THE EFFECT OF DIFFERENT SOIL AMENDMENTS ON GROWTH AND FLOWERING OF AFRICAN MARIGOLD (*Tagetes erecta* L.) 'QUEEN'

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A B S T R A C T

The application of compost mixture in growth media is an integral element for improving growth, flowering and development of bedding plants. To achieve this aim, the present comparative study was conducted on African marigold as a complete block design with 9 treatments (soil amendments: "Agrobiosol", "Alkan", "Barvar-2" phosphate biofertilizer, animal and plant vermicompost, animal manure) and 3 replications over 2007 at the Research Field of Landscape Organization Shiraz Municipality, Iran. Chemical properties of soil including EC, pH and organic carbon (OC), N, P, K, Fe, Zn, Cu, and Mn contents were measured prior to and after the experimental period. The seedlings were transplanted in the plots after soil amendments with various substrates. Forty five and 85 days after transplanting (DAT), flower number, length and diameter, florets, flower number per plant, flower durability, shoot, root and flower fresh and dry weight, and visual quality were measured. The results indicated that some traits were affected significantly by soil amendments. The highest flower number, flower fresh weight, shoot fresh and dry weight and visual quality 45 days DAT and also the highest floret number, flower length and shoot fresh and dry weight, 85 DAT were obtained in soil amended with "Alkan", although the difference was not significant in comparison with some other treatments particularly with plant vermicompost. The highest flower diameter, root

fresh and dry weight 45 DAT and the highest flower dry weight and flower number per plant 85 DAT were observed in soil amended withrelated to plant vemicompost., The highest flower length 45 DAT and the highest root fresh and dry weight 85 DAT were obtained soil supplemented with Agrobiosol. No significant differences were observed among the other treatments. According to the finding of this research and regarding economic matters and environmental anxieties, it may be recommended that plant vermicompost be used as a soil amendment in the nursery or field production of ornamental plants.

Key words: African marigold, amendments, vegetative and reproductive, vermicompost

INTRODUCTON

Marigold (*Tagetes erecta* L.) belongs to Compositae family and is a herbaceous plant with aromatic, pinnately divided leaves and is usually used as a bedding plant, cut flower or as a coloring agent in poultry feed to obtain yellow egg yolks (Dole and Wilkins, 2005).

The use of organic amendments, such as traditional thermophilic composts, has long been recognized as an effective means of improving soil structure, enhancing soil fertility (Follet et al., 1981), increasing soil microbial diversity and population (Barakan et al., 1995), microbial activity (Zink and Allen, 1998), improving the moisture-holding capacity of soils and increasing crop yield. Vermicomposts are finely-structured mature peat-like materials with a high porosity, aeration, drainage, and water-holding capacity and microbial activity which are stabilized by interaction between earthworm and microorganisems in a non-thermophilic process (Edwards and Burrows, 1988).

Vermicompost (VC) contains most nutrients in plant-available forms such as nitrates, phosphates, exchangeable calcium and soluble potassium (Orozco et al., 1996; Edwards, 1998). Vermicomposts are rich in microbial populations, particularly fungi, bacteria and actionmycetes (Edwards, 1998; Tomati et al., 1987).

Premuzic et al. (1998) reported that fruit of tomatoes grown on organic substrates, such as VC, contained significantly more Ca and vitamin C and less Fe than these grown in hydroponics media, but no changes were found in concentrations of P and K. Compost is homogenous, retains most of the original nutrients and reduces levels of organic contaminants (Ndegwa et al., 2000). It can be applied to soil to increase soil organic matter and nutrient content, improve soil structure and increase cation exchange capacity.

Gajalakshmi and Abbasi (2002) indicated that application of compost/VC obtained from water hyacinth (*Eichhornia crassipes*, Mart. Solms) led to significant improvement in the growth and flowering of angiosperm crossandra (*Crossandra undulaefolia*), compared to the untreated plants. Bachman and Metzger (2007) reported that incorporation of

up to 20% (v/v) of VC originating from pig manure into germination media enhanced shoot and root weight, leaf area, and shoot:root ratio of both tomato and French marigold seedlings. However amendment with VC had little influence on pepper and cornflower seedling growth.

Dash and Petra, 1979 indicated that increase in plant growth have mostly been related to improvements in physical and chemical structure of growth media. However, the use of VC appears to affect plant growth in ways that can not be directly linked to its physical or chemical properties. It seem likely that some growth promotion is due to plant hormone-like activity related to microflora associated with vermicomposting and to metabolites produced as a consequence of secondary metabolism (Tomati et al., 1987; Atiyeh et al., 2002).

Nazari et al. (2007) indicated that application of natural zeolite to the pot mixture resulted in a significant increase of photosynthesis, mesophyll efficiency, water use efficiency, chlorophyll content, fresh and dry weights of roots and shoots, leaf area and flower length in *Tagetes erecta* L. 'Queen'. Keshavarzi et al. (2005) reported that the use of compost improved growth, flowering and development of *Narcissus pseudonarcissus* cv. 'Golden Harvest'. Khalighi and Padasht-Dehkaee (2000) reported the positive effects of tree bark, tea waste, rice hull and Azolla, as peat substitutes, on growth and development of *Tagetes patula* cv. 'Golden Boy'.

The objective of this study was to assess the effects of some soil amendments on growth and development of African marigold 'Queen' (*Tagetes erecta* L.).

MATERIAL AND METHODS

Soil analysis

Soil analysis was preformed prior to and after the end of experimental period. EC and pH were measured in a soil/double distillated water suspension (10:1, v/v) using pH meter (Santorious model pp-20) and EC meter (Metrohm modal 644). Total N and organic carbon (OC) contents were measured by Kjeldal and Walky-Black procedures, respectively. Phosphorus was measured by spectrophothometric method and K, Fe, Mn, Zn, and Cu by atomic absorption.

Preparing the mixtures

This research was conducted in Field Research of Landscape Organization of Shiraz Municipality in 2007. The characteristics of each amendment are given below (All amendments were purchased from Green Biotech Company in Iran):

- "Agrobiosol" – 90% organic substance (fungal biomass); 7% N – total nitrogen (organically bound); 1% P_2O_5, 1.5% K_2O.
- "Alkan" – poultry manure, sulfur, *Thiobacillus*.
- "Barvar-2 phosphate biofertilizer" –: BARVAR-2 phosphate Biofertilizer contains two types of phosphate solubilizing bacteria (PSB):

1. Bacterial strain P5 that release phosphate form inorganic compounds by producing organic acids.
2. Bacterial strain P13 that release phosphate from organic compounds by secreting strong phosphates enzymes.

- Plant vermicompost (PVC) – compost produced from vegetable and plant wastes with earthworms.
- Animal vermicompost (AVC) – compost produced from animal manure and earthworms.
- Animal manure (AM) – sheep manure

According to recommendation of the producer, the given amounts of each soil amendment was added to the soil and mixed to a depth of 10 cm. The recommended amount of: "Agrobiosol", "Alkan", "Barvar-2" phosphate biofertilizer, animal and plant vermicompost and animal manure were: 150 g m^{-2}, 150 g m^{-2}, 0.01 g m^{-2}, 2 kg m^{-2} and 5 kg m^{-2}, respectively. The experiment was performed as complete block design with 10 treatments and 3 replications (each experimental unit was a plot 1 × 4 m) as follow:

1. Control (field soil solely),
2. "Agrobiosol",
3. "Agrobiosol" + "Barvar-2" phosphate biofertilizer (B-2 PHB),
4. Plant vermicompost (PVC),
5. Animal vermicompost (AVC),
6. Vermicompost (plant+animal) + B-2 PHB,
7. "Alkan",
8. "Alkan"+ B-2 PHB,
9. Animal manure (AM),
10. Animal manure + B-2 PHB.

The seeds were sown by hand in nursery beds and uniform 8-12 cm seedlings were selected for transplanting in the field at 10 × 10 cm spacing.

Data recording and analysis

Forty five and 85 days after transplanting (DAT) flower number, diameter and length, the number of florets and shoots, root and flower fresh and dry weight, and also flower number per a plant were measured. Visual quality and flowering durability were estimated 85 DAT as well. To determine dry weight of shoots, roots and flowers, the materials were kept in an oven at 75°C for 48 hr. Visual quality was estimated giving scores from 1 to 10 based on quality (1 stands for the least and 10 for the best quality, respectively). Data were elaborated statistically using MSTATC software and the means were compared at 5% level of significance using Duncan's new multiple range test (DNMRT).

RESULTS

Soil analysis

The soil used in this experiment had high pH and EC (Tab. 1 and 2), as is typical for the soils of southern parts of Iran. However, no physiological disorders occurred on the plants grown in this soil type. The application of soil amendments reduced EC and it was obvious in the case of animal composted manure compared to other mixtures. All soil

Table 1. Chemical properties of soil before transplanting of African marigold cv. 'Queen' seedlings

pH	EC	OC	N	K	P	Fe	Zn	Cu	Mn
	[dSm^{-1}]	[%]		[mg kg^{-1}]					
7.71	2.64	0.41	0.04	256	9.10	1.80	0.03	0.62	4.20

amendments increased soil pH, but the highest pH was observed in PVC that significantly was different compared to other treatments. The highest amount of K, P and OC after the end of experiment were obtained from 10th and 9th treatments. Soil nitrogen showed no particular trend. The highest amount of Zn were in 5th and 7th Cu in 3rd and 7th, and Fe were measured in 5th and 7th treatments. Content of manganese was higher in treatments 2nd, 3rd and 8th .

Flower number, length and diameter 45 and 85 DAT

The results in Table 3 indicated that the highest number of flowers 45 DAT, was related to treatment 7th (solely "Alkan"), although there was no significant difference with compared to 1st, 3rd, 4th, 8th, and 10th (Tab. 3). Flower number 85 DAT followed no particular trend. The highest flower length 45 DAT was obtained in 2nd treatment ("Agrobiosol") which was significant in comparison with control only. In the case of 85 DAT, the highest flower length was observed in treatment 7th ("Alkan") (Tab. 3). The highest flower diameter 45 DAT was observed in 3. Flower diameter 85 DAT was not affected by any soil amendments (Tab. 3).

Flowering durability and floret number 85 DAT

Flowering durability was not significantly affected by the treatments. The highest floret number 45 DAT, was obtained in 7th treatment, and was significant in comparison with 6th, 8th and 9th (Tab. 4).

Flower fresh and dry weight 45 and 85 DAT

The highest flower fresh weight 45 DAT was obtained for plants grown in soil amended with "Alkan", but dry weight 45 DAT was not affected by the treatments applied. The amendments had significant effect on flower fresh weight 85 DAT (Tab. 4). The highest flower fresh weight 85 DAT (8.3 g) was obtained in soil amended with "Alkan" which was significant as compared to other treatments with the exception of treatment 4th. The highest flower dry weight was recorded in soil treated with PVC (Tab. 4).

Visual quality and flower number per plant

The highest visual quality and flower number per plant was recorded in treatments 7th and 5th, respectively (Tab. 5).

Table 2. Chemical properties of soil at the end of experiment period

Treatment No.	Treatments	pH	EC	OC	N	K	P	Fe	Zn	Cu	Mn
			[dSm^{-1}]	[%]		[mg kg^{-1}]					
1	Control	8.20bc*	1.24de	0.21g	0.02ab	136.0g	0.90i	3.00de	0.23f	0.14e	2.30c
2	Agrobiosol	8.14c	1.79b	0.16h	0.02ab	130.0h	4.40g	8.20a	0.28f	0.18de	3.60a
3	Agrobiosol + B-2 PHB	7.90d	1.83b	0.12i	0.01b	144.0e	11.60d	6.80b	0.48d	0.30ab	3.40a
4	PVC	8.80a	2.22a	0.31c	0.03a	202.0c	7.90e	2.80e	0.54c	0.26bc	1.80d
5	AVC	8.35b	1.32cde	0.25e	0.03a	142.0ef	13.30c	2.70e	1.00a	0.22cd	2.80b
6	VC (P+A) + B-2 PHB	8.31bc	1.46c	0.23f	0.02ab	142.0ef	5.70f	1.87f	0.02g	0.14e	2.70b
7	Alkan	8.33b	1.28cde	0.27d	0.03a	160.0d	4.00g	8.00a	0.62b	0.32a	1.60d
8	Alkan + B-2 PHB	8.22bc	1.68b	0.10j	0.01b	138.0fg	2.40h	4.20c	0.24f	0.26bc	3.40a
9	AM	8.21bc	1.15e	0.33b	0.03a	296.00b	17.77a	3.40d	0.38e	0.20d	2.80b
10	AM + B-2 PHB	8.30bc	1.38cd	0.35a	0.03a	372.00a	15.30b	2.60e	0.34e	0.04f	1.68d

*In each column, means with the same letter(s) are not significantly different at 5% level of significance, using DNMRT

Table 3. The effect of different soil amendments on number, length and diameter of flower 45 and 85 DAT** of African marigold 'Queen' seedlings

Treatment No.	Treatments	Flower number		Flower length [mm]		Flower diameter [mm]	
		45 DAT	85 DAT	45 DAT	85 DAT	45 DAT	85 DAT
1	Control	3.33abc*	4.66a	5.17b	4.57abc	5.67ab	6.16a
2	Agrobiosol	2.33bc	3.00b	6.20a	5.33ab	6.17ab	7.67a
3	Agrobiosol + B-2 PHB	4.00ab	3.33b	6.13ab	4.33b	6.57ab	6.50a
4	PVC	4.00ab	5.00a	5.67ab	5.40ab	7.00a	6.17a
5	AVC	2.67bc	5.00a	5.33ab	4.50ab	5.33b	6.67a
6	VC (P+A) + B-2 PHB	2.00c	2.00c	5.33ab	5.00ab	6.00ab	7.16a
7	Alkan	4.67a	4.67a	6.00ab	5.50a	6.00ab	7.67a
8	Alkan + B-2 PHB	3.67abc	5.00a	5.73ab	4.93ab	6.67ab	6.83a
9	AM	2.00c	5.33a	5.50ab	4.83ab	5.67ab	6.00a
10	AM + B-2 PHB	3.00abc	3.33b	5.67ab	4.67ab	6.33ab	6.67a

*In each column, means with the same letter(s) are not significantly different at 5% level of significance using DNMRT

**Days after transplanting

Table 4. The effect of different soil amendments on flower durability, floret number 45 days, flower fresh and dry weight 45 and 85 DAT** of African marigold 'Queen' seedlings

Treatment No.	Treatments	Flower durability	Floret number 85 DAT	Flower fresh weight [g]		Flower dry weight [g]	
				45 DAT	85 DAT	45 DAT	85 DAT
1	Control	29.43a*	77.33ab	5.10b	5.40de	0.90a	1.00bcd
2	Agrobiosol	31.03a	92.67ab	7.46ab	5.86bcde	1.23a	1.30ab
3	Agrobiosol + B-2 PHB	26.60a	70.33ab	6.40b	5.71cde	1.10a	1.31ab
4	PVC	29.60a	73.34ab	7.43ab	7.18ab	1.30a	1.40a
5	AVC	27.03a	81.33ab	5.23b	4.93e	0.87a	0.94cd
6	VC (P+A) + B-2 PHB	28.67a	67.00b	6.36b	4.87e	1.03a	0.87d
7	Alkan	29.67a	110.00a	9.15a	8.30a	1.43a	1.33ab
8	Alkan + B-2 PHB	29.83a	64.00b	6.60b	6.50bcd	1.17a	1.17abcd
9	AM	25.58a	62.00b	6.40b	6.93bc	1.10a	1.28ab
10	AM + B-2 PHB	29.55a	85.00ab	6.00b	6.57bcd	0.97a	1.23abc

*,**Explanations: see Table 3

Table 5. The effect of different soil amendments on visual quality 45 DAT, flower per plant 85 DAT, shoot fresh and dry weight 45 and 85 DAT** of African marigold 'Queen' seedlings

Treatment No.	Treatments	Visual Quality 45 DAT	Flower per plant 85 DAT	Shoot fresh weight [g]		Shoot dry weight [g]	
				45 DAT	85 DAT	45 DAT	85 DAT
1	Control	6.10bc*	4.13bc	16.88b	16.98e	3.73abc	3.41de
2	Agrobiosol	6.97abc	3.09d	15.67b	22.53c	2.53cd	4.33bcde
3	Agrobiosol + B-2 PHB	5.23c	3.44bcd	18.73b	13.64f	3.37bcd	4.57abc
4	PVC	5.83bc	4.37ab	25.23ab	19.70d	4.35ab	3.30e
5	AVC	6.50bc	5.10a	20.07b	13.03f	2.70cd	5.33ab
6	VC (P+A) + B-2 PHB	7.00abc	3.61bcd	16.03b	22.03c	2.20d	3.93cde
7	Alkan	8.50a	3.03d	32.77a	34.77a	4.97a	5.42a
8	Alkan + B-2 PHB	6.67abc	3.25cd	23.63ab	25.73b	3.83abc	4.40abcd
9	AM	7.13ab	3.16d	15.30b	10.43g	2.50cd	1.87f
10	AM + B-2 PHB	6.83abc	2.95d	16.53b	12.03fg	2.70cd	2.03f

*,**Explanations: see Table 3

Shoot fresh and dry weight 45 and 85 DAT

The highest shoot fresh and dry weights 45 DAT were observed in treatment 7th, although the difference was not significant in comparison with treatments 2nd and 6th (Tab. 5). The highest shoot fresh (34.77 g) and dry (5.42 g) weights 85 DAT were recorded in treatment 7th (Tab. 5).

Root fresh and dry weight 45 and 85 DAT

The highest root fresh (6.16 g) and dry (1.17 g) weights 45 DAT were obtained in treatments 4th and 7th, respectively. Considering fresh weight, this difference was significant when compared with 1st, 6th and 8th treatments but in the case of dry weight, the difference was not significant in comparison 7th and 10th. Root fresh and dry weights 85 DAT was affected by soil amendments and the highest amount was recorded in 2nd treatment. (Tab. 6).

DISCUSSION

The comparison of vegetative and reproductive characteristics of *Tagetes erecta* L. 'Queen' indicated that among the all amendments, "Alkan" and PVC were found to improve soil characteristics, which resulted in better plant response. The processing of "Alkan" production is not cost-effective as compared to PVC. Meanwhile, PVC production is more convenient and does not require the equipment and facilities that "Alkan" needs. Accordingly, considering the increasing production of urban wastes as a raw material for composting, it is suggested that PVC be used as soil amendment for ornamental plants.

The highest flower diameter and root fresh and dry weights 45 DAT and also the highest flower dry weight and flower number per plant 85 DAT were observed in plants grown in soil amended with PVC. These findings confirmed those reported by Bachman and Metzger (2007) that VC increased root fresh and dry weight in French marigold, pepper, tomato and cornflower. VC is reported to have hormone-like activity, and this has been hypothesized to result in grater root initiation, increased root biomass, enhanced plant growth and development, and altered morphology of plants grown in VC-amended media (Bachman and Metzger, 2007). Recently, Canellas et al. (2000) identified exchangeable auxin groups in humic acids extracted from cattle manure, which enhanced root elongation, lateral root emergence and plasma membrane H^+-ATPase activity of maize roots. Furthermore, the increased productivity of crops in response to VC was attributed to a greater availability of mineral nutrients than in commercial plant growth media containing only inorganic nutrients (Edwards and Burrows, 1988; Werner and Cuevas, 1996); as well as their rich microbial population (Edwards, 1983; Tomati et al., 1987; Carlile and Wilson, 1993).

Positive effect of PVC on growth and development of *Tagetes erecta* L. 'Queen' reported here may be related to VC characteristic as

Table 6. The effect of different soil amendments on root fresh and dry weight 45 and 85 DAT** of African marigold 'Queen' seedlings

Treatment No.	Treatments	Root fresh weight [g]		Root dry weight [g]	
		45 DAT	85 DAT	45 DAT	85 DAT
1	Control	4.20bcd*	3.68cde*	0.70de	0.73cd
2	Agrobiosol	5.25abc	5.53a	0.90b	1.93a
3	Agrobiosol + B-2 PHB	4.33abcd	4.32abcd	0.83bcd	1.20b
4	PVC	6.16a	5.07ab	1.13a	1.43b
5	AVC	4.80abc	3.93bcde	0.87bc	0.70cd
6	VC (P+A) + B-2 PHB	2.90d	3.60de	0.53f	0.80cd
7	Alkan	5.93ab	4.93abc	1.17a	1.23b
8	Alkan + B-2 PHB	3.80cd	3.77cde	0.67ef	1.37b
9	AM	4.60abcd	3.00e	0.73cde	1.07bc
10	AM + B-2 PHB	5.25abc	2.87e	1.10a	0.60d

*,**Explanations: see Table 3

mentioned above. Our results are also in agreement with those presented by Keshavarzi et al. (2005), on *Narcissus pseudonarcissus* cv. 'Golden Harvest' and by Khalighi and Padasht-Dehkaee (2000) on *Tagetes patula* cv. 'Golden Boy'. Considering the increasing anxieties over environmental pollution around the world due to industrialization, it seem highly necessary to use natural materials (e.g. plant vermicompost) or their modified products as soil amendments to give the earth a chance for upcoming generations.

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WPŁYW RÓŻNYCH DODATKÓW DO GLEBY NA WZROST I KWITNIENIE AKSAMITKI (*Tagetes erecta*) 'QUEEN'

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S T R E S Z C Z E N I E

Do gleby dodawano różne substraty pochodzenia roślinnego (komposty), zwierzęcego (komposty, obornik), składniki mineralne i określano ich wpływ na wzrost roślin – liczbę kwiatów, długość i średnicę kwiatów, liczbę kwiatów na roślinie, trwałość kwiatów, świeżą i suchą masę poszczególnych organów po 45 i 85 dniach uprawy. Analizowano zawartość składników mineralnych w glebie przed założeniem doświadczeń i po ich zakończeniu. Spośród wszystkich badanych substratów najlepsze oddziaływanie na wzrost *Tagetes erecta* wykazywał dodatek do gleby wermikompostu pochodzenia roślinnego.

Słowa kluczowe: aksamitki, substraty, wzrost wegetatywny, kwitnienie, wermikompost