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Effects of Organic Waste Substrates on the Growth of Impatiens

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Abstract: The use of peat and peat substitute organic wastes as substrates for container-grown flowers was studied. Peat, hazelnut husk, and maize straw were considered as support materials and MSWC (municipal solid waste compost) and poultry manure as fertilizer supplements. Eight substrates were prepared by combining each additive with peat, hazelnut husk, and maize straw. Hazelnut husk and maize straw substitution by 50% and compost and poultry manure addition by 25% in peat exhibited acceptable physical and chemical properties that are important for container substrates. Nitrogen provided by the compost and poultry manure influenced plant growth and flowering. The lowest rate of plant growth was obtained with commercial peat, while the highest was obtained with peat+maize straw+poultry manure. The presence of compost in the substrate produced fewer flowers per plant even though the plants had a similar vegetative frame, and fresh and dry mass. Higher electrical conductivity (EC) of the substrate and lower nitrogen content in peat+MSWC and peat+hazelnut husk+MSWC reduced the number of flowers per plant more than the control did. On the other hand, plants in commercial peat flowered abundantly at the beginning of season, while plants in the substrate with MSWC and poultry manure added flowered 1 or 2 weeks later and had a longer abundant flowering period. Our results suggest that it is possible to use organic materials, such as those we tested, as an alternative growing media component to peat.

Key Words: Organic waste container substrate, municipal solid waste compost, poultry manure, impatiens

Organik Atıklardan Hazırlanan Yetiştirme Ortamlarının Impatiens Bitkisine Etkisi

Özet: Saksıda yetiştirilen çiçekler için yetiştirme ortamı olarak torf ve torf yerine kullanılabilecek organik atıkların denendiği çalışmada, torf, fındık zürufu ve mısır sapı ana bileşen, kentsel katı atık kompostu ve tavuk gübresi gübre sağlayıcı olarak denenmiştir. Kentsel katı atık kompostu ve tavuk gübresi, torf, fındık zürufu ve mısır samanı ile karıştırılarak 9 farklı yetiştirme ortamı hazırlanmıştır. Torfa % 50 oranında fındık zürufu ve mısır samanı ile % 25 oranında kompost ve tavuk gübresi karıştırılması yetiştirme ortamları için gerekli fiziksel ve kimyasal özelikleri sağlamıştır. Kompost ve tavuk gübresinin sağladığı besin elementleri, özelikle azot, bitki büyümesi ve çiçeklenmesini pozitif etkilemiştir. En düşük bitki gelişimi torfta tespit edilirken, en yüksek bitki gelişimini torf+mısır sapı+tavuk gübresi kombinasyonu sağlamıştır. Bitki büyüklüğü, yaş ve kuru ağırlığı aynı olmasına rağmen kompost eklenen karışımlarda çiçek sayısı daha düşük olmuştur. Torf+kompost ve torf+fındık zürufu+kompost karışımlarında, yüksek EC ve düşük azot kapsamı nedeniyle, bitkide çiçek sayısı kontrolden de daha düşük gerçekleşmiştir. Diğer yandan, torfta yetiştirilen bitkiler erken dönemde en yüksek oranda çiçeklenme gösterirken, kompost ve tavuk gübresi eklenmiş karışımlarda çiçeklenme 1-2 hafta daha geç başlamış, fakat bol çiçeklenme periyodu uzamıştır. Sonuçlar, çalışmada kullanılan organik materyallerin alternatif olarak torf yerine kullanılabileceğini göstermektedir.

Anahtar Sözcükler: Organik atık; yetiştirme ortamı; MSW kompost, tavuk gübresi, Impatiens

Introduction

For sustainability of the environment, organic materials from municipal and industrial waste, as well as residues from agriculture, forestry, green areas, and livestock farming are strongly recommended for use as renewable resources that mitigate their negative impact on regional and global environmental degradation. One sustainable solution for cleaner, safer, and more eco-efficient use of wastes is recycling agricultural waste. For a sustainable solution, many countries have tried recycling nutrients and improving soil characteristics for both agricultural and horticultural purposes. Decreasing peat reserves and environmental constraints due to its excavation encourage the use of renewable resources in agricultural processes.

