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EFFECT OF FLY ASH AND PRESS MUD AS POTTING SUBSTRATES ON GROWTH AND FLOWERING OF AFRICAN MARIGOLD (*TAGETES ERECTA* L.)

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ABSTRACT

Potting substrate is an important input which contributes prominently to the production cost of ornamental plants nurseries. Considering the availability in terms of quantity, time and low cost, usage of many agro-industrial residues as potting substrates is in practice. Fly ash and press mud have been known for their use as soil additive and soil amendment respectively. Both of them are reported to contain essential plant nutrients in considerable quantities. Pot experiments were conducted to evaluate the suitability of fly ash and press mud as potting substrates at varying proportions along with vermicompost and cocopeat. Eleven potting substrate combinations were evaluated as treatments in three replications and African marigold cultivars Arka Agni and Orange Dwarf were used as test crops. Bulk density of potting substrate combinations ranged from 0.22 to 0.55 Mg m^{-3}. pH of substrate combinations varied from neutral to slightly alkaline and electrical conductivity of all potting substrate combinations was less than 1.0 dS m^{-1}. Maximum total nitrogen (0.96 %), total phosphorous (0.74 %) and total potassium (0.95 %) contents were determined in substrate combinations Press mud+Vermicompost+Cocopeat (45:15:40), Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) and Cocopeat+ Vermiculite+ Perlite (33.3:33.3:33.3) respectively. In cv. Arka Agni, significantly higher number of buds, flowers and flower yield were recorded in substrate combination Fly ash+Press mud+ Cocopeat+Vermicompost (15:35:40:10). In *cv*. Orange Dwarf, maximum growth and flowering attributes were recorded in potting substrate combination Press mud+Vermicompost+Cocopeat (45:15:40). In both the experiments minimum plant growth, number of flowers and flower yield were recorded in substrate combination Fly ash+Vermicompost+Cocopeat (20:30:50). Experimental results inferred that, fly ash and press mud can be effectively used as potting substrates in combination with cocopeat and vermicompost for pot plant production of African marigold.

***Key words*:** Potting substrate combinations, Fly ash, Press mud, African marigold

Introduction

Ornamental nursery sector has been gaining importance in terms of value and commercialization in India. Among the various inputs of ornamental plants cultivation, potting substrate is the second prominent input contributing to total production cost of greenhouse nurseries (Pascual *et al.*, 2018). Nursery men/ Horticulturists who use soil media often have to deal with soil borne pathogens, insects and salinity problems. Heterogenous fertility and inherent properties like buffering capacity and cation exchange capacity of soil media make it difficult to ensure the supply of required quantity of nutrients throughout crop growth period. These problems have led the horticulturists to shift from soil-based media to alternates substrates and soilless media. Over the decades between 1950’s and 1970’s, substrates like peat and rockwool were extensively used as growing media for cultivation of greenhouse crops like vegetables. In the 1980’s and 1990’s, increased ecological concerns related to growing substrates influenced their development and refinement in horticulture (Gruda, 2009). Cocopeat, due to its similarity in properties to peat, has been extensively used in containerized production of ornamental potted plants (Tariq *et al*., 2012). Volume reduction, water saturation at the lower layers and insufficient anchorage to full grown plants are some of the reasons for not using cocopeat alone as potting substrate. Apart from cocopeat, substrates like bark, wood fiber, compost derived from several agro-residues and vermicompost either alone or in combination were also identified to have the potential as alternate substrates to replace peat (Pratibha *et al*., 2021). Considering the availability in terms of quantity, time and low cost, usage of many agro-industrial residues as potting substrates is gaining popularity.

In the present study fly ash and press mud were used at varying proportions along with cocopeat and vermicompost to find their suitability as potting substrates for pot plant production of African marigold. Fly ash is a by-product of coal/lignite based thermal power stations and its composition and chemical properties depend on the quality of coal/lignite used for combustion. Previous studies have indicated that fly ash usage as a soil additive can have positive effect on agronomic properties of soil and plant growth (Sharma *et al*., 1990). In addition, fly ash has essential plant nutrients like potassium, iron, calcium and magnesium in significant percentages and also trace elements like lanthanum, terbium, mercury, cobalt and chromium (Adriano *et al*., 1980). Presence of heavy metals in fly ash discourages its use as potting substrate for vegetables and other edible plants. But presence of nutrients, its fine and heavy particles which can improve compactness when added to a lighter media like cocopeat would make it a beneficial substrate component for ornamental plants nurseries.

Press mud which is the residue left over after filtration of sugarcane juice is reported to contain essential plant nutrients like nitrogen, phosphorus, potassium, calcium and sulfur in varying amounts (Namita and Sonal, 2010). A nutrient rich substrate has an added advantage of supporting the growth of seedlings at early stages till fertilizer application. Keeping these points in view the present study was carried out.

Materials and Methods

Pot experiments were carried out at ICAR-Directorate of Floricultural Research, Pune under open conditions with the following treatments.

