

Effects of different potting growing media for *Petunia grandiflora* and *Nicotiana alata* Link & Otto on photosynthetic capacity, leaf area, and flowering potential

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Petunia grandiflora Juss. and *Nicotiana alata* Link & Otto are two of the most widely spread plants on the market for annual potted ornamental plants. In order to identify the most adequate substrate formula we analyzed the effects of different potting growing media used for *P. hybrida grandiflora* 'Bravo' and *N. alata* 'Dinamo' on their photosynthetic capacity, leaf area, and flowering potential. Optimization of growing media formula for petunia and ornamental tobacco was performed by preparing four growing media mixing fallow soil (FS), Biolan peat (BP), acid peat (AP), leaf compost (C), and perlite (P) in different proportions. The physiological potential of petunia and ornamental tobacco was investigated by photosynthesis and respiration rate and chlorophyll pigments in leaves, while the vegetative and flowering phenological stages were evaluated by number of leaves per plant, leaf area, number of flowers per plant and leaf area/flowers ratio. These measurements were significantly influenced by the different potting growing media used in this study. In the flowering stage, the highest photosynthesis rates ($8.612 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) as well as leaf area (1.766 dm^2) of petunias were obtained on growing media with 60% biolan peat, 30% acid peat and 10% perlite (BP60-AP30-P10). Flowering responses to growing conditions vary greatly among plants and the biggest number of ornamental tobacco flowers (22 flowers plant⁻¹) was registered as an effect of BP60-AP30-P10 media. Growing media with the BP60-AP30-P10 formula seem to be the most adequate growth substrate to develop profitable crops for petunias and ornamental tobacco with high decorative value.

Key words: Flowering potential, growth substrate, photosynthesis.

INTRODUCTION

In recent years, in Romania, *Petunia grandiflora* Juss. and *Nicotiana alata* Link & Otto have become popular annual bedding ornamental plants and economically profitable potted plants cultivated in different growth substrates in greenhouses. Petunias belong to the Solanaceae family and are used in landscape, private garden, and building decoration (Dole and Wilkins, 2004; Arancon et al., 2008; Francescangeli and Zagabria, 2008; Xu et al., 2010), pharmaceutical and cosmetics industry, and phytoremediation (Watharkar et al., 2013). *Nicotiana alata* (ornamental tobacco) has a good potential for commercial horticulture and is also used in pharmacy or to provide antifungal substances for pathogens control (Gaspar et al., 2014). In Romania the demand for annual ornamental plants is increasing.

Numerous studies in petunia species have been described previously. Warner (2010) documented in a greenhouse the influence of temperature and photoperiod on flowering and morphology of petunias. Gerats and

Vandenbussche (2005) noted that petunias are often used for physiological studies because these annual plants are characterized by a short life cycle, color diversity, compact plant size, and relatively easy growth. Flowering capacity of petunia plants can be influenced by breeding and cultivation technology (Nishijima et al., 2006).

Zhanga et al. (2012) reported that the optimization of nutrient uptake and the influence of environmental factors are necessary to apply efficient cultural management for plant growth and development of petunia production. Growers typically use peat, perlite, vermiculite, sand, fallow land, and various organic and inorganic composted materials to prepare nutritious mixtures for floricultural plant production. Currently, in the entire world, different composting technologies are used for plant production; these are based on several types of wastes such as: municipal organic waste, sewage sludge, agricultural waste, animal manures, and some sorts of industrial waste (Castaldi et al., 2005; Tognetti et al., 2007; Hernández et al., 2010; Ntoulas et al., 2011). Humic acids are one of the natural organic compounds from the soil or composted materials which are included in growth substrates to increase substrate fertility, growth and yield for horticultural crops (Atiyeh et al., 2002; Arancon et al., 2006; Campitelli and Ceppi, 2008; Ahmad et al., 2013).

Arancon et al. (2008) studied the effects of different substitution rates for three types of vermicomposts

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(produced from cattle manure, food waste, and paper waste) on the germination, growth, and flowering of petunias in a soilless growth medium. Soilless growing media preparation from different organic materials and waste components is promoted as an alternative to agricultural land and as a way to eliminate the environmental impact of wastes (Garcia-Gomez et al., 2002; Di Benedetto et al., 2006; Civeira, 2010).

The production of potted ornamental plants is greatly influenced especially by growth medium components prepared in different proportions. The majority of ornamental plants are cultivated in greenhouses in growth substrates which usually contain different types of peat and perlite.

