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Comparative effect of different potting substrates on vegetative and floral attributes of marigold under mid hill conditions of Himachal Pradesh, India

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Abstract

The influence of various potting substrates on the vegetative and floral attributes of three marigold cultivars ('Pusa Bahar', 'Pusa Deep', and 'Seracole') was investigated in the mid-hills of Himachal Pradesh. Eight different substrates were utilized, including soil+FYM (1:1, v/v), soil+FYM (2:1, v/v), soil+sand+FYM (1:1:1, v/v), sand+soil+FYM (2:1:1, v/v), spent mushroom compost (SMC), smc+soil+sand+FYM (1:1:1:1, v/v), leaf mould and leaf mould+soil+FYM (1:1:1, v/v). Among the different potting substrates, the substrate composed of leaf mould+soil+FYM (1:1:1, v/v) exhibited superior performance, resulting in maximum plant height (50.52 cm), plant spread (34.70 cm), number of shoots (11.74), number of flower heads open at a time (12.49), largest flower head diameter (5.60 cm), total number of flowers per plant (18.37), pot presentability score (80.60), available NPK (659.16 kg ha^{-1}, 23.87 kg ha^{-1} and 335.61 kg ha^{-1}, respectively) and OC (44.61 g kg^{-1}). Regarding cultivar variation, 'Pusa Deep' demonstrated significant attributes with the maximum plant spread (36.24 cm), number of flower heads open at a time (15.75), total number of flowers per plant (24.57) and pot presentability score (79.40). However, 'Seracole' exhibited the highest number of shoots (12.02), largest flower head size (5.81 cm), maximum available NPK (505.26 kg ha^{-1}, 18.15 kg ha^{-1} and 43.25 kg ha^{-1}, respectively) and OC (43.25 g kg^{-1}). This study suggests that a potting medium containing Leaf Mould+Soil+FYM (1:1:1, v/v) coupled with the 'Pusa Deep' cultivar is optimal for producing high-quality potted marigold plants. These findings offer practical insights for improving marigold cultivation practices by selecting optimal potting substrates along with the cultivar in similar agro-climatic regions, potentially enhancing flowering, marketability and economic returns for farmers.

Key words: Marigold, *Tagetes* spp, Pusa Deep, Pusa Bahar, Seracole, potting substrate, vegetative attributes, flowering, leaf mould, spent mushroom compost, pot presentability

Introduction

Potted plants are significant in both global and domestic floriculture markets. The indoor plants market, valued at USD 17.93 billion in 2021, is projected to grow to USD 26.23 billion by 2029, with a yearly growth rate of 4.87% (Anonymous, 2022). Beyond their aesthetic appeal, flowering potted plants, such as marigold, petunia, geranium, and orchids, positively affect human psychology and can enhance indoor air quality (Nair *et al.,* 2023). Marigold, a plant, native to Central and South America, holds a significant position within the Asteraceae family, revered for both its medicinal properties and ornamental value (Kaur *et al.,* 2023). The genus Tagetes, encompassing 33 species, extends its cultural significance, particularly in Asia, where it stands as a pivotal commercial flower crop, prominently cultivated in India (Salehi *et al.,* 2018). Named after the demigod 'Tages', Marigold is highly favored for its versatility in decorative applications, such as cut flowers, loose blooms, and potted plants. Its ability to adapt well and maintain prolonged blooming periods has made it popular at festivals and social events (Chauhan *et al.,* 2022). Beyond its aesthetic charm, Marigold serves utilitarian functions as well, serving as a nutritional supplement in poultry feed due to its rich lutein content, further accentuating its economic value (Atay, 2022).

Recent undertakings have seen a shift towards cultivating Marigold as a potted plant, exploring substrates ranging from conventional compositions like soil, sand, and farmyard manure (FYM) to alternative mediums such as bagasse and coco peat (Sirai *et al.,* 2023). While these substrates yield promising results, they often entail higher production costs than locally available materials. Crucial for root anchorage, nutrient retention, and moisture regulation, these substrates are pivotal in providing an optimal growth environment, facilitating oxygen diffusion and gaseous exchange essential for robust plant development (Khosravi *et al.,* 2019). The composition of the potting medium emerges as a decisive factor influencing Marigold's growth trajectory, flower production, and overall pot quality, underscoring the imperative of selecting a suitable growing medium (Al-Mazroui *et al.,* 2020). Several researchers investigated the impact of various substrates assumes paramount importance in increasing Marigold's growth, flowering potential and overall presentation as a potted plant. Nair *et al*. (2023) suggested application of potting media combination of Arka fermented cocopeat+ vermicompost (1:1 v/v) supplemented with weekly application of nutrient solution of 128:24:144 ppm N: P_2O_5: K_2O @ 50 mL pot^{-1} for marigold. In a similar study, conducted by Mann *et al*. (2023) on different potting substrates, the media substrate composition comprising cocopeat+ burnt rice husk + farmyard manure (FYM) (25:25:50) was found to be suitable for sustaining the growth of potted marigold plants. The selection of cultivars is pivotal in Marigold production, especially considering how each cultivar interacts with the potting substrate and the specific agroclimatic conditions (Singh *et al.,* 2022). By comprehending the distinct traits of various cultivars, growers can tailor their choices to meet specific cultivation goals, thereby improving the quality and market appeal of potted Marigold plants (Stewart-Wade, 2020).

Despite these advancements, there remains a gap in understanding the specific influence of different potting substrates (including locally available substrate) on the vegetative and floral attributes of marigold cultivars in specific geographic regions, such as the mid hills of Himachal Pradesh. The study was conducted with an objective to provide recommendations for optimal potting substrate and variety selection for maximizing vegetative and floral growth of marigold. By examining the interaction between substrate composition and cultivar performance, present research aims to provide insights into optimizing marigold cultivation practices under specific agro-climatic conditions of mid hills in Himachal Pradesh.

Materials and methods

Experimental site: The experiment was conducted from 2021 to 2022 at Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). The experimental farm is located at an altitude of 1060 m above mean sea level, with a latitude of 30.51°N and longitude of 77.10°E. Mean monthly meteorological data from July, 2021 to January, 2022 is presented in Figure 1.

Planting material: The pure, robust and disease-free seeds of three varieties of marigold, namely 'Pusa Bahar' (V_1), 'Pusa Deep' (V_2) and 'Seracole' (V_3) were used to perform the experimental studies. The seeds of 'Pusa Bahar' and 'Pusa Deep' were obtained from IARI, RS, Karnal (Haryana) and rooted cuttings of 'Seracole' from the Department of Floriculture and Landscape Architecture, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). The healthy, bold and disease free seeds of two varieties, 'Pusa Bahar' and 'Pusa Deep', were sown in the nursery. Land was thoroughly prepared for raising the nursery. Soil of good tilth was prepared and well rotten FYM @ 5Kg/m^2 was added into the soil. Seeds were sown by line sowing method at 3-5cm depth. The seedlings were ready for transplanting 30-35 days after sowing

Potting substrate preparation: Eight potting substrates *viz.,* PS_1 = Soil + FYM (1:1, v/v), PS_2 = Soil + FYM (2:1, v/v), PS_3 = Soil + Sand + FYM (1:1:1, v/v), PS_4 = Soil + Sand + FYM (2:1:1, v/v), PS_5 = Spent Mushroom Compost (SMC), PS_6 = SMC + Soil + Sand + FYM (1:1:1:1, v/v), PS_7 = Leaf mould (LM), PS_8 = Leaf mould + Soil + FYM (1:1:1, v/v) were prepared after combining of varied ingredients on volume by volume basis and after sterelization, filled up in plastic pots (17.5 cm in height). Media samples were collected to analyze physico-chemical properties (Table 1).

Planting and cultural practices: The healthy, disease free and stocky seedlings of 'Pusa Bahar', 'Pusa Deep' and rootedcuttings of 'Seracole' cv. of marigold (*Tagetes* spp) were planted in the plastic and irrigated gently immediately after planting. 300 mg each of NPK was applied in all the pots as a basal dose. All the cultural practices were followed as and when required.

Observations recorded: The observations on vegetative and flowering parameters like plant height (cm), plant spread (cm), number of shoots per plant, maximum number of flower head open at a time, flower head size (cm), number of flower heads per plant and pot presentability score were recorded at the time of peak flowering. The physico-chemical properties were recorded after the termination of the experiment by following the standard procedures *i.e.* pH and EC (Jackson, 1973), particle density and bulk density (Singh, 1980), available N (Subbiah and Ashija, 1956), available P (Olsen *et al.,* 1954), available K (Merwin and Peech, 1951) and OC (Walkley and Black, 1934).

Statistical analysis: The data obtained during the research was analysed using OP STAT (Sheoran,2006) and Microsoft Excel Software. Employing a factorial completely randomized design (CRD), analysis of variance (ANOVA) was performed on the data, and the treatments were compared at the 0.05% significance level. Pots were assessed for their presentability on the basis of point system modified after Conover (1986).

Results and discussion

Vegetative parameters: The vegetative parameters of marigold revealed statistically significant difference with respect to different growing media and cultivars (Table 1). The maximum mean plant height (50.52 cm), plant spread (34.70 cm) and number of shoots/plant (11.74) was in media PS_8 and minimum in PS_3 (40.01 cm, 27.21 cm and 7.26 cm, respectively). The potting media PS_8 improved all the vegetative parameters and aligns with our objective to provide recommendations for optimal potting substrate selection for maximizing vegetative growth in marigold.

Table 1. Physico-chemical properties of potting substrates before the start of the experiment

Potting substrates	pH	EC (ds m^{-1})	Bulk density (kg/m^{-3})	Particle density (kg/m^{-3})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	OC (g kg^{-1})
PS1	7.28	0.218	1076.2	1869	194	32	302	16.80
PS2	7.26	0.224	1199.2	1950	288	34	354	10.60
PS3	7.25	0.144	1358	2150	194	22	289	6.57
PS4	7.30	0.145	1403.8	1890	157	45	360	7.92
PS5	7.20	0.243	860.8	1570	389	50	401	16.30
PS6	7.24	0.206	1222.2	2100	389	73	516	6.22
PS7	7.18	0.234	799.8	1455	458	65	404	10.80
PS8	7.06	0.253	909.8	1920	420	81	580	6.70

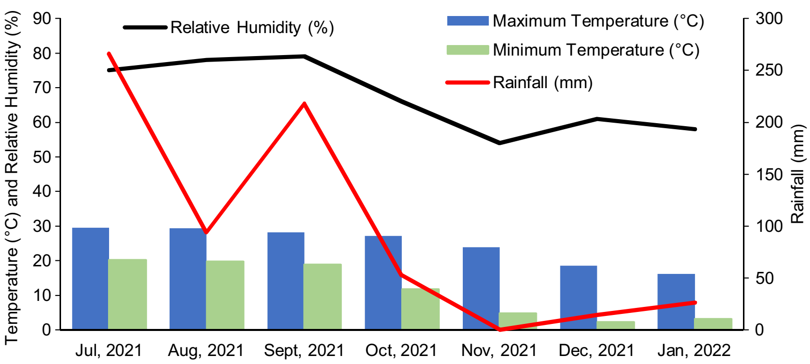

Fig. 1. Mean monthly meteorological data during the experiment (2021-22)

Among cultivars, maximum plant height (53.53 cm) was in V_1 and minimum (39.29 cm) in V_3. Maximum plant spread (36.24 cm) was in V_2 and minimum (24.34 cm) in V_1. However, highest number of shoots/plant (12.02) was in V_3 and lowest (5.47) in V_1. The cultivar V_2 outstands in plant spread, which is an important criterion for variety to be selected as pot cultivars.

Among interactions, maximum plant spread (41.73 cm) was in PS_8 x V_2, maximum plant height (59.42 cm) was in PS_8 x V_1 and maximum number of side shoots/plant (14.80) was in PS_8 x V_3. The combination of cultivar V_2 and potting media PS_8 outstands in terms of plant spread, which is an important criterion for variety to be selected as a pot cultivar on vegetative growth parameter.

The differences in the plant's growth characteristics are likely linked to the physico-chemical properties of the growing substrates. A well-balanced potting mix is crucial because it provides plants with the essential nutrients and organic matter, necessary for optimal growth and development. In particular, the potting mix containing FYM and leaf mould emerged as a superior source of organic matter compared to using soil alone.

The increased availability of NPK in PS_8 substrate likely facilitated nutrient supply to plants, resulting in enhanced growth parameters such as plant height, spread, and shoot count. Nitrogen (N) supports leaf and stem growth through protein and chlorophyll synthesis (Perchlik and Tegeder, 2018), phosphorus (P) stimulates root development and energy transfer (Ikhajiagbe *et al.,* 2020), while potassium (K) aids in nutrient transport and water uptake, collectively promoting robust vegetative growth (Mostofa *et al.,* 2022). This finding aligns with previous studies that supported the effectiveness of these organic components in fostering plant growth (Mann *et al.,* 2023; Sirai *et al.,* 2023; Monika and Chandla, 2021). The variations in plant height, spread, and the number of shoots per plant among different varieties can be attributed to their genetic makeup. These findings are consistent with Mohanty *et al*. (2015) in marigold.

Flowering Parameters: Flowering parameters varied significantly for potting substrate, varieties, and interaction. Data presented in Table 3 revealed that he maximum number of flower heads open at a time (12.49), flower head size (5.60 cm) and number of flower heads/plant (18.37) was recorded in PS_8 whereas minimum number of flower heads open at a time (6.98), flower head size (4.64 cm) and number of flower heads/plant (18.37) was in PS_3. The potting media PS_8 improved all the flowering parameters and aligns with our objective to provide recommendations for optimal

Table 2. Effect of potting substrates on vegetative parameters of different marigold cultivars

Treaments	Plant height (cm)			Mean	Plant spread (cm)			Mean	No. of shoots per plant			Mean
	V_1	V_2	V_3		V_1	V_2	V_3		V_1	V_2	V_3	
PS_1	50.60	42.16	36.07	42.94	22.53	32.23	29.95	28.24	4.87	8.93	10.41	8.07
PS_2	51.63	43.67	38.67	44.66	23.48	34.79	30.27	29.51	5.27	10.10	11.33	8.90
PS_3	46.82	38.89	34.33	40.01	21.98	30.83	28.83	27.21	4.13	8.27	9.37	7.26
PS_4	52.02	44.90	39.53	45.48	24.01	35.13	31.41	30.18	5.60	10.60	11.93	9.38
PS_5	54.50	45.52	40.13	46.72	24.94	38.47	32.41	31.94	5.97	11.81	12.71	10.16
PS_6	57.79	47.33	42.53	49.22	25.87	39.97	34.03	33.29	5.81	12.53	13.87	10.73
PS_7	55.50	46.33	40.75	47.53	24.68	36.77	32.03	31.16	5.99	11.01	11.73	9.58
PS_8	59.42	49.86	42.29	50.52	27.19	41.73	35.17	34.70	6.09	14.33	14.80	11.74
Mean	53.53	44.83	39.29		24.34	36.24	31.76		5.47	10.95	12.02	

$CD_{0.05}$ Potting substrates (PS) = 0.83 Varieties (V) = 0.51 PS × V = 1.43	$CD_{0.05}$ Potting substrates (PS) = 0.86 Varieties (V) = 0.53 PS × V = 1.49	$CD_{0.05}$ Potting substrates (PS) = 0.49 Varieties (V) = 0.30 PS × V = 0.85

Table 3. Effect of potting substrates on flower parameters of different marigold cultivars

Treatments	Maximum number of flower heads open at a time			Mean	Flower head size (cm)			Mean	Number of flower heads per plant			Mean
	V_1	V_2	V_3		V_1	V_2	V_3		V_1	V_2	V_3	
PS_1	3.83	11.93	7.67	7.81	4.93	4.08	5.41	4.81	9.12	21.33	10.93	13.79
PS_2	4.06	13.07	6.87	8.00	5.03	4.01	5.57	4.87	9.30	22.27	11.07	14.21
PS_3	3.33	11.41	6.18	6.98	4.87	3.83	5.23	4.64	8.85	20.60	8.97	12.81
PS_4	4.06	13.27	7.35	8.23	5.37	4.10	5.73	5.07	9.47	22.87	11.87	14.73
PS_5	4.57	19.25	8.37	10.73	5.61	4.27	5.97	5.28	10.37	26.41	12.67	16.48
PS_6	4.96	19.81	10.33	11.70	5.73	4.37	6.27	5.46	10.53	28.20	12.87	17.20
PS_7	4.39	15.31	8.51	9.40	5.53	4.13	5.81	5.16	9.87	25.40	11.03	15.43
PS_8	5.15	21.92	10.39	12.49	5.85	4.43	6.51	5.60	11.11	29.47	14.53	18.37
Mean	4.29	15.75	8.21		5.37	4.15	5.81		9.83	24.57	11.74	

$CD_{0.05}$ Potting substrates (PS) = 0.61 Varieties (V) = 0.37 PS × V = 1.05	$CD_{0.05}$ Potting substrates (PS) = 0.08: Varieties (V) = 0.05 PS × V = 0.14	$CD_{0.05}$ Potting substrates (PS) = 0.85 Varieties (V) = 0.52 PS × V = 1.47

potting substrate selection for maximizing flowering in marigold. Maximum number of flower heads open at a time (15.75), number of flower heads per plant (24.57) was in V_2 and flower head size (5.81 cm) was in V_3, whereas minimum number of flower heads open at a time (4.29), number of flower heads per plant (24.57 cm) was in V_1 and flower head size (4.15 cm) in V_2. The cultivar V_2 outstands in terms of number of flower heads per plant and number of flower heads open at a time, which makes the pot more presentable and thus increased the value of pot.

In case of interaction, maximum number of flower heads/plant (29.47) and the maximum number of flower heads open at a time (21.92) was in PS_8 x V_2. The maximum flower head size (6.51 cm) was in PS_8 x V_3. The combination of cultivar V_2 and potting media PS_8 outstands in terms of number of flower heads per plant and number of flower heads open at a time, which is an important criteria for variety to be selected as an pot cultivars based on flowering parameter.

The variations in flowering parameters appear to be linked to the superior qualities of the potting substrate, resulting in enhanced vegetative and reproductive growth of the plants, thereby leading to improved flower production. This can be attributed to the substrate's excellent physical and chemical attributes. The blend of PS_8 substrate in the right proportions optimizes water and oxygen retention, facilitating superior nutrient absorption for adequate plant growth and development. Consequently, plants cultivated in this substrate (PS_8) exhibited better vegetative growth, prompting the generation of more lateral reproductive buds and larger flower heads. The roles of phosphorus (P), potassium (K), and nitrogen (N) are pivotal, with P crucial for flower formation, K enhancing flower quality, and N supporting overall plant vigor, thus ensuring optimal flower production and larger flower head diameter (de Bang *et al.,* 2021). These outcomes align closely with the findings of Mehmood *et al*. (2013) in Antirrhinum and Singh *et al*. (2016) in chrysanthemum. The difference in flowering parameters among cultivars is due to their genetic makeup (Dilta *et al.,* 2019).

Physico-chemical properties: Physico-chemical properties of the substrate is also greatly influenced in the experiment as shown in the Table 4, 5 and 6. The results obtained revealed that none of the treatments had a substantial impact on pH and EC of the potting substrate. The maximum bulk density (1,348.18 kg m^{-3}) was in PS_3 and minimum (838.27 kg m^{-3}) in PS_7. Regarding the effects of varieties, maximum bulk density (1,140.49 kg m^{-3}) was in the substrate where V_1 variety was pot cultured. However, minimum bulk density (1,029.72 kg m^{-3}) was in the potting substrate of V_3. The highest bulk density (1,386.01 kg m^{-3}) was in $PS_3 \times V_1$ interaction and minimum (806.33 kg m^{-3}) in the

Table 4. Physico-chemical properties of potting substrates after completion of the experiment

Treaments	pH			Mean	EC (dS m^{-1})			Mean	Bulk density (kg m^{-3})			Mean
	V_1	V_2	V_3		V_1	V_2	V_3		V_1	V_2	V_3	
PS_1	7.20	7.28	7.24	7.24	0.25	0.22	0.26	0.24	1,086.67	1,072.33	991.27	1,050.09
PS_2	7.26	7.26	7.26	7.26	0.22	0.22	0.24	0.23	1,246.67	1,217.03	1,097.60	1,187.09
PS_3	7.23	7.25	7.13	7.20	0.18	0.14	0.22	0.18	1,386.01	1,294.20	1,364.33	1,348.18
PS_4	7.20	7.30	7.20	7.23	0.17	0.15	0.26	0.19	1,376.01	1,371.02	1,081.67	1,276.22
PS_5	7.18	7.20	7.17	7.19	0.27	0.24	0.26	0.26	896.17	895.01	896.07	895.74
PS_6	7.24	7.24	7.12	7.20	0.25	0.21	0.21	0.22	1,225.01	1,228.01	974.00	1,142.33
PS_7	7.24	7.18	7.18	7.20	0.22	0.23	0.25	0.24	893.33	815.13	806.33	838.27
PS_8	7.03	7.06	7.13	7.07	0.25	0.25	0.25	0.25	1,014.00	1,011.01	1,026.47	1,017.16
Mean	7.20	7.22	7.18		0.23	0.21	0.25		1,140.49	1,112.98	1,029.72	

pH	EC	Bulk density
$CD_{0.05}$	$CD_{0.05}$	$CD_{0.05}$
Potting substrates (PS) = NS	Potting substrates (PS) = NS	Potting substrates (PS) = 1.82:
Varieties (V) = NS	Varieties (V) = NS	Varieties (V) = 1.12 :
PS × V = NS	PS × V = NS	PS × V = 3.15

Table 5. Physico-chemical properties of potting substrates after completion of experiment

Treaments	Particle density (kg m^{-3})			Mean	Available N (kg ha^{-1})			Mean	Available P (kg ha^{-1})			Mean
	V_1	V_2	V_3		V_1	V_2	V_3		V_1	V_2	V_3	
PS_1	1,695.33	1,722.04	1,823.07	1,746.82	408.54	413.50	522.47	448.17	15.40	13.90	15.60	14.97
PS_2	2,020.10	1,972.06	2,126.06	2,039.41	337.67	300.33	422.34	353.45	13.60	16.40	14.73	14.91
PS_3	2,220.04	2,351.33	2,365.00	2,312.13	287.67	261.33	270.53	273.18	10.30	13.60	17.40	13.77
PS_4	2,232.00	2,285.00	2,276.67	2,264.56	458.58	437.33	507.67	467.86	16.80	15.47	14.23	15.50
PS_5	1,233.00	1,325.00	1,256.00	1,271.33	458.39	476.45	532.50	489.12	16.73	19.50	17.43	17.89
PS_6	2,394.00	2,374.33	2,414.67	2,394.33	553.35	565.40	576.46	565.07	15.55	22.50	24.30	20.78
PS_7	1,450.00	1,482.00	1,422.33	1,451.44	537.33	457.00	537.67	510.67	22.30	18.40	13.50	18.07
PS_8	1,625.33	1,543.00	1,585.67	1,584.67	647.33	657.67	672.48	659.16	20.40	23.20	28.00	23.87
Mean	1,858.73	1,881.85	1,908.68		461.11	446.13	505.26		16.39	17.87	18.15	

Particle density	Available N	Available P
$CD_{0.05}$	$CD_{0.05}$	$CD_{0.05}$
Potting substrates (PS) = 2.07	Potting substrates (PS) = 1.53:	Potting substrates (PS) = 0.77:
Varieties (V) = 1.27	Varieties (V) = 0.94	Varieties (V) = 0.44 :
PS × V = 3.58	PS × V 2.65	PS × V = 1.24

Table 6. Physico-chemical properties of potting substrates after completion of experiment

Treatments	Available K (kg ha^{-1})			Mean	OC (g kg^{-1})			Mean
	V_1	V_2	V_3		V_1	V_2	V_3	
PS_1	177.33	182.31	146.53	168.73	26.24	41.46	45.53	37.75
PS_2	129.32	113.16	111.21	117.90	22.37	22.66	29.50	24.84
PS_3	104.30	100.95	116.30	107.18	12.47	15.28	21.50	16.42
PS_4	185.51	206.44	266.47	219.47	17.43	12.61	42.43	24.16
PS_5	250.43	238.57	260.53	249.84	58.44	55.93	56.63	57.00
PS_6	333.32	263.08	329.47	308.62	27.53	26.67	47.37	33.86
PS_7	285.40	228.29	324.27	279.32	58.67	56.73	59.62	58.34
PS_8	325.50	323.90	357.43	335.61	44.72	45.70	43.40	44.61
Mean	223.89	207.09	239.03		33.48	34.63	43.25	

$CD_{0.05}$
Potting substrates (PS) = 1.25
Varieties (V) = 0.77
PS × V = 2.17

$CD_{0.05}$
Potting substrates (PS) = 1.05
Varieties (V) = 0.64
PS × V = 1.82

interaction, $PS_7 \times V_3$. The maximum particle density (2,394.42 kg m^{-3}) was in PS_6 and the minimum (1,271.44kg m^{-3}) in PS_5. Amongst the varietal effects, maximum particle density (1,908.77 kg m^{-3}) was in the substrate of V_3 and minimum (1,858.82 kg m^{-3}) was in the substrate of V_1. The variations in bulk density and particle density among different potting substrates and varieties can be attributed to the varying proportions of soil components, such as sand, soil, leaf mould, and organic materials like FYM. Higher sand content in PS_3 likely contributed to its higher bulk density. Regarding particle density, the presence of different organic and inorganic components in the substrates and their interactions with specific plant varieties root structures might have influenced particle packing, resulting in observed variations across PS_6, PS_5, and their respective varieties' interactions. These findings align closely with the research conducted by Bar-Tal *et al*. (2019) and Younis *et al*. (2022).

The maximum available nitrogen (659.16 kg ha^{-1}) was in PS_8 and it was minimum (273.18kg ha^{-1}) in PS_3. As per the effect of varieties, the maximum quantum of available N (505.26 kg ha^{-1}) was in the substrate used for pot production of V_3 and the minimum available N (446.13 kg ha^{-1}) was in the substrate used for V_2. Among interaction effects of potting substrates and varieties, maximum available N content (672.48 kg ha^{-1}) was in the interaction $PS_8 \times V_3$ and the minimum available N (261.33 kg ha^{-1}) was in $PS_3 \times V_2$. The maximum available phosphorus (23.87 kg ha^{-1}) and potassium (335.61 kg ha^{-1}) was in PS_8 and minimum (13.77 kg ha^{-1}, 107.18 kg ha^{-1}, respectively)in PS_3. As per the effect of varieties, maximum available P and K (18.15 kg ha^{-1}, 239.03 kg ha^{-1}, respectively) was in the substrate used for V_3 and minimum available P (16.39 kg ha^{-1}) in V_1 and minimum available K (207.09 kg ha^{-1}) in the potting substrate of V_2. The interaction effects of potting substrates and varieties revealed that maximum available P (28.00 kg ha^{-1}) and K (357.43 kg ha^{-1}) was in $PS_8 \times V_3$ and minimum (10.30 kg ha^{-1}, 100.95 kg ha^{-1}, respectively) in $PS_3 \times V_1$. The variations in available N, P and K among potting substrates and varieties can be attributed to the substrates' diverse compositions and nutrient contents. Potting substrate PS_8 possibly contained higher organic matter or nutrient-rich components, resulting in elevated nitrogen, phosphorus, and potassium availability. The specific interactions between PS_8 and certain varieties, possibly exhibiting favorable nutrient uptake or release characteristics, could have further amplified nutrient availability. Similar results were reported by Mehmood *et al*. (2013) in potted antirrhinum and Singh *et al*. (2022) in potted chrysanthemum. The maximum organic carbon (OC) (58.34 g kg^{-1}) was in PS_7, whereas, minimum OC (16.42 g kg^{-1}) in PS_3. As regards varietal effect, highest value of OC (43.25 g kg^{-1}) was in the substrate in which plants of V_3 were grown. However, minimum OC (33.48 g kg^{-1}) was in the potting mixture used for pot culture of V_1. Among the interaction effects of potting substrates and varieties, maximum OC (59.62 g kg^{-1}) was in $PS_7 \times V_3$ and minimum (12.47g kg^{-1}) in $PS_3 \times V_1$. Differences in OC content across varied potting substrates, varieties, and their interactions stem from distinct substrate compositions and varying organic material levels, influencing the accumulation and accessibility of OC crucial for plant development. Prior studies by Mahmood *et al*. (2017) and Singh *et al*. (2022) have similarly highlighted the role of OC in enhancing nutrient availability.

The analysis of pot presentability scores (Table 7) indicates significant impacts of both potting substrates and marigold varieties on pot presentability. The highest score (80.60) was in potting substrate PS_8, while lowest (65.90) in PS_3. Among varieties, highest score (79.40) was in V_2, significantly surpassing other varieties, whereas V_1 had the lowest score (65.70). Interactions between substrates and varieties didn't show significant effects on pot presentability scores, yet highest score (85.20) was in $PS_8 \times V_2$ and the $PS_3 \times V_1$ had the lowest (57.80). The higher pot presentability in PS_8 and V_2 may be due to optimal nutrient supply and favorable physico-chemical properties, including better bulk density, aeration, and water retention which ultimately resulted in better growth and flowering thus, increasing the pot presentability. Gopal (2021) found similar results in African marigold grown in leaf mould + MSW. Additionally, V_2 variety likely possesses genetic traits favoring higher pot presentability.

Table 7. Effect of potting substrates on pot presentability of marigold

Treatments	V_1	V_2	V_3	Mean
PS_1	60.50	73.70	71.70	68.60
PS_2	61.80	77.30	72.80	70.70
PS_3	57.80	71.70	68.20	65.90
PS_4	64.20	79.70	73.80	72.60
PS_5	66.80	81.70	77.70	75.40
PS_6	71.80	83.30	81.30	78.80
PS_7	69.30	82.30	80.30	77.30
PS_8	73.20	85.20	83.30	80.60
Mean	65.70	79.40	76.10	

$CD_{0.05}$
Potting substrates (PS) = 2.17
Varieties (V) = 1.39
PS × V = NS

The present investigation showed the positive effect of potting substrate on different marigold cultivars for growth, flowering and soil parameters. The results demonstrate and recommend Leaf mould + Soil + FYM (1:1:1, v/v) growing media for all the three cultivars, however, marigold cultivar 'Pusa Deep' performed well for growth, flowering and pot presentability. Furthermore, this study opens up avenues for future research exploring additional factors influencing marigold growth and performance, such as irrigation management, nutrient supplementation and pest control strategies. Investigating the interactions between these factors and potting substrate composition could further enhance our understanding of optimal cultivation practices and contribute to the sustainable production of high-quality marigold flowers.

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