- T_1 **:** Fly ash+Vermicompost+Cocopeat (10:30:60)
- T_2 **:** Fly ash +Vermicompost+Cocopeat (15:35:50)
- T_3 **:** Fly ash+Vermicompost+Cocopeat (20:30:50)
- T_4 **:** Press mud+Vermicompost+Cocopeat (25:25:50)
- T_5 **:** Press mud+Vermicompost+Cocopeat (35:20:45)
- T_6 **:** Press mud+Vermicompost+Cocopeat (45:15:40)
- T_7 **:** Fly ash+Press mud+ Cocopeat+Vermicompost (10:25:25:40)
- T_8 **:** Fly ash+Press mud+Cocopeat+Vermicompost (12.5:37.5:25:25)
- T_9 **:** Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10)
- T_{10} **:** Fly ash+ Press mud+Cocopeat+Vermicompost (20:45:25:10)
- T_{11} **:** Cocopeat+Vermiculite+Perlite (33.3:33.3:33.3)

All the substrate components were weighed on dry weight basis according to the treatments, mixed thoroughly and filled into 10" plastic pots. Treatment 11 consisting Cocopeat+Vermiculite+Perlite at 33.3:33.3:33.3 w/w was treated as standard. The experiment was laid out in randomized block design with African marigold as test crop and replicated thrice. African marigold cultivars Orange Dwarf and Arka Agni were grown during 2020-21 and 2021-22 respectively. One month old, matured and well rooted single cutting of African marigold cultivars Orange Dwarf (October 2020) and Arka Agni (October 2021) were transplanted into each of the pots. Plants were watered manually when the surface of media was observed to be dry and foliar application of 1% of NPK (19:19:19) was given at fortnightly interval starting from 30 days after transplanting until bud initiation stage. Plants were pinched once at 40 days after transplanting.

Air dried potting substrate combination samples were used for determination of bulk density and maximum water holding capacity (MWHC) by Keen's box method (steel box of height 1.7 cm and inner diameter 5.8 cm) at the start of the experiment. Potting substrates of different treatment combinations were also analyzed for initial macro and micronutrients content. pH (1:10 dilution), electrical conductivity (1:10 dilution) and total phosphorus were assessed following Jackson (1973) method and nitrogen content was estimated by micro-Kjeldahl method. Total potassium content was estimated using flame photometer (Jackson, 1973). DTPA extractable copper, zinc and manganese were estimated by Atomic Absorption Spectroscopy.

Plant growth observations *viz*., plant height (cm), number of primary and secondary branches plant^{-1}, average plant spread (cm) at full bloom and number of buds plant^{-1} at color break stage of bud were recorded. Marigold flowers were plucked when they have attained full size and flower yield plant^{-1} (g), shoot fresh weight (g), root fresh weight (g) and root length (cm) were recorded at harvest. Leaf samples were collected at the beginning of flowering and analyzed for macro and micronutrients content. The experimental results were analyzed for statistical significance at 5% level of significance as per the standard procedure given by Panse and Sukatme (1978).

Results and Discussion

Initial physico-chemical properties of potting substrate combinations

The highest bulk density of 0.55 Mg m^{-3} was recorded in potting substrate combination Fly ash+Vermicompost +Cocopeat (20:30:50) (T_3) and lowest bulk density (0.22 Mg m^{-3}) was recorded in Cocopeat+ Vermiculite+ Perlite (33.3:33.3:33.3) (T_{11}) (Fig. 1). Inversely, maximum water holding capacity was highest in T_{11} (314 %) and lowest in T_3 (160 %) (Fig. 1). Menzies and Aitken (1996) has reported that addition of fly ash reduces air-filled porosity of potting media. The difference in proportion, weight and particle size distribution of media substrates could be responsible for variation in bulk density and maximum water holding capacity. Also, variation in total porosity and pore-size distribution of media substrates could result in different water holding capacity of treatments (Kukal *et al*., 2012).

