Pakistan Journal of Biological Sciences 10 (9): 1438-1444, 2007
ISSN 1028-8880

Study of Calendula and Gaillardia Growth in Two Composts Prepared from Agroindustrial Wastes

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Abstract: Two composts prepared from agroindustrial wastes were assayed as substrates: C_1 from brewing waste (yeast and malt) plus lemon tree pruning and C_2 from the solid fraction of olive mill wastewater plus olive leaves. Sixteen substrates were prepared by combining each compost with *Sphagnum* peat or a Commercial Substrate (CS) in different proportions. The nutrients (N and K) provided by the composts, which acted as slow-release fertilizers, influenced especially the development of calendula, although the physical and physico-chemical properties such as total pore space and Electrical Conductivity (EC) were also relevant. On the other hand, in the salt-sensitive Gaillardia hybrid, EC and chloride concentration were the main factors influencing growth. The best results were found in substrates prepared by mixing C_1 at up to 75% with peat, or at up to 50% with CS, or by mixing C_2 at up to 50% with peat or CS, for calendula. For salt-sensitive species such as Gaillardia, adequate substrates for plant development were found for C_1 at up to 50% with peat or CS, but the use of C_2 should be limited to 25% in mixtures with peat or CS. Therefore, composts of agroindustrial origin such as these can be used as an alternative to peat and CSs for growing ornamental plants, provided the mixture contains at least 25% peat or CS.

Key words: Compost, substrate, agroindustrial waste, calendula, gaillardia, salinity

INTRODUCTION

Soil-less substrates are used in horticulture for growing seedlings, plant propagation, vegetable production and the production of ornamental plants in pots. The most common substrate for such cultures is prepared with *Sphagnum* peat, due to its high physical and chemical stability and low degradation rate. The cost of high quality peat for horticultural use, together with the declining availability of peat in the near future due to environmental constraints, especially in countries without peat moss resources (such as Iran), make it necessary to look for alternative materials (Raviv *et al*., 1986; Padasht Dehkaei, 1998; Abad *et al*., 2001; Hasandokht *et al*., 2005; Mahbob Khomami, 2005). As a consequence, composted organic wastes are increasing in value commercially because the Organic Matter (OM) and nutrients from the organic wastes are recycled (Nappi and Barberis, 1993). Additionally there is evidence in the literature which shows that, unlike peat, composts possess plant growth regulators and properties which suppress soil-borne plant pathogens (Lumsden *et al*., 1986; Atiyeh *et al*., 2001).

Composts used as substrates should have a high degree of maturity and adequate physical and chemical properties, such as particle size, porosity, water-holding capacity, air capacity, Electrical Conductivity (EC) and pH, which are even more important than the concentrations of nutrients, because these latter can be added by fertilization (Gouin, 1998; Padasht Dehkaei, 1998; Mahbob Khomami, 2005). Composts usually show a high porosity and air capacity and a low water-holding capacity (Abad *et al*., 2001). They also have a high salt and nutrient content (López-Real *et al*., 1989). EC has been shown to be an important factor when compost is used as a substrate for horticultural plants and seedlings (Eklind *et al*., 1998). Composts often require leaching or mixing with nutrient-poor material in order to become suitable substrates with better physico-chemical properties for container-grown vegetables and flowers. Composts from many different origins, like sewage sludge, sweet sorghum bagasse, Municipal Solid Waste (MSW), wood bark, garden waste and manure, as well as vermicompost, have been assayed as substrates, good results often being obtained by mixing with peat (López-Real *et al*., 1989; Nappi and Barberis, 1993; Eklind *et al*., 1998; Padasht Dehkaei, 1998; Atiyeh *et al*., 2001; Nadi and Golchin, 2005; Keshavarzi *et al*., 2005). For ornamental plants,

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Pinamonti *et al*. (1997) reported a good production of plants with 50% sewage sludge and poplar bark compost. Klock (1997) suggested that impatiens and snapdragons can be grown successfully in 100% compost made from biosolids and garden wastes. There is a wide range of wastes of agroindustrial origin, but information concerning the feasibility of the use of composts prepared from such wastes as substrates is scarce. Abad *et al*. (2001) prepared an inventory of materials suitable for use as growing media for ornamental plant production, which included agroindustrial wastes such as bagasse, slaughter waste, brewing waste, etc.

The aim of the present work was, therefore, to evaluate the use of composts made from some agroindustrial wastes in the preparation of substrates for ornamental plants, as a peat substitute and as an alternative to commercial composts used as substrates and to determine any limitation to their use.

MATERIALS AND METHODS

Two mature composts from different agroindustrial wastes were studied:

- C_1: 2.5% brewing waste (yeast+ malt)+97.5% lemon tree prunings (dry weight basis);
- C_2: 65% solid fraction of olive mill wastewater+35% olive leaves (dry weight basis).

The brewing waste was a mixture of yeast and residual malt from the fermentation process. These mixtures were composted in a pilot plant by the static pile system, with forced aeration and controlled temperature (Finstein *et al*., 1983), for 90 and 190 days (C_1 and C_2, respectively) and then for two months more of maturation. Both composts reached a good degree of maturity according to the following criteria: total organic carbon to total nitrogen ratio (TOC/TN) of C_1= 16.7 and C_2= 14.1, cation exchange capacity (CEC) >67 $cmol_c\ kg^{-1}$ on an ash-free basis (123 and 150 in C_1 and C_2, respectively), CEC/TOC ratio>1.9 (2.2 and 2.6 in C_1 and C_2, respectively) and a germination index (GI) >50% (89 and 95 in C_1 and C_2, respectively) (Zucconi *et al*., 1981; Iglesias-Jiménez and Pérez-García, 1992). The nutrient concentrations of both composts ($g\ kg^{-1}$) were the following:

C_1:TN = 24.9, P = 2.1, K = 8.5, Ca = 75.3, Mg = 6.8, Na = 0.7, Fe = 1.2;

C_2:TN = 17.6, P = 1.5, K = 12.6, Ca = 127.5, Mg = 6.8, Na= 1.1, Fe= 9.1.

The composts were mixed in different proportions with *Sphagnum* peat (pH 3.8), without any fertilization, or with a Commercial Substrate (CS). The CS is widely used as an organic fertilizer and as a substrate in growing media. Sixteen substrates were then prepared from combinations of two composts (C_1 and C_2), two diluents (peat and CS) and four different proportions of compost (25, 50, 75 and 100% v/v compost). Pure peat (pH corrected with dolomite; Table 1) and CS were also tested as controls. All the substrates were fertilized before planting with a slow-release fertilizer (15:11:13+ micronutrients) (Osmocote Plus, 3-4 months) at a rate of 1.5 kg m^{-3} substrate.

Two plant species of differing salt sensitivities were selected: the less sensitive calendula (var. Nana Bon-Bon) and the salt-sensitive Gaillardia (dwarf). Commercial seedlings (calendula, height = 6 cm, Gaillardia, height = 4 cm) were planted in pots of 0.4 l capacity, containing the different substrates and then watered with tap water. The experiments were run in a glasshouse, using a randomized block design of three replicates per treatment in three blocks (9 pots per treatment and per plant species). The pots were watered as required and no extra fertilization was applied. Plant height was measured from the point where the stem entered the substrate to the upper tip of the plant. The experiments lasted three months. When the plants had flowers of commercial size the aerial parts of the plants were weighed fresh, the flowers were counted and the quality of roots was evaluated according to the following criteria:

- Visible root density at the substrate surfaces (1-low, 5-high).
- Kind of roots (1-thin and weak, 5-thick and strong).
- Colour of roots (1-dark, 5-white).

Compost EC and pH were determined in a water-soluble extract 1:10 (w/v). Dry matter was calculated by drying at 105°C for 12 h and organic matter (OM) content by loss on ignition at 430°C for 24 h (Navarro *et al*., 1993). TN and TOC were determined by an automatic microanalyzis method (Navarro *et al*., 1991). NH_4^+-N was extracted with 2 M KCl and determined by a colorimetric method based on Berthelot's reaction (Sommers *et al*., 1992). NO_3^- -N was determined by ion chromatography in a 1:20 (w/v) water extract. After $HNO_3/HClO_4$ digestion, P was determined colorimetrically by the method of Kitson and Mellon (1944), Na and K by flame photometry and Ca, Mg and Fe by atomic absorption spectrophotometry. The CEC was

Table 1: Physico-chemical and chemical characteristics of the substrates: ideal substrate (IS), *Sphagnum* peat (P), commercial substrate (CS) and compost

Sub stratus	pH	EC (dS m^{-1})	OM (%)	NO_3^--N (μg mL^{-1})	K^+ (μg mL^{-1})	Na^+ (μg mL^{-1})	Cl^- (μg mL^{-1})	SO^{2-}_4 S (μg mL^{-1})
IS	5.2-6.3	0.75-3.49	>80	100-199	150-249	<115	<180	<960
Peat	5.10	0.14	94.27	20	42	6	39	36
CS	6.16	3.98	67.76	418	420	210	404	390
C_1	8.05	4.26	74.71	42	1540	88	328	331
C_2	7.54	3.70	42.31	20	1420	210	715	333
C_1+P (25%)	5.01	0.68	89.77	6	260	25	68	53
C_1+P (50%)	6.67	1.31	83.46	18	360	49	131	159
C_1+P (75%)	7.40	2.48	76.87	9	820	70	147	168
C_2+P (25%)	6.61	0.46	74.97	0	200	53	110	53
C_2+P (50%)	6.84	2.63	58.64	15	840	130	246	100
C_2+P (75%)	7.32	3.65	42.84	9	920	140	343	112
C_1+CS (25%)	6.83	5.33	64.70	314	680	210	381	564
C_1+CS (50%)	7.21	5.60	70.79	211	1340	230	454	738
C_1+CS (75%)	7.51	5.88	73.42	73	1840	240	437	612
C_2+CS (25%)	6.92	4.95	60.45	338	800	370	466	592
C_2+CS (50%)	7.15	4.45	54.19	313	1100	200	767	657
C_2+CS (75%)	7.33	4.10	45.32	39	1900	380	536	500

Cation and anion concentrations refer to the water saturated extract. N-NH_4^+: 152 and 34 mg kg^{-1} in C_1 and C_2, respectively.Soluble phosphorus <0.5 μg mL^{-1} in all substrates

Table 2: Physical characteristics of the substrates: ideal substrate (IS), *Sphagnum* peat (P), commercial substrate (CS) and compost (C_1 y C_2)

Sub stratus	Bulk density(g cm^{-3})	Particle density(g cm^{-3})	Total pore space (% v/v)	Air capacity (% v/v)	Total water-holding capacity (mL L^{-1})
IS	<0.40	1.4-2.0	>85	20-30	600-1000
Peat	0.10	1.49	93	18	760
CS	0.24	1.70	86	47	392
C_1	0.15	1.64	91	65	258
C_2	0.37	1.96	81	31	505
C_1+P (25%)	0.10	1.52	93	38	553
C_1+P (50%)	0.11	1.57	93	46	464
C_1+P (75%)	0.13	1.62	92	51	413
C_2+P (25%)	0.15	1.64	91	45	464
C_2+P (50%)	0.21	1.78	88	43	458
C_2+P (75%)	0.29	1.96	85	37	484
C_1+CS (25%)	0.24	1.73	86	40	463
C_1+CS (50%)	0.20	1.67	88	44	437
C_1+CS (75%)	0.18	1.65	89	53	365
C_2+CS (25%)	0.29	1.77	84	41	424
C_2+CS (50%)	0.31	1.83	83	44	395
C_2+CS (75%)	0.34	1.93	82	38	438

determinated with $BaCl_2$-triethanolamine (Lax *et al*., 1986). The GI (Germination index) was calculated using seeds of *Lepidium sativum* L. (Zucconi *et al*., 1981). Substrate pH, EC and the NO_3^--N, Cl^-, SO_4^{2-}-S, P, K and Na concentrations were determined in the water-saturated extracts. The physical properties of the materials were determined according to the methods of Verdonck and Gabriels (1992) All analyzes were done at least in duplicate.

RESULTS AND DISCUSSION

The pH values of C_1 and C_2 were greater than the established limits for an ideal substrate (IS) (Abad *et al*., 2001), whilst CS was in the upper range for an IS (Table 1). The pH decreased when the composts were mixed with peat or CS. The EC values of the composts (C_1 and C_2), the CS and their mixtures were higher than the limit for an IS, due to their high concentrations of soluble salts (Cl^- and SO_4^{2-}-S) and nutrients (NO_3^--N and K^+) in the water-saturated extract (Table 1). Of note is the high chloride content of C_2, potassium contents of C_1 and C_2 and nitrate content of CS, probably added previously to CS as fertilizer. Mixing C_1 and C_2 with peat improved these properties to values within the range of an IS.

In C_2 and CS the OM concentration was very low and the substrates prepared from them had values below the level for an IS. This may have led to high air capacity and low total water-holding capacity in most of the substrates (Table 2); even mixing with peat hardly improved these properties. This means that water should be applied frequently and in small amounts, as leaching may easily occur. Bulk density, particle density and total pore space were adequate in most of the substrates. In general, the characteristics of the composts assayed are common to a large variety of organic waste materials and composts (Abad *et al*., 2001).

Table 3: Effect of the different growing media on the growth and nutritional state of calendula (9 plants per treatment)

Sub stratus	Fresh weight (g/plant)	Root quality	Flower No.	Na (g kg^{-1})	P (g kg^{-1})	N (g kg^{-1})	K (g kg^{-1})
Peat	13.24b	4.52b	1.11a-d	28.7g	1.7a	32.0fg	20.8
CS	17.28b-e	4.94a	1.17a-c	32.8e-g	3.9e	27.5g	21.5
C_1	16.79c-f	3.46f-h	1.12a-d	41.9a	1.9hi	65.6bc	20.1
C_2	14.62e-h	3.29h	0.56c	37.1b-e	2.0hi	77.7a	20.8
C_1+P (25%)	15.97e-h	4.62ab	1.11a-d	30.4fg	2.3e-g	30.1fg	23.2
C_1+P (50%)	14.27f-h	3.96c-e	1.00b-e	32.8f-h	2.4ef	51.3de	22.9
C_1+P (75%)	20.82a	4.07c	1.56a	37.2b-e	2.2e-h	60.7b-d	23.2
C_2+P (25%)	13.80gh	4.09c	1.11a-d	35.0c-f	2.0hi	39.6f	18.9
C_2+P (50%)	16.49d-g	3.69d-g	1.00b-e	38.0a-d	2.0g-i	55.7c-e	19.9
C_2+P (75%)	16.50d-g	3.35gh	0.78c-e	39.7ab	2.1f-h	67.9ab	20.9
C_1CS+(25%)	19.09a-c	4.08c	1.33ab	37.8a-d	3.5b	53.6de	19.0
C_1CS+(50%)	19.87ab	3.80c-f	1.33ab	38.8a-d	2.8cd	58.2b-e	22.9
C_1CS+(75%)	14.61e-h	3.59c-h	1.00b-e	37.6a-d	2.8cd	50.5e	18.8
C_2CS+(25%)	17.54b-d	3.87c-e	1.00a-d	34.3d-f	3.4b	51.2de	22.5
C_2CS+(50%)	14.84a-d	4.06cd	1.22a-c	39.3a-c	2.9e	56.3c-e	19.7
C_2CS+(75%)	13.35b	3.59e-h	0.67d	41.6ab	2.5de	55.5de	17.8
ANOVA	***	***	***	***	***	***	n.s
LSD	2.935	0.400	0.416	4.62	0.38	10.26	

***, *, *: p0.001, 0.01, 0.05. LSD: least significant difference. Values followed by the same letter are not statistically different according to the Waller-Duncan test at p0.05

Table 4:Effect of the different growing media on the growth and nutritional state of Gaillardia (9 plants per treatment)

Sub stratus	Fresh weight (g/plant)	Root quality	Flower number	Na (g kg^{-1})	P (g kg^{-1})	N (g kg^{-1})	K (g kg^{-1})
Peat	10.78ef	4.00ab	1.78ef	18.1c-f	1.3de	20.0i	5.4e
CS	14.52de	3.57bc	4.17d-f	22.8a-d	5.2a	50.0d-g	6.5c-e
C_1	0.74i	1.11fg	0.25ef	19.0b-e	2.2cd	65.8a	12.7a
C_2	2.61hi	1.48ef	0.22ef	14.2ef	1.6cde	39.8h	7.4cd
C_1+P(25%)	19.74a-c	4.09a	8.37cd	13.5f	1.2e	26.5i	6.3de
C_1+P(50%)	21.68a	2.69d	14.87ab	17.3d-f	1.3de	40.2gh	7.0cd
C_1+P(75%)	13.46de	2.71d	8.62b-d	17.3d-f	1.6c-e	51.7c-f	7.9c
C_2+P(25%)	21.83a	3.81a-c	9.14a-d	17.9c-f	1.0e	45.8e-h	6.5c-e
C_2+P(50%)	16.78b-d	2.81d	5.89d-f	17.9c-f	1.2e	50.0c-f	6.9c-e
C_2+P(75%)	5.22gh	1.33e-g	0.44ef	20.4b-d	1.7c-e	46.2e-h	7.9c
C_1CS+(25%)	20.87ab	3.82a-c	6.50de	23.1a-c	1.6c-e	53.3c-e	7.3cd
C_1CS+(50%)	19.57a-c	2.81d	13.0a-c	13.2a-c	2.3bc	52.7c-e	7.5cd
C_1CS+(75%)	8.98fg	1.74e	4.78d-f	24.5ab	2.5bc	63.6ab	10.0b
C_2CS+(25%)	16.74cd	3.41c	15.22a	19.7b-e	3.3b	55.9b-d	7.5cd
C_2CS+(50%)	13.66de	2.52d	8.56b-d	20.5b	2.5bc	56.3a-c	702.0cd
C_2CS+(75%)	2.26hi	1.00g	0.18f	19.8b-e	1.6c-e	42.0f-h	7.9c
ANOVA	***	***	***	***	***	***	***
LSD	4.552	0.527	6.199	5.08	0.96	10.11	1.50

***, *, *: $p<0.001$, 0.01, 0.05. LSD: least significant difference. Values followed by the same letter are not statistically different according to the Waller-Duncan test at p0.05

After three months, the height of calendula plants was similar in all substrates, ranging from 12.6 cm in C_1+CS (25%) to 8.8 cm in C_1+P (50%). The yields of calendula, expressed as fresh weight of the aerial part, did not differ statistically in C_1, C_2 and CS, but only peat, of the pure substrates, produced a rather lower yield (Table 3). The highest yields of calendula were obtained in C_1+P (75%), C_2+P (50-75%) and in both composts+CS (50%), all producing an acceptable degree of root quality and number of flowers (Table 3). These results may be due to the great contribution of nutrients, N and K, by the composts (Table 1).

Higher yields of broccoli seedlings was observed with increasing proportions of composts in the substrates and associated this with the increased amount of nutrients (Sánchez-Monedero *et al*., 2004). Tomatoes have also been shown to grow better with the higher nutritional input of increasing proportions of vermicompost (Atiyeh *et al*., 2001).

Highly significant differences ($p<0.001$) in the N, P and K concentrations were observed in the calendula plants (Table 3). The highest N concentration was obtained in plants grown in pure C_1, due to the high total and inorganic nitrogen concentrations of this compost, followed by C_2, while the lowest levels were for plants grown in peat. The concentration of P in calendula plants was greatest with pure CS and its mixtures (Table 3), also no significant differences were observed in the plants grown on C_1, C_2, peat or their mixtures. The highest K concentration was exhibited in the plants grown in the pure C_2 compost (Table 3), due to the high K content of the olive mill waste (Paredes *et al*., 1999). In the mixtures containing either C_1 or C_2 and peat, the N and K concentrations of the plants increased with increasing proportions of compost. Therefore, plants assimilated the nutrients provided by both composts and the CS, which improved growth. The lower weight of the calendula plants grown on peat compared with C_1 and C_2 might have been due to lower availability of macronutrients. Regarding Na, no significant differences were observed between the different treatments (Table 3), due to its low concentration in the composts, well below those of K, Ca and Mg.

Since no differences in the nutrient levels of the plants grown in mixtures C_1 or C_2 with CS were observed (Table 3), the fall in yield at 75% compost could be due to the physical properties of the substrates, such as low total pore space in the case of C_2+CS (75%) or excessive EC in the case of C_1+CS (75%). Eklind *et al.* (1998) also observed a fall in yield and a reduction in the number of flowers in marguerite as the proportion of compost increased in mixtures with peat, due to excess salinity. However, the Na concentration of calendula, a salt-tolerant species, was not affected by the composition of the substrates (Table 3). It was not only the fertilizing effect of the composts that influenced yield and root quality, but also the physical and chemical properties of the mixtures as a whole, as the lowest yields and root quality of plants were obtained in 100% compost (Table 3).

For Gaillardia, maximum height was achieved in plants grown in mixtures at 25% compost (4.1-5.3 cm), especially with CS, while plants grown in pure compost (1.7-1.9 cm) and in the mixtures at 75% (1.6-3.8 cm) were the smallest. Therefore, the fresh weights of Gaillardia obtained in pure C_1 and C_2 were the lowest (Table 4). The maximum yields for C_1 were obtained at 50 or 25 % compost mixed with peat or CS and for C_2 at 25% with peat or CS, with a good number of flowers, as happened with calendula. The EC values of the composts may have affected plant growth in the substrates with peat, as the best results were obtained in mixtures with the lowest EC, C_1+P (25-50%) (EC 0.68-1.31 dS m^{-1} and C_2+P (25%) (EC 0.46 dS m^{-1} Higher proportions of compost resulted in higher EC values and lower yields. Therefore, Gaillardia behaved as a salt-sensitive species. High yields were also obtained for C_1+CS (50%) and C_2+CS (25%), which had higher EC values, of 5.60 and 4.95 dS m^{-1}, respectively. It is possible that the cations and anions contributing to the EC in CS were mainly nutrients such as K^+ and NO^-_3-N and thus had a beneficial effect which over-compensated for the osmotic effect. The fall in yield in the 75% compost mixtures may have been due to excess salinity, which, in this case, may have caused an osmotic imbalance, or the high level of a particular ion such as chloride (François and Maas, 1994). Chloride was the main anion contributing to the EC in C_2 and this may have been responsible for the low yield of Gaillardia grown in substrate with a high proportion of C_2, by the additive effects of osmotic stress and specific ion toxicity.

The quality of the roots decreased with increasing compost rate in both CS and peat mixtures (Table 4). The best root quality of the plants occurred in the controls, peat and CS, meaning that the negative effect of high EC of the composts had an effect first at root level. These results agree with those of López-Real *et al.* (1989), who found that the root weight of geranium, petunia and coleus increased as the proportion of a sewage sludge plus straw compost increased up to 50% in peat, while with 75% compost the yield decreased.

The highest concentrations of N and P in Gaillardia were observed in plants grown on CS, alone or mixed with compost (Table 4). There were no significant differences between the different proportions of compost in the substrates. Thus, the lower yield and root quality observed in Gaillardia grown in pure compost and its mixtures with a high proportion of compost would not have been due to a deficit of nitrogen but to the physico-chemical properties of the substrates already discussed. The highest K concentrations were in plants grown on C_1 followed by CS and C_2, all of which had high levels of available K (Table 1). In the treatments involving C_2, lower K concentrations than expected were recorded, given the high levels of available K in the compost (Table 1). Maybe the high K concentrations in these substrates contributed to a high EC and this, together with the high Na content in the C_2 saturation extracts (Table 1), may have had an osmotic effect on plant growth in C_2 and mixtures of C_2+CS (Table 4). The Na content was noticeably lower in Gaillardia than in calendula.

It can be concluded, from the results obtained here, that the composts used in the preparation of substrates were not phytotoxic and permitted the plants to grow disease-free and with no weeds. Due to their physical and chemical characteristics, the composts prepared from brewing waste and from the solid fraction of olive mill wastewater may be considered as partial peat substitutes and as an alternative to other CSs. Among the advantages which these composts can provide are the nutrients, mainly N and K and thus they act as slow-release organic fertilizers. Their use as substrates depends on the species to be cultivated, as the EC is the main limiting factor. For their use as substrates to grow ornamental plants the best results were found in substrates prepared by mixing C_1 at up to 75% with peat, or at up to 50% with CS, or by mixing C_2 at up to 50% with peat or CS, for plant species moderately tolerant to salinity. For salt-sensitive species such as Gaillardia, adequate substrates for plant development were found for C_1 at up to 50% with peat or CS, but the use of C_2 should be limited to 25% in mixtures with peat or CS.

Considering the use of compost in substrate preparation, the EC is the main factor which can limit their use and the presence of certain anions such as chloride should be minimized to avoid phytotoxic effects.

ACKNOWLEDGMENTS

The authors wish to thank the council of ornamental plants and flower of north of Iran for financial supporting this work and Dr. A.M. Mahdavi Damghani for the English revision.

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