The purpose of this study was to evaluate the effect of some organic growth components used in commercial potting substrates for two popular ornamental plants: *Petunia grandiflora* and *Nicotiana glauca*. In this paper we performed a comparative analysis of the influence of peat, leaf compost, perlite, and fallow land prepared in different proportions and compositions on plant growth and development. The current study aimed to explain the effect of growing media on these aspects by analyzing some physiological parameters, leaf area, and flowering potential of *P. grandiflora* and *N. glauca*. In this experiment we optimized the growth substrate composition of *P. grandiflora* and *N. glauca* in order to provide good agricultural practices to ornamental plant producers.

MATERIALS AND METHODS

Plant material and culture conditions

The study was conducted at the laboratories and greenhouse of the University of Pitesti, Pitesti, Romania. The plant material tested and evaluated in this research were two annual Solanaceae ornamental potted plants: *Petunia grandiflora* Juss. 'Bravo' and *Nicotiana glauca* Link & Otto 'Dinamo'. The cultivars were selected from the potted plants on the Romanian flower market, based on their popularity, availability, ornamental value, and commercial profitability. The chosen cultivars are characterized by flowering precocity, relatively compact size, uniformity and diversity of flower color, and abundance of flowers.

Several types of organic or inorganic materials such as biolan peat, acid peat, leaf compost, perlite, and fallow soil were evaluated as growing media components for ornamental plants. It is important to select an adequate growing medium to provide an essential tool for managing ornamental potted plants. Four growth substrates were prepared by mixing these growing media components in different proportions: 100% fallow soil (FS100); 30% biolan peat + 60% acid peat + 10% perlite (BP30-AP60-P10); 60% biolan peat + 30% acid peat + 10% perlite (BP60-AP30-P10); and 33% biolan peat + 33% leaf compost + 33% perlite (BP33-C33-P33).

Leaf compost is an organic product with a pH around 7 prepared by fermentation of plant debris from gardens and deciduous forests. Acid peat (Klasmann Baltica, Klasmann-Deilmann GmbH, Geeste, Germany) has a pH around 4.2 and biolan peat is a natural resource usually with a pH around 6 (Biolan Oy, Kauttua, Finland). In Romania, fallow soil is often used as a component for growth substrates in horticulture and it is obtained from the top layer of soil on fallow land with perennial grasses. In order to stimulate rooting system development of each plant in the growth medium, the fertilizer Osmocote Exact (The Scotts Company Ltd., Godalming, Surrey, UK) was added when planting cuttings. Cuttings from selected cultivars were planted in plastic pots (1 plant pot⁻¹) with a diameter of 12 cm. The growing temperature in the greenhouse was 24 ± 2 °C. In this study we used leaf compost and fallow soil from private household, while acid peat and biolan peat are natural resources provided by Klasmann-Deilmann and Biolan companies. In a factorial experimental design four horticultural growing media containing peat, leaf compost, perlite, and fallow land in different proportions and compositions were considered as treatments. The experiment was set according to a randomized complete block design with four treatments and five replicates, and a pot was the experimental unit for a total of 20 units for each studied species. Each replication consisted of one plant per pot.

Measurements

Photosynthetic capacity is an important indicator that explains the physiological activity of plants and the potential for vegetative development. As regards the assessment of the growth medium influence on plant physiological activity, we determined the effect of photosynthesis ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) and the respiration rate ($\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) in leaves, the content of chlorophyll a (Chl a, mg g^{-1}) and chlorophyll b (Chl b, mg g^{-1}), the Chl a/Chl b ratio in leaves, total leaf chlorophyll content (mg g^{-1}), carotenoids (Car, mg g^{-1}), and the Chl a+b/Car ratio in leaves.

Leaf gas exchange parameters were measured with a portable plant CO₂ analysis package (S151 Infrared CO₂ analyzer, Qubit Biology Inc., Ontario, Canada). Photosynthesis was measured in attached leaves maintained in an assimilation chamber. The CO₂ concentration was measured with an infrared gas analyzer (IRGA). The difference between the initial CO₂ concentration in the air and that in the air of the leaf chamber is used to measure the rate of photosynthesis. During testing, photosynthetic photon flux density (PPFD) was 1800 $\mu\text{mol m}^{-2} \text{ s}^{-1}$, air temperature was 24 ± 2 °C, and ambient relative humidity was between 60% and 65%. Photosynthesis and respiration rates were expressed as $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$.