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The availability and cost of growing media is a primary concern in the production of container-grown plants. The most widely used growing substrate, peat, is a non-renewable resource, and new peat substitutes are searched for worldwide. While peat and mixes are the industrial standard, various alternative waste materials, such as coir, yard waste, olive mill, grape marc, and biosolids continue to be evaluated for use as container media components, to help reduce media costs. Now, various formulations of alternative growing media for bedding and potting flowers are being developed and effectively used in many production systems as container substrate (Abad et al., 2001). These materials are usually composted before use and generally have favorable results with container-grown plants (Ingelmo et al., 1998; Riberio et al., 2000; Garcia-Gomez et al., 2002).

The physical and chemical properties of substrates are responsible for providing adequate support and a reservoir for plant water and nutrients. The incorporation of locally available organic materials to reduce peat and fertilizer usage, without reducing plant quality, is the most important challenge faced by the bedding flower industry. Studies have indicated that various sources and forms of composted and raw wastes can be used effectively as organic support media, a fertilizer source with reduced cost (Ingelmo et al., 1998; Riberio et al., 2000; Garcia-Gomez et al., 2002; Marfa et al., 2002).

Hazelnut husk (H), maize straw (M), and poultry manure (PM) are inexpensive materials that are available locally in large quantities for container growers; however, beneficial use of these raw materials is limited. In this paper, an attempt was made to examine the use of H and M as peat substitutes and the effects of the addition of municipal solid waste compost (MSWC) and PM on the growth of potted impatiens. We also aimed to assist growers in selecting container media based on media parameters and plant growth.

Materials and Methods

The materials used in the substrate mixes were peat (P), decomposed H, composted M, MSWC, and matured PM. Chemical properties of these materials are presented in Table 1. P, H, and M were considered as media, whereas MSWC and PM were used as fertilizer additives. Eight substrates were then prepared from different combinations of media and additives (Table 2), each containing 75% media and 25% fertilizer additives. Commercial P was tested as a control. Natural H was collected from a dump and then ground in a crushing machine before use. M was harvested with a silage thresher and composted for 1.5 years. One-year-old PM containing rice hull was collected from a local poultry producer. MSWC was obtained from the İstanbul

Table 1. Chemical properties of growing media components used in the study.

	Peat	Maize straw	Hazelnut husk	Municipal solid waste compost	Poultry manure
Organic matter (%)	79.0	68.2	73.7	43.7	72.5
Total N (%)	1.50	1.24	1.33	1.95	2.92
P (mg kg^{-1})	250	828	592	710	18,400
K (mg kg^{-1})	350	1270	10,344	5120	23,000
C/N	31	32	32	13	14
Cu (mg kg^{-1})	-*	-	-	403	-
Zn (mg kg^{-1})	-	-	-	985	-
Cr (mg kg^{-1})	-	-	-	243	-
Ni (mg kg^{-1})	-	-	-	94	-
Pb (mg kg^{-1})	-	-	-	255	-
pH	4.88	5.86	7.42	7.56	6.48
EC µS cm^{-1}	3190	814	756	7610	2423

* not determined

Table. 2. Physical characteristics of the substrates prepared from peat and different organic wastes.
P: peat, H: hazelnut husk, M: maize straw, PM: poultry manure, MSWC: municipal solid waste compost.

Substrates	Bulk density ($g\ cm^{-3}$)	Particle density ($g\ cm^{-3}$)	Porosity (% v/v)	Air capacity (% v/v)	Water-holding capacity ($ml\ l^{-1}$)
Acceptable range[a]	< 40	1.4-2.0	> 85	20-30	600-1000
P, 100%	0.26 c	1.650 f	84.08 bc	36.38 b	477 d
P+PM (3:1 v/v)	0.27 c	1.674 ef	84.08 bc	38.28 b	458 d
P+MSWC (3:1 v/v)	0.33 a	1.733 bc	80.69 d	30.69 d	500 c
P+H+PM (1:2:1 v/v)	0.20 d	1.768 ab	88.69 a	41.47 a	472 d
P+H+MSWC (1:2:1 v/v)	0.32 ab	1.787 a	82.00 bcd	35.39 bc	466 d
P+M+PM (1:2:1 v/v)	0.21 d	1.726 cd	88.27 a	32.93 cd	553 b
P+M+MSWC (1:2:1 v/v)	0.33 a	1.791 a	81.57 cd	25.25 e	563 b
H+M+PM (1.5:1.5:1 v/v)	0.20 d	1.693 e	88.90 a	32.47 cd	557 b
H+M+MSWC (1.5:1.5:1 v/v)	0.27 c	1.766 de	84.71 ab	26.25 e	585 a
ANOVA	**	**	**	**	**
LSD	0.01288	0.04074	3.082	3.000	18.79

[a] Abad et al. (2001).
***, **, *: Significant at P < 0.001, 0.01, and 0.05, respectively. LSD: Least significant difference. Values followed by the same letter are not significantly different according to Duncan's multiple range test at P < 0.05.

municipal composting facility. Commercial P containing 15% (w/w) perlite was purchased from a local dealer.

Impatiens wallerana (common impatiens) was chosen as the test plant because it is nitrogen-demanding, fast-growing, and easy to grow in pots, and is a popular bedding plant throughout Turkey. The seeds of impatiens were sown in germination trays containing prepared substrate mixes on April 15. Seeded trays were irrigated with water-diluted fungicide and covered with a layer of clear plastic to maintain moisture. The seedlings were transplanted when they had formed the first set of true leaves, on May 10, into pots (0.5 l) containing the same mix that was used in sowing. After transplanting, pots were irrigated with water-diluted fungicide and placed in a polyethylene-covered greenhouse. The experiment used a completely randomized design with 5 replications of each prepared substrate. Pots were transferred outdoors on May 25 and the plants were raised in a saran covered structure with 30% shade. Plants were irrigated daily with spring water to field capacity, avoiding excess leaching. During the experiment, no additional fertilization was carried out.

The number of flowers per plant was recorded daily. The experiment was terminated on September 28, 2003, 140 days after transplanting. At the end of the experiment, plant height (from the stem base to the inflorescence tip), fresh weight, and number of branches per plant were recorded for each pot. The fresh shoots were then dried in an oven at 78 °C until a constant weight was obtained, and dry mass was determined. Chemical analyses were carried out on whole dried plant (leaves, stems, and flowers) samples.

Physical properties of mixtures were determined according to Verdonck and Gabriels (1992), with 2 duplicates of 5 replications. pH and electrical conductivity (EC) were measured in a 1:10 water-soluble extract (w/v). Total organic matter (OM) of the prepared growing medium was determined after samples were ashed at 550 °C. Nitrogen in substrates and plant material was determined by Kjeldahl digestion. Zinc, copper, chromium, nickel, and lead in MSWC samples were determined by atomic absorption spectrophotometry. Media shrinkage was determined by measuring the difference between the initial media height and the final media height.

The statistical significance of results obtained was assessed with one-way ANOVA analysis, followed by the Duncan multiple range test; P < 0.05 was considered significant. A simple linear correlation was used to test the significance of the relationship.

Results and Discussion

The main physicochemical characteristics of the substrates prepared are presented in Tables 2 and 3. There were significant statistical differences between the mixes for all properties measured in this study. Physical and chemical properties of the substrates were dependent on both media additives and proportional mix.

Bulk density and particle density of the substrates containing MSWC were higher than that of the substrates containing PM and the control (Table 2) because of the higher inorganic content of MSWC, but were still within the acceptable range proposed by Bunt (1988). Substrates containing PM resulted in higher porosity and air capacity (Table 2) than the established limits for an ideal substrate (Abad et al., 2001) because it contained rice hull. Mixing MSWC with media improved its air capacity to values within the acceptable range, but decreased the total porosity in some mixtures below the optimum, such as P+MSWC, P+M+MSWC, and P+H+MSWC (Table 2). The decrease in porosity with MSWC addition was also reported by other authors (Ingelmo et al., 1998; Guerreo et al., 2002). Of the tested mixes, the highest water holding capacity was recorded for H+M+MSWC, and the lowest was for P+PM (Table 2). Replacement of P by 50% H in the growing medium decreased the water holding capacity to below optimum, but the difference between it and the control was not significant (Table 2). On the other hand, replacement of P by 50% M improved the water holding capacity of the substrates.

EC increased with MSWC and PM addition to the mixtures as compared to the control (Table 3), except when P was 100% replaced by H and M, indicating the contribution of P to elevated EC. In contrast, H and M stabilized EC because of their low initial EC levels. It is reported that native P has some quality problems, such as salinity and high pH (Çaycı et al., 1989). Substrates' pHs were normal for the container substrate (Abad et al., 2001).

The highest value of total organic matter content was recorded in the control, whereas the other mixes recorded comparatively lower values (Table 3). In the P substitute substrates, PM slightly increased the total organic matter content as compared to MSWC, but values were still below the optimum level. The substrate nitrogen content was obviously increased by the addition of PM, as expected, and the maximum value was recorded for the P+M+PM mixture (Table 3). Significant media

Table. 3. Physicochemical characteristics of the substrates prepared from P and different organic wastes. For abbreviations see legend of Table 2.

Substrates	pH	EC dS m^{-1}	Organic material (%)	Total N (%)	Shrinkage
Acceptable range[a]	5.2-6.5	0.75-3.49	> 80		
Peat, 100%	4.88 f	3.19 e	79 a	1.49 f	1.62 a
P+PM (3:1 v/v)	5.42 e	3.62 c	76 b	1.81 d	1.52 a
P+MSWC (3:1 v/v)	6.16 d	4.95 a	69 e	1.47 f	1.52 a
P+H+PM (1:2:1 v/v)	6.65 c	3.33 d	65 f	2.08 c	1.06 bc
P+H+MSWC (1:2:1 v/v)	6.81 ab	4.05 b	63 g	1.51 f	1.08 bc
P+M+PM (1:2:1 v/v)	6.66 c	3.24 e	70 d	2.54 a	1.14 b
P+M+MSWC (1:2:1 v/v)	6.73 bc	3.25 e	63 g	1.72 de	0.88 bc
H+M+PM (1.5:1.5:1 v/v)	6.88 a	2.46 f	74 c	2.44 b	0.84 c
H:M:MSWC (1.5:1.5:1 v/v)	6.72 bc	2.41 f	65 f	1.63 e	0.90 bc
ANOVA	**	**	**	***	**
LSD	0.1152	0.0576	0.9979	0.09979	0.2444

[a] Abad et al. (2001).

***, **, *: Significant at $P < 0.001$, 0.01, and 0.05, respectively. LSD: Least significant difference. Values followed by the same letter are not significantly different according to Duncan's multiple range test at $P < 0.05$.

shrinkage was noted after 5 months of production. The maximum shrinkage was recorded for P and the minimum was recorded for P+H+PM (Table 3). In general, proportional mixes of the materials exhibited acceptable physical and chemical properties for container substrates (Table 3).

Plant size varied significantly among the different mixtures (Table 4). The lowest fresh and dry weight was obtained from the commercial P substrate and the highest was from the P+M+PM mixture, as presented in Table 4. Variability in fresh and dry mass resulted mainly from plant height, even though the branches per plant were not significantly different. The commercial P without fertilizer addition did not satisfy the nutritional demand for optimum growth. Both PM and MSWC added to P doubled the fresh and dry mass. H added to P performed similarly to P, but the addition of M returned better results in terms of plant height, and fresh and dry weight. Higher nitrogen concentration in growing media was positively reflected in plant height, fresh weight, and dry weight ($r = 0.577$, 0.743, and 0.711, respectively). Thus, PM added to the mixes had a more profound effect on increasing plant growth than MSWC, in each combination. The M+PM combination gave substantially higher fresh and dry weights. The higher organic material and nitrogen content, and easy mineralization of nitrogen in PM and M might have been responsible for such a positive response (Berna et al., 1988; Adegbidi and Briggs, 2003).

MSWC and PM added to mixes increased the nitrogen concentration in plants more than the control, but the PM+M combination had a greater effect than the MSWC and H mixes (Table 4). Impatiens is known to respond greatly to nitrogen and its growth is determined mostly by substrate and tissue nitrogen concentration. Phosphorus and potassium in substrate or shoot tissue had little or no effect on shoot growth (Van Iersel et al., 1999). The required optimum tissue nitrogen concentration for impatiens ranges from 28 to 40 mg g^{-1} (Van Iersel et al., 1999). In the present study, tissue nitrogen concentrations were below the optimum levels for impatiens. These low values could be attributed to the fact that the nitrogen analysis was performed at the end of active plant growth. Plants in P exhibited nutrient deficiencies 2 months after transplanting, while MSWC and PM acted as slow-release fertilizers, and plants grown in these substrates produced larger canopies and exhibited less nutrient deficiency symptoms at the end of the study. This may have been due to the fact that organic nutrient sources in the growing medium remained present for a longer period and supplied substantial amounts of nutrients to the plants. Even though the initial

Table 4. Effect of different growing media on the growth of Impatiens (5 plants per treatment). For abbreviations see legend of Table 2.

	Plant height (cm)	Number of Branches ($plant^{-1}$)	Fresh weight (g $plant^{-1}$)	Dry weight (g $plant^{-1}$)	Flower number ($plant^{-1}$)	Nitrogen content (g kg^{-1})
Peat, 100%	13.40 c	14.0	6.88 e	0.622 d	74 f	12.69 c
P+PM (3:1 v/v)	15.8 b	13.2	17.38 cd	1.193 c	115 c	20.89 a
P+MSWC (3:1 v/v)	14.8 bc	12.8	14.46 d	1.109 c	63 g	15.85 b
P+H+PM (1:2:1 v/v)	15.0 bc	15.6	19.18 cd	1.235 c	86 e	16.01 b
P+H+MSWC (1:2:1 v/v)	15.0 bc	10.8	16.70 d	1.153 c	61 g	12.83 c
P+M+PM (1:2:1 v/v)	18.6 a	14.4	36.30 a	2.137 a	131 a	19.41 a
P+M+MSWC (1:2:1 v/v)	17.8 a	13.6	27.08 b	1.683 b	93 d	18.36 ab
H+M+PM (1.5:1.5:1 v/v)	19.4 a	13.4	30.98 b	1.725 b	123 b	19.98 a
H+M+MSWC (1.5:1.5:1 v/v)	18.0 a	12.8	22.24 c	1.252 c	76 f	15.79 b
ANOVA	***	NS	***	***	***	***
LSD	1.595		4.628	0.2822	2.967	2.664

***, **, *: Significant at $P < 0.001$, 0.01, and 0.05, respectively. LSD: Least significant difference. Values followed by the same letter are not significantly different according to Duncan's multiple range test at $P < 0.05$.

substrate nitrogen concentration was similar to commercial P, P+MSWC, and P+H+MSWC, the nitrogen in P was a mineral form and it was consumed or lost during the early plant growth period. Thus, P without additional fertilization did not support long-term optimum plant growth. Nitrogen is required in large quantities by plants and is easily leached during irrigation, making it the most difficult nutrient to manage in container production systems.

The number of flowers per plant varied significantly among the mixtures (Table 4). MSWC in mixes produced fewer flowers per plant even though the plants were in a similar vegetative frame, and had similar fresh and dry mass, and general appearance (P+MSWC, P+H+MSWC, and H+M+MSWC). The number of flowers per plant for P+MSWC and P+H+MSWC was even lower than that of the control. This can be attributed to the higher EC in MSWC substrates, which is concordant with previous research (Riberio et al., 2000; Garcia-Gomez et al., 2002; Wilson et al., 2002). PM increased the number of flowers per plant and the increase was more apparent with M mixes (Table 4). The higher nitrogen release rate of PM (Adegbidi and Briggs, 2003) and steady decomposing of M (Bernai et al., 1988) could be a reason for the high levels of nitrogen, both in substrates and plant samples, and the higher number of flowers per plant as compared to H. Flowering pattern varied according to mixture. Plants in commercial P flowered abundantly at the beginning of the season, while plants in MSWC and PM flowered 1 or 2 weeks later. The duration of the abundant flowering period was significantly longer in MSWC and PM substrates (Figure 1), and most probably resulted from the steady release of nutrients from organic materials to the benefit of the plants. These plants also produced more dry weight and positively correlated with flower number (r = 0.675).

In our previous observations, the addition of 50% MSWC to soil reduced the infiltration rate caused by water lodging and soil compaction that depressed the plant growth (Ozdemir et al., 2004). In the present study, water lodging, soil compaction, and depressed plant growth were not observed, but still the number of

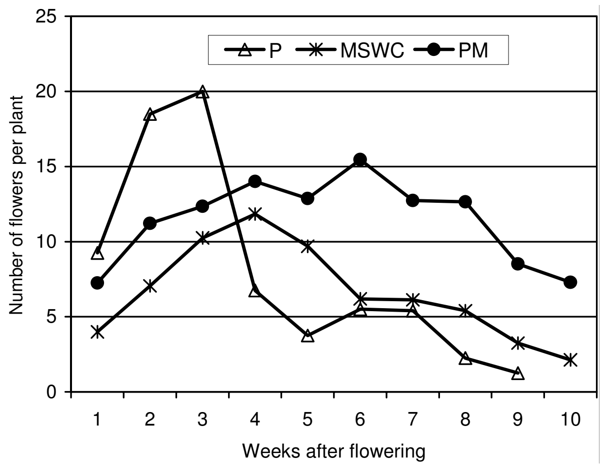

Figure 1. Number of flowers produced by impatiens grown in commercial P, MSWC, and PM during the flowering period. For abbreviations see legend of Table 2.

flowers per plant was significantly lower. Toxic minerals combined with elevated substrate EC could be the cause of reduced flower number (Eklind et al., 1998; Kuehny and Morales, 1998; Wilson et al., 2002). When substrate EC was reduced to an acceptable range with the MSWC+M combination (Table 3), the number of flowers increased, but was still lower than that of the PM analogue (Table 4). These results suggest that substrate nitrogen is relevant to improvement of both plant growth and flower development (Lang and Pannkuk, 1998), regardless of EC. The correlation between the number of flowers and substrate nitrogen concentration (r = 0.858) was higher than that of the number of flowers and substrate EC (r = –0.460).

Comparing the physical and physicochemical properties, and plant growth and development of H- and M-based substrates to the P-based medium, these materials appear to be promising growing media components for container-grown ornamental plants. Furthermore, PM and MSWC could be alternative slow-release nutrient sources for container-grown ornamental plants that improve plant vigor and appearance. However, EC of MSWC must be taken into consideration before using it in container substrates.

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