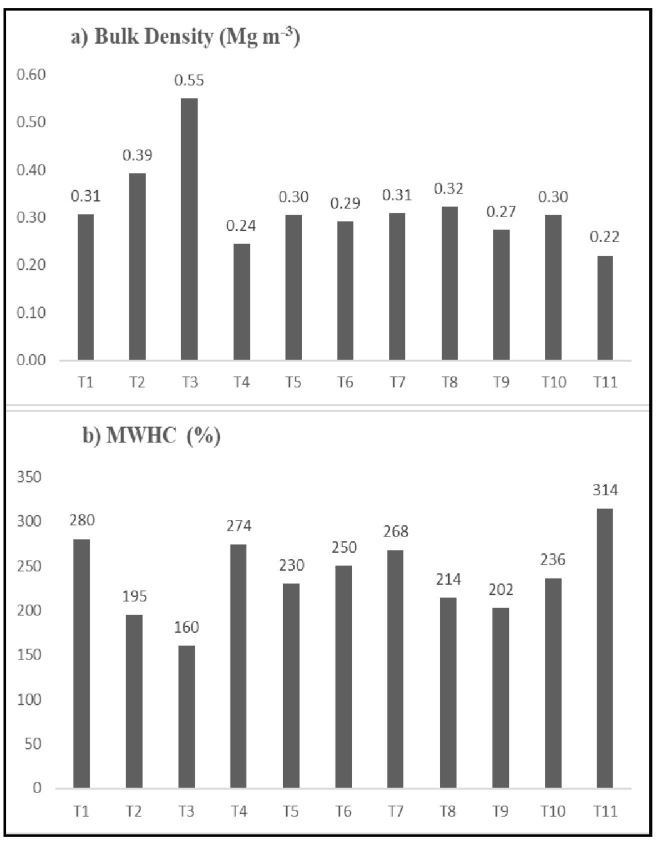

Fig. 1: Initial bulk density and maximum water holding capacity (MWHC) of potting substrate combinations.

pH of potting substrate combinations varied from neutral to slightly alkaline with the highest in T_6 Press mud+Vermicompost+Cocopeat (45:15:40) (7.62) and lowest in T_1 Fly ash+Vermicompost+Cocopeat (10:30:60) (6.61) (Fig. 2). Electrical conductivity of all potting substrate combinations was less than 1.0 dS m^{-1} (Fig. 2) indicating that the amount of salts present in them was not harmful to plant growth. It was observed that addition of fly ash to cocopeat and vermicompost resulted near neutral pH and lower electrical conductivity (T_1, T_2, T_3) while addition of filter press mud increased pH and electrical conductivity (T_4, T_5, T_6) of potting substrate combinations. pH and electrical conductivity of substrates play a significant role in plant growth and development (Chen *et al*., 1999) as they impact nutrient and water availability to growing plants.

Maximum total nitrogen (0.96 %), total phosphorous (0.74 %) and total potassium (0.95 %) were determined in potting substrate combinations T_6 [Press mud+ Vermicompost+Cocopeat (45:15:40)], T_9 [Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10)] and T_{11} [Cocopeat+ Vermiculite+ Perlite (33.3:33.3:33.3)] respectively (Fig. 3). Among micronutrients, maximum zinc (164.9 ppm) and manganese (195.1 ppm) contents were recorded in substrate combination Fly ash+Press

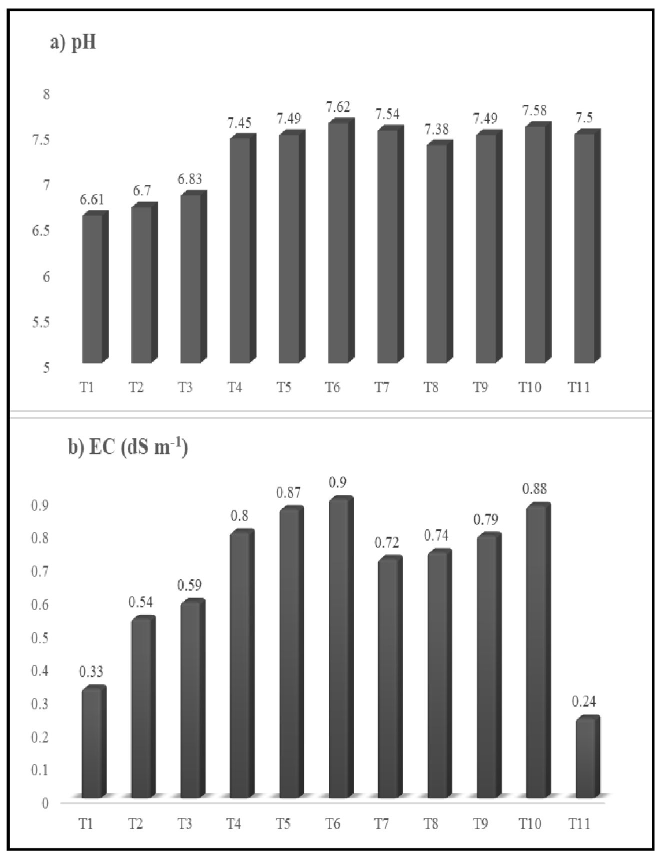

Fig. 2: Initial pH and electrical conductivity (EC) of potting substrate combinations.

Table 1: Effect of different potting substrate combinations on growth and flowering of marigold cv. Arka Agni.

Treat-ments	Plant height (cm)	Plant spread (cm)	No. of primary branches	No. of secondary branches	No. of buds/ plant	No. of flowers/ plant	Flower yield/ plant (g)	Flower diameter (cm)	Shoot fresh weight (g plant^{-1})	Root fresh weight (g plant^{-1})	Root length (cm)
T_1	46.92	26.54	1.43	7.36	29.50	26.72	109.01	4.78	47.03	16.87	15.57
T_2	49.86	27.47	1.44	7.43	37.24	34.46	151.32	4.79	48.03	17.43	12.57
T_3	43.39	25.52	1.36	7.34	29.34	25.16	103.58	4.68	46.77	16.53	11.32
T_4	54.89	32.03	1.63	8.43	44.73	40.20	235.15	5.33	99.47	28.87	28.03
T_5	54.43	32.00	1.59	8.11	42.06	39.64	216.83	5.30	85.77	28.73	27.27
T_6	56.93	33.14	1.65	8.33	44.34	41.39	231.82	5.37	88.63	31.27	30.60
T_7	53.94	31.94	1.54	8.06	39.35	37.92	191.51	5.23	79.07	28.60	26.93
T_8	51.85	31.78	1.52	8.00	37.70	36.61	174.60	5.15	65.53	25.03	23.33
T_9	56.22	33.24	1.62	8.48	46.17	42.16	243.90	5.31	110.33	36.93	26.30
T_{10}	52.02	31.78	1.52	8.05	40.05	37.17	182.54	5.22	69.37	27.03	25.33
T_{11}	50.13	30.09	1.50	7.63	37.16	34.23	149.51	4.85	53.70	22.73	26.53
SEm(±)	1.73	1.38	NS	NS	2.08	3.47	28.92	NS	6.71	4.33	3.63
LSD (*P*=0.05)	5.10	4.06			6.15	10.23	85.32		19.80	13.43	10.71

mud+Cocopeat+Vermicompost (15:35:40:10) (T_9) while lowest copper (34.3 ppm), zinc (32.9 ppm) and manganese (195.1 ppm) were recorded in T_4 and T_{11} respectively (Fig. 3). When cocopeat was added to vermicompost, an increased nutrient and water retention capacity was also reported by Abbey *et al*., (2012).

Effect of potting substrate combinations on growth attributes

Data on influence of potting substrate combinations on vegetative growth parameters of African marigold cultivars Arka Agni and Orange Dwarf are presented in Table 1 and 2 respectively.

In cultivars Arka Agni and Orange Dwarf, highest plant height was recorded in substrate combination T_6 which is Press mud+Vermicompost+Cocopeat (45:15:40) (56.22 cm and 60.79 cm) and it was at par with T_9, T_5 and T_4. The lowest plant height was recorded in T_3 Fly ash+Vermicompost+Cocopeat (20:30:50) in both the cultivars. Plants were remarkably shorter in fly ash containing potting substrate combinations without press mud. In cultivar Arka Agni, Plant spread was maximum in T_9 (33.24 cm) with the combination Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) and it was at par with all other treatments except T_1, T_2 and T_3 (Table 1). In cultivar Orange Dwarf, plant spread was maximum in T_6 (47.62 cm) and it was at par with T_1, T_7 and T_9 (Table 2). In both the cultivars, plant spread was minimum in T_3 which is Fly ash+Vermicompost+Cocopeat (20:30:50). Different potting substrate combinations did not significantly influence the development of branches in both the cultivars.

Nutrient content analysis data of substrate combinations has indicated maximum total nitrogen (0.96 %) and total phosphorous (0.74 %) contents in potting substrate combinations T_6 [Press mud+ Vermicompost +Cocopeat (45:15:40)] and T_9 [Fly ash+Press mud+ Cocopeat+Vermicompost (15:35:40:10)] respectively (Fig. 3). Nitrogen is a key essential nutrient for plants which impacts both number and size of vegetative storage organs

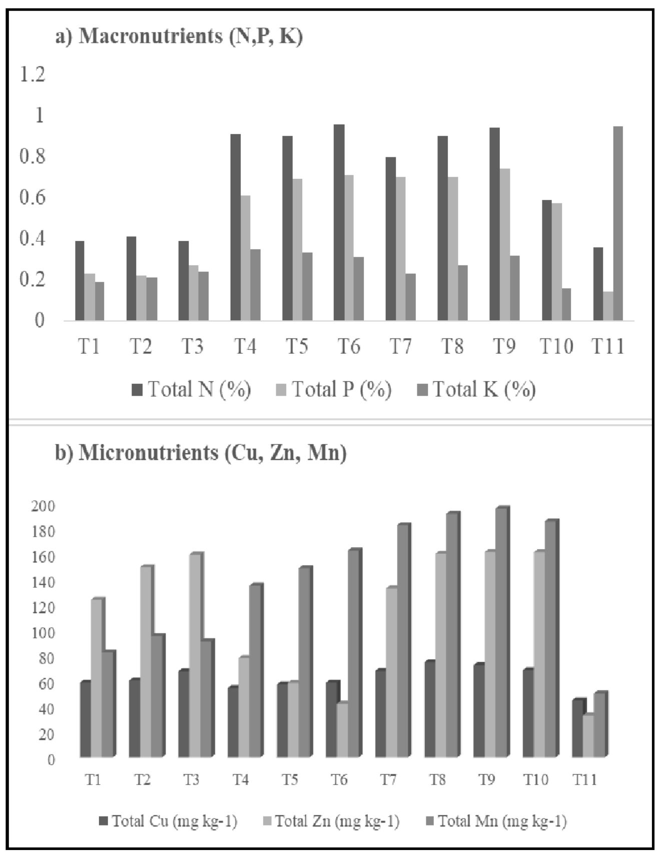

Fig. 3: Initial macro and micro nutrients content of potting substrate combinations.

Table 2: Effect of different potting substrate combinations on growth and flowering of marigold cv. Orange dwarf.

Treat-ments	Plant height (cm)	Plant spread (cm)	No. of secondary branches	No. of buds/ plant	No. of flowers/ plant	Flower yield/ plant (g)	Flower diameter (cm)	Shoot fresh weight (g $plant^{-1}$)	Root fresh weight (g $plant^{-1}$)
T_1	47.19	42.47	8.10	36.42	30.24	123.37	5.00	41.70	18.61
T_2	57.34	33.69	7.90	32.74	29.21	128.27	5.18	44.43	18.56
T_3	50.48	30.67	7.00	28.30	23.90	102.30	5.20	43.20	17.54
T_4	54.73	38.05	8.05	33.20	30.62	171.42	5.13	67.70	21.72
T_5	57.30	43.57	8.17	37.10	32.80	186.72	5.03	70.97	26.04
T_6	60.79	47.62	8.93	40.03	37.48	210.58	5.70	80.25	30.08
T_7	55.99	41.02	8.28	36.00	33.64	169.88	5.63	70.14	25.68
T_8	55.64	39.10	8.38	33.08	30.00	163.08	5.58	63.70	20.20
T_9	59.65	39.81	8.61	38.83	36.40	209.90	5.60	75.26	25.00
T_{10}	54.43	38.83	8.43	36.17	33.79	165.92	5.22	63.05	22.50
T_{11}	50.80	36.64	8.38	32.43	30.52	133.29	5.30	47.87	26.22
SEm(±)	2.39	1.88	NS	1.66	1.82	24.18	NS	7.70	1.82
LSD (P=0.05)	7.06	5.55		4.83	5.37	71.33		22.73	5.36

by influencing leaf growth and photosynthetic rate per unit leaf area (Enggels and Marschner, 1995). Phosphorus plays an important role in cell division, tissue formation and photosynthesis (Arnon, 1959) and thereby influences development of new leaves and branches. Presence of essential nutrients in substantially high amounts along with adequate porosity and water availability constituted by suitable proportion of cocopeat, vermicompost, press mud and fly ash might have influenced the better growth and development of marigold plants in the potting substrate combination Fly ash+Press mud+Cocopeat+ Vermicompost(15:35:40:10). An amplified level of chlorophyll a, b and carotenoids in varieties of *Cicer arietinum* were reported by Gupta *et al*., (2007) due to addition of either press mud or garden soil to fly ash.

Effect of potting substrate combinations on floral attributes and post-harvest parameters

Significant variations were observed in floral attributes *viz*., number of buds, and number of flowers and flower yield of African marigold cultivars Arka Agni (Table 1) and Orange Dwarf (Table 2) due to different potting substrate combinations.

In *cv*. Arka Agni, the flower count was not consistent with respect to increasing proportions of press mud and fly ash. It was observed that flower diameter did not vary significantly due to substrate combinations in both the cultivars. In *cv*. Arka Agni, maximum number of buds (46.10) were recorded in substrate combination Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) (T_9) and it was on par with T_6 and T_4. Whereas in cv. Orange Dwarf highest number of buds were recorded in T_6 which was at par with T_9 and T_5. In both the cultivars, minimum number of buds were recorded in Fly ash+Vermicompost+Cocopeat (20:30:50) (T_3). Likewise, in cv. Arka Agni significantly higher number of flowers (42.16) and flower yield (243.90 g $plant^{-1}$) were recorded in substrate combination Fly ash+Press mud+Cocopeat +Vermicompost (15:35:40:10) (T_9) which was closely followed by T_6. Minimum number of flowers (25.16 $plant^{-1}$) and flower yield (103.58 g $plant^{-1}$) were recorded in Fly ash+Vermicompost+Cocopeat (20:30:50) (T_3) (Table 1 and Fig. 4). Flower yield $plant^{-1}$ in T_9 was statistically at par with all other substrate combinations except T_2, T_{11}, T_1 and T_3. In cv. Orange Dwarf, maximum number of flowers (37.48) and flower yield (210.58 g $plant^{-1}$) were recorded in T_6 Press mud+Vermicompost+Cocopeat (45:15:40) and it was statistically at par with T_9.

Table 3: Correlation matrix showing the relationship between macronutrient contents of potting substrate combinations, number of flowers $plant^{-1}$ and flower yield $plant^{-1}$ of marigold cv. Arka Agni.

	Total N (%)	Total P (%)	Total K (%)	No. of flowers $plant^{-1}$	Flower yield $plant^{-1}$
Total N (%)	1.00				
Total P (%)	0.94**	1.00			
Total K (%)	0.43*	0.51*	1.00		
Number of flowers $plant^{-1}$	0.82*	0.77*	0.51*	1.00	
Flower yield $plant^{-1}$	0.87**	0.82*	0.59*	0.97**	1.00

(*: P<0.05 and **: P<0.01)

Table 4: Correlation matrix showing the relationship between physico-chemical properties of potting substrate combinations, number of flowers plant^{-1} and flower yield plant^{-1} of marigold cv. Arka Agni.

	Bulk density (Mg m^{-3})	MWHC (%)	pH	EC (dS m^{-1})	Number of flowers plant^{-1}	Flower yield plant^{-1}
Bulk density (Mg m^{-3})	1					
MWHC (%)	-0.77*	1				
pH	-0.61*	0.32	1			
EC (dS m^{-1})	-0.07	-0.34	0.58	1		
Number of flowers plant^{-1}	-0.66*	0.18	0.80*	0.69*	1	
Flower yield plant^{-1}	-0.59	0.11	0.77*	0.75*	0.97**	1

(*: P<0.05 and **: P<0.01)

Higher number of flowers and flower yield recorded in T_9 and T_6 could be attributed to better growth parameters recorded in these treatment combinations. Similar relationship was observed by Chan (1959) who has reported an increase in number of flowers and yield in carnation due to increased growth parameters like number of branches caused by the application of nitrogen. Augmented growth parameters contribute to synthesis of more plant metabolites which would lead to increased flower production. In addition, higher phosphorous content (Fig. 3) of substrate combination T_9 Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) might have contributed to better flower production and yield. An increase in number of flower stems per plant in chrysanthemum *cv*. Thai Chen Queen was reported by Rajan *et al*., (2019) due to phosphorous application. A highly significant and positive correlation was also observed between macronutrients content of potting substrate combinations with number of flowers and flower yield of marigold cv. Arka Agni (Table 3). In addition to nutrient content, physico-chemical properties of substrate combinations also had influence on flower production. Bulk density of potting substrate combinations recorded significant negative correlation with number of flowers and flower yield produced in marigold cv. Arka Agni (Table 4). This could be due to more compaction and less aeration to plant roots in potting substrate with high bulk density. Whereas, maximum water holding capacity of growing media combinations has positive but non-significant correlation with number of flowers and flower yield. Similarly, pH and EC of media combinations were observed to be having significant positive correlation with number of flowers and flower yield produced in marigold cv. Arka Agni (Table 4).

In cv. Arka Agni, T_9 (Fly ash+Press mud+Cocopeat +Vermicompost (15:35:40:10)) recorded significantly higher shoot (110.33 g plant^{-1}) and root fresh weight (36.93 g plant^{-1}) and it was at par with T_4 Press mud+ Vermicompost+Cocopeat (25:25:50) (Table 1). In cv.