Leaves were collected in early morning, and transported in an ice box to the laboratory for later determinations of

assimilatory pigments content. Photosynthetic pigments were extracted in 80% acetone. Absorbance at 662, 646, and 440.5 nm was determined using a BOECO S-20VIS spectrophotometer (Boeckel & Co, Hamburg, Germany). The amounts of chlorophyll and carotenoid pigments were calculated using Holm's formulas (Holm, 1954):

$$\text{Chl a} = 9.78 A_{662} - 0.99 A_{644}$$

$$\text{Chl b} = 21.4 A_{644} - 4.65 A_{662}$$

$$\text{Car} = 4.69 A_{440.5} - 0.267 (\text{Chl a} + \text{Chl b})$$

The total chlorophyll content was calculated as the sum of Chl a and Chl b. The results are obtained as mg pigments g⁻¹ FW.

The effect of the growth substrates was also evaluated by counting number of leaves per each plant. The measurements for photosynthetic capacity, number of leaves, and leaf area were calculated at two major phenophases of plant life-cycle according to the BBCH scale (Meier, 2001): leafing stage and flowering stage. The influence of growth substrates on flowering potential was analyzed by counting number of flowers per plant and leaf area/flowers ratio. The measurements in the growth stage were made 4 wk after planting while measurements in the flowering stage were recorded when plants gained ornamental value for selling, 12 wk after planting.

Statistical analysis

A statistical analysis was performed using the ANOVA in the SPSS 16.0 software (IBM Corporation, Armonk, New York, USA) and means were compared using Duncan's multiple range tests at 5% level. The results of this study are expressed as mean.

RESULTS

The results of the analysis regarding the effects produced by the growth substrates of 'Bravo' and 'Dinamo' on photosynthesis and respiration rate are presented in Table 1. Petunias and ornamental tobacco grown in media with 100% fallow soil had the lowest respiration and photosynthesis rates for both leafing and flowering stages. The respiration and photosynthesis rates for both petunias

and ornamental tobacco were greatly influenced by the growth substrate with the BP60-AP30-P10 formula. No significant differences regarding the respiration rate of petunias were found between the BP60-AP30-P10 and BP33-C33-P33 media in the flowering stage. The photosynthesis process in the flowering stage for 'Dinamo' showed significant differences between all growth media (Table 1).

Growth substrates used for *P. grandiflora* 'Bravo' and *N. alata* 'Dinamo' did not show significant differences in terms of Chl a and Chl b content between the BP30-AP60-P10, BP60-AP30-P10, and BP33-C33-P33 media (Table 2). The chlorophyll content increased with increasing amount of biolan peat and was negatively influenced by FS100 media. In this study, for both ornamental species, the content of chlorophyll a and b was higher in the flowering stage of the plants. The Chl a/Chl b ratio in leaves of petunias was enhanced by the medium containing FS100, while the Chl a/Chl b ratio in ornamental tobacco showed higher values in growth media with different proportions of peat (Table 2).

The growth substrates used in this study had a higher effect at flowering stage than leafing stage for total leaf chlorophyll content for both petunia and ornamental tobacco plants (Table 3). Total leaf chlorophyll content

Table 1. Effect of growth substrate on photosynthesis and respiration rate in leaves of *Petunia grandiflora* 'Bravo' and *Nicotiana alata* 'Dinamo'.

Cultivars	Growth substrates	Photosynthesis rate		Respiration rate	
		Leafing stage	Flowering stage	Leafing stage	Flowering stage
		μmol CO ₂ m ⁻² s ⁻¹		μmol CO ₂ m ⁻² s ⁻¹	
<i>Petunia grandiflora</i> 'Bravo'	FS100	3.008c	3.105d	0.812c	1.005c
	BP30-AP60-P10	5.114b	7.125c	1.815b	2.104b
	BP60-AP30-P10	7.505a	8.612a	2.442a	3.125a
	BP33-C33-P33	6.122b	8.005b	1.912b	2.845a
<i>Nicotiana alata</i> 'Dinamo'	FS100	2.881c	3.002d	0.618c	1.125d
	BP30-AP60-P10	4.138b	6.445c	1.613b	2.004c
	BP60-AP30-P10	7.722a	8.851a	2.660a	3.425a
	BP33-C33-P33	6.551b	8.105b	1.885b	2.704b

Mean values followed by the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$).

FS100: 100% fallow soil; BP30-AP60-P10: 30% biolan peat + 60% acid peat + 10% perlite; BP60-AP30-P10: 60% biolan peat + 30% acid peat + 10% perlite; and BP33-C33-P33: 33% biolan peat + 33% leaf compost + 33% perlite.

Table 2. Effect of growth substrate on chlorophyll a, chlorophyll b, and Chl a/Chl b ratio in leaves of *Petunia grandiflora* 'