98.78	122.00	55.89	30.44	4.82	96.00	258.33	5.26	5.26	167.53	21.33
T_7	68.67	98.67	119.33	54.22	33.78	4.97	214.11	260.67	7.13	5.33	519.67	24.44
T_8	70.00	98.45	117.11	52.67	29.56	4.60	136.44	254.44	5.21	5.21	237.10	23.33
T_9	69.00	99.78	117.00	50.11	30.78	4.90	169.78	254.33	4.81	4.81	272.12	15.11
T_{10}	67.67	95.33	110.33	54.00	21.78	4.19	135.33	246.89	4.52	4.52	203.63	18.44
SE	0.60	0.75	1.77	0.38	0.22	0.46	16.24	4.39	0.04	0.61	29.01	0.51
C.D. @ 5%	1.04	1.30	3.05	1.11	0.39	0.25	27.86	7.53	0.15	0.24	49.77	0.88
HSD@5%	1.72	2.14	5.03	1.09	0.65	1.33	45.94	12.42	0.92	1.73	82.09	1.45

T_1 Soil + Sand + FYM (2:1:1 *v*/*v*/*v*), T_2 Soil + Sand + Vermicompost (2:1:1 *v*/*v*/*v*), T_3 Soil + Sand + Vermicompost + Cocopeat (2:1:1:1 *v*/*v*/*v*/*v*), T_4 Cocopeat + Perlite + Vermicompost (2:1:1 *v*/*v*/*v*), T_5 Cocopeat + Vermicompost + Vermiculite (2:1:1 *v*/*v*/*v*), T_6 Cocopeat + Perlite + Leaf mould (2:1:1 *v*/*v*/*v*), T_7 Cocopeat + Vermicompost + Leaf mould (2:1:1 *v*/*v*/*v*), T_8 Soil + Leaf mould + Sand (2:1:1 *v*/*v*/*v*), T_9 Cocopeat + FYM + Sand + Vermicompost (2:1:0.5:0.5 *v*/*v*/*v*/*v*), T_{10} Soil (control). SE: Standard error, CD: Critical difference, HSD: Honestly significant difference.

4. Discussion

4.1. Vegetative Parameters

Diversified compositions of growing media have had a profound effect on physical, chemical and biological properties of the substrate, and these parameters influence plant growth and development by affecting nutrient availability, water availability and aeration of substrate [14]. These diversified compositions also alter the activities of microorganisms, which ultimately decrease the nitrogen losses and increase the cation exchange capacity [34]. Media with Cocopeat, Leafmould and Vermicompost resulted in better vegetative growth of the plants. Significantly higher plant height at initial bud appearance (30.72 cm) and harvesting stage (41.95 cm) was recorded in Cocopeat + Vermicompost +Leaf mould in a ratio of 2:1:1. Increase in the plant height may be due to the presence of cocopeat, vermicompost and leaf mould in media, which considerably improved the aeration, water holding capacity and nutrients uptake by the root system. The findings of the experiment are consistent with those of [45] in petunia, [25] in cymbidium, [32] in rose [26,46] and in *Chrysanthemum*. These substrate mixtures have better organic carbon, higher nutrient content, lower bulk density and high-water content. Low bulk density and high-water content also indicates that such substrate mixture will have higher air volume in the pot [8]. Better results of substrate substituted with Cocopeat were observed in gerbera [47] in terms of better stalk length and flower yield. Mixing of substrate with a high nutrient-containing component such as sewage sludge [8] has been reported to result in better performance of petunia in pots.

The number of primary and secondary branches per plant was significantly impacted by various growing media compositions. Treatment T7 (Cocopeat + Vermicompost + Leaf mould) in ratio of 2:1:1 recorded the highest number of primary (15.33) and secondary branches per plant (33.00).This could be due to its better physiochemical characteristics, including lower bulk density, higher total porosity, water holding capacity and higher nitrogen availability to the plants [14]. The above results are in line with the findings of [47] in gerbera, [25] in cymbidium, [8] in petunia, [34,48] in *Chrysanthemum*. Since nitrogen in growing media significantly affects plant growth, an increase in the number of leaves of plants may also be due to adequate availability of nitrogen content in media [49,50]. Number of leaves per plant (424.89) was significantly higher in treatment T7 (Cocopeat + Vermicompost +Leaf mould, 2:1:1). Similar findings were also reported by [31] and [24] in gerbera, [33] in *Lilium* and [37] in *Chrysanthemum*. This might be because of growing media composition T7 (Cocopeat + Vermicompost + Leaf mould 2:1:1) has more organic carbon (5.530%), optimum bulk density (0.34 g/cc), good WHC (205%), pH (7.171), suitable EC (1.350 dSm^{-1}), higher total nitrogen (359.91 ppm), phosphorous (3615 ppm), exchangeable potassium (2212.24 ppm), exchangeable calcium (0.390%), Fe (52.880 ppm) and Copper (4.710 ppm) as compared to conventional soil (control) and other soil-based media.

The exchangeable phosphorus, manganese, zinc, copper and sodium content in cocopeat media was higher in comparison with potassium and calcium, as reported by [51]. In addition, vermicompost and leaf mould add organic matter to the potting media and are a source of nutrition. [26] reported that the addition of an appropriate quantity of vermicompost and leaf mould in addition to cocopeat in media has a synergistic effect on plant shoot biomass, root biomass and plant height in marigold. Leaf biomass (306.50 g), average fresh weight of leaf (0.71 g) and dry weight of root (52.82 g) were also recorded to be best in treatment T7 (Cocopeat + Vermicompost + Leaf mould, 2:1:1), since organic carbon, bulk density (BD), WHC, pH, EC and nitrogen in growing media significantly affect the plant growth. An increase in the number of leaves per plant may also be due to adequate availability of nitrogen, boron, potassium and zinc content in media [36]. The growing media that are light in weight, rich in nutrients and well-drained are considered best for the growth and development of flowering plants [17,52–55].

Internodal length was observed to be higher in treatment T4 (Cocopeat + Perlite + Vermicompost, 2:1:1) because cocopeat and perlite help to improve proper aeration, and, with a decrease in media optimum organic carbon percentage (4.2%), bulk density up to 0.22 g/cc, good water holding capacity (80%) and vermicompost supply a substantial amount of nutrients via root absorption, which improves photosynthesis, cell division and cell elongation [37,56].

Stem diameter (0.90 cm) and plant spread (47.21 cm) were found to be best in treatment T9 (Cocopeat + FYM + Sand + Vermicompost, 2:1:0.5:0.5). This might be due to the fact that nutrition supply to the plant and availability of moisture are taken care by vermicompost, FYM and cocopeat. Sand in media provided better aeration to the plant, and this composition has a higher organic carbon percentage (7.442%), normal pH (7.512) and high total phosphorus (4070 ppm) in comparison to normal soil or soil-based media. Such results also have been observed by [31] in gerbera.

The number of suckers per plant (27.22) was found to be maximum in T6 (Cocopeat + perlite+ leaf mould, 2:1:1). This is because good organic carbon percentage (6.64%) promotes soil structure or tilth, which improves soil aeration, water drainage and retention, and leaf mould helps to promote phosphorus availability in media (3940 ppm), which maintains the nutrition level in the media [36]. A similar result was observed in *Chrysanthemum* cv. Haldighati. High weight of growing media per pot (6.42 kg) was recorded with treatment T10 (Soil only). As pot weight is an important factor during transport and shipping, and soil is heavy and prone to diseases, the soil may get compacted after potting. Hence, cocopeat based medium compositions could replace the traditional potting medium (soil) for *Chrysanthemum* production [37].

4.2. Flowering Parameters

The number of flowers per plant in the pot mum decides the visual appearance and acceptance to the consumer. The findings of the present investigation showed that there is a positive effect of cocopeat- and vermicompost-based media on the number of flowers per plant. The most crucial factors in plant development are physical characteristics such as aeration and water holding capacity, and, among chemical parameters, nutritional status and salinity level [55].

Early flower bud appearance was observed in T1 (66.67 days) with growing media composition of soil, sand and FYM in a ratio of 2:1:1. It might be due to the vigorous growth of the plant growing in the media with rapid uptake of nutrients and water havinga pronounced effect on early production [14]. This is also attributed to the accumulation of more photosynthates in this media resulting in early flowering [56] in gerbera and [57] in carnation.

Different plant species (and cultivars) require different pH ranges for optimum growth;6.0 is generally considered to be the ideal pH of soilless media for good availability of critical nutrients. Despite the low final pHs of all the medium, observation showed that plant growth was normal and that there were no signs of elemental deficiency or toxicity [14]. Maximum flowering duration (55.89 days) was observed in media composition with Cocopeat +Perlite +Leaf mould in a 2:1:1 ratio (T6), which might be due to the fact that the media composition favours good aeration with better drainage properties, and high total nitrogen as compared to soil [53].

Flower longevity (33.78 days), flower diameter (4.97 cm), number of flowers per plant (214.11), number of ray florets (260.67), average fresh weight of flower (7.13 g), flower yield per plant (519.67 g) and vase life of flower (24.44 days) were significantly higher in T7 (Cocopeat +Vermicompost +Leaf mould, 2:1:1) composition. [35] in *Chrysanthemum* cv. 'Mother Teresa' also reported maximum flower longevity (15.60 days) while [46] in *Chrysanthemum* var. Yellow Charm recorded the highest flower diameter (3.91 cm) with growing media consisting of Soil: Sand: FYM: Vermicompost in the ratio of 2:1:0.5:0.5 [58] also recorded maximum flower diameter (8 cm) with media combination of Cow dung: Vermicompost: Soil in marigold. Better flower diameter and flowering duration in cocopeat- and vermiculite-amended media might be due to higher availability of potassium in media mixture. These results are supported by [59], who reported the significant increase in the flower size by the application of urea with combination of potash and FYM in *Dahlia*. The higher number of flowers per plant and nitrogen content were recorded in potting media containing cocopeat as cocopeat adds organic matter to the medium and contains more nitrogen as a source of nutrition for the development of more numbers of flower [60]. They observed higher numbers of flowers in *Zinnia elegans* and marigold in medium containing cocopeat coir. These results are in conformity with [7,61], who reported the highest number of flowers per plant in *Chrysanthemum* in potting media containing cocopeat alone.

5. Conclusions

The present findings suggest that growing media compositions consisting of cocopeat and organic amendments with vermicompost and leaf moulds have a positive effect on the physical environment of media, and they also improve the water retention and aeration properties of media. The combination of environmentally safe and low-cost cocopeat along with vermicompost and leaf mould(2:1:1 $v/v/v$)with lighter media was found best for better plant morphological development and sustained quality flower production of pot mum. If the use of such type of growing media is adopted, the faster growth and development of ornamentals plant can be achieved. It would be economically attractive for indoor plants growers and consumers at a commercial level.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15010536/s1, Figure S1: Root spread and Root length in different growing media compositions; Figure S2: Performance of pot mum in different growing media.

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