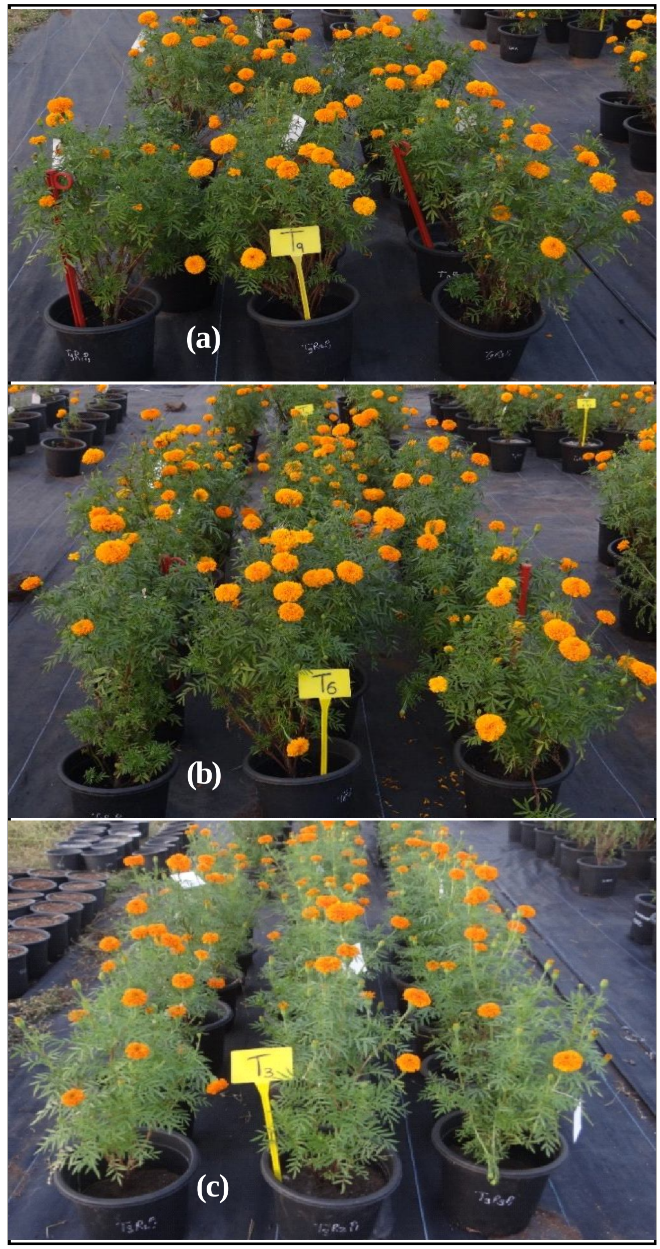

Fig. 4: Growth and flowering of African marigold cv. Arka Agni in potting substrate combinations a) T_9: Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) b) T_6: Press mud+Vermicompost+Cocopeat (45:15:40) and c) T_3: Fly ash+Vermicompost+Cocopeat (20:30:50).

Table 5: Leaf nutrient content of marigold cv. Arka Agni grown in different potting substrate combinations.

Treat-ments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
T_1	2.47	0.33	0.60	4.18	0.88	0.83	543.50	111.00	225.50	144.00
T_2	2.53	0.45	0.79	4.59	1.07	0.77	647.00	116.50	229.00	239.50
T_3	2.47	0.40	0.71	4.77	0.85	0.57	619.00	114.00	191.00	188.00
T_4	2.84	0.50	1.19	4.77	1.01	0.61	646.00	107.00	181.00	381.00
T_5	2.96	0.44	1.05	4.87	1.05	0.71	778.00	131.00	198.00	242.00
T_6	3.02	0.47	0.85	4.91	1.11	0.69	974.00	161.50	193.00	333.00
T_7	2.90	0.43	1.10	5.14	1.16	0.52	763.00	169.50	221.00	189.00
T_8	2.53	0.33	1.07	4.76	1.34	0.43	767.50	139.50	181.50	255.00
T_9	3.19	0.47	1.30	4.97	1.23	0.64	863.00	167.00	322.00	368.00
T_{10}	2.65	0.47	1.03	4.63	0.94	0.64	805.50	165.00	190.00	241.00
T_{11}	2.84	0.45	1.46	4.23	1.01	0.54	563.00	134.50	221.50	231.50
LSD (*P*=0.05)	NS	0.06	0.10	0.36	NS	0.22	NS	37.54	29.12	83.45

Orange Dwarf, significantly higher shoot (80.25 g plant^{-1}) and root fresh weight (30.08 g plant^{-1}) were recorded in T_6 (Table 2). Whereas, in both the cultivars minimum shoot and root fresh weight were recorded in T_3 Fly ash+Vermicompost+Cocopeat (20:30:50). In cv. Arka Agni, significantly higher root length was recorded in T_6 Press mud+Vermicompost+Cocopeat (30.60 cm) while root length was minimum in T_3 (11.32 cm) (Table 1). Physical properties of potting substrate like bulk density influences root growth. A compact, poorly aerated media inhibits root growth and affects water and nutrients absorption. Potting substrate combinations which are less dense, with good maximum water holding capacity and nutrients have resulted in better root growth.

Effect of potting substrate combinations on leaf nutrient content

Leaf nutrients content of marigold cv. Arka Agni indicated a significant difference due to different potting substrate combinations except nitrogen, magnesium and iron (Table 5). Maximum nitrogen content was recorded in leaves of marigold plants grown in T_9 Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) (3.19 %) and minimum was in T_3 Fly ash+Vermicompost +Cocopeat (20:30:50) (2.47 %). Significantly higher phosphorous content was observed in leaves of plants grown in T_4 Press mud+Vermicompost+Cocopeat (25:25:50) (0.5%) which was at par with T_9, T_{10}, T_6 and T_2 while lowest was recorded in T_1 (0.33 %). High nutrient content and favorable physico-chemical conditions of potting substrate combinations can aid in better nutrient uptake and utilization resulting in improved shoot growth and leaf nutrient content (Dutt and Sonawane, 2006).

Among secondary nutrients, significantly higher calcium and sulfur contents were observed in plants grown in T_7 Fly ash+Press mud+ Cocopeat+ Vermicompost (10:25:25:40) (5.14 %) and T_1 Fly ash+Vermicompost +Cocopeat (10:30:60) (0.83 %) respectively. Among micronutrients, maximum DTPA extractable Manganese, zinc and copper were recorded in plants grown in T_7 (169.50 mg kg^{-1}), T_9 (322 mg kg^{-1}) and T_4 (381 mg kg^{-1}) respectively. High nutrient content of plants grown in these potting substrate combinations could be due to the chemical composition of substrate combinations which was influenced by presence of vermicompost, press mud, fly ash and cocopeat in varying proportions.

Conclusion

From the present experiment it can be inferred that, fly ash and press mud can be effectively used as potting substrates in combination with cocopeat and vermicompost for pot plant production of African marigold cultivars Arka Agni and Orange Dwarf.

Higher growth and yield attributes of marigold cv. Arka Agni were recorded in potting substrate combination T_9 Fly ash+Press mud+Cocopeat+Vermicompost (15:35:40:10) followed by T_6 Press mud+Vermicompost +Cocopeat (45:15:40) and T_4 Press mud+Vermicompost +Cocopeat (25:25:50). In cv. Orange Dwarf, potting substrate combination T_6 Press mud+Vermicompost +Cocopeat (45:15:40) produced taller plants with maximum plant spread, maximum number of flowers and flower yield followed by T_9 Fly ash+Press mud+ Cocopeat+ Vermicompost (15:35:40:10).

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References

Agarwal Pratibha, Saha Sampa and Hariprasad P. (2021). Agro-industrial-residues as potting media- Physicochemical and biological characters and their influence on plant growth. *Biomass conversion and Biorefinery*, **13(11)**, 1-24. https://doi.org/10.1007/s13399-021-01998-6.

Abbey, L.C., Young R., Teitel-Payne and Howe K. (2012). Evaluation of proportions of vermicompost and coir in a medium for container grown Swiss chard. *Int. J. Veg. Sci.*, **18(2)**, 109-120.

Adriano, D.C., Page A.L., Elseewi A.A., Chang A.C. and Straughan I. (1980). Utilization and disposal of fly ash and other coal residues in terrestrial ecosystems: A review. *J. Environ. Qual.*, **9**, 333-344.

Arnon, D.I. (1959). Chloroplast and photosynthesis in the photochemical apparatus, its structure and function. *Brookhaven Symposia in Biol*. **11**, 181.

Chan, A.P. (1959). Mineral nutritional studies on carnation: Effect of N, P, K, Ca and temperature on flower production. *Proc. Am. Soc. Hort. Sci*., **72**, 473.

Chen, F.D., Fang W.M., Vu Z.X. and Yuan C. (1999). Preliminary study on soilless culture of *Dianthus*. *Acta Agri.*, **15**, 87-89.

Dutt, M. and Sonawane P.C. (2006). Nutrient uptake in chrysanthemum grown on various substrates. *Indian J. Hortic*., **63(1)**, 66-69.

Enggels, C. and Marschner H. (1995). Plant uptake and utilization of nitrogen. In: P.E. Bacon (eds). *Nitrogen fertilization in the environment.* New York: Marcel Dekker Publishers. 41-81.

Gupta, D.K., Tripathi R.D., Rai U.N., Mishra S., Srivastava S., Dwivedi S. and Maathuis F.J.M. (2007). Growth and biochemical parameters of *Cicer arietinum* L. grown on amended fly ash. *Environ. Monit. Assess*., **134**, 479-487.

Gruda, N. (2009). Do soilless culture systems have an influence on product quality of vegetables. *J. Appl. Bot. Food Qual.*, **82**, 141-147.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Kukal, S.S., Debasish Saha, Arnab Bhowmik and Dubey R.K. (2012). Water retention characteristics of soil bio-amendments used as growing media in pot culture. *J. Appl. Hortic.*, **14(2)**, 92-97.

Menzies, N.W. and Aitken (1996). Evaluation of fly ash as a component of potting substrates. *Sci. Hortic*., **67(1-2)**, 87-99.

Namita, J. and Sonal S. (2010). Physico-chemical characterization of sulphidation press mud, composted press mud and Vermicomposted press mud. *Report and Opinion*, **2(3)**, 79-82.

Panse, U.G. and Sukatme P.V. (1978). Statistical Method of Agricultural Workers. Indian Council of Agricultural Research, New Delhi.

Pascual, J.A., Ceglie F. and Tuzel Y. (2018). Organic substrate for transplant production in organic nurseries. A review. *Agron. Sustain. Dev.*, **38**, 35. https://doi.org/10.1007/s13593-018-0508-4.

Rajan, K., Bhatt D.S., Chawla S.L., Bhatt S.T. and Sangeetha Priya S. (2019). Effect of Nitrogen and Phosphorus on Growth, Flowering and Yield of Cut Chrysanthemum *cv*. Thai Chen Queen. *Curr. Agri. Res*., **7(3)**, 337-342.

Sharma, B.M., Aggarwal, R.K. and Kumar, P. (1990). Water retention and nutrient availability in a fly ash amended desert sandy soil: A study in vitro. *Arid Soil Res. Rehab.*, **4**, 53-58.

Tariq, U., Rehman S.U., Khan M.A., Younis A., Yaseen M. and Ahsan M. (2012). Agricultural and municipal waste as potting media components for the growth and flowering of *Dahlia hortensis* 'Figaro'. *Turkish J. Bot.*, **36(4)**, 378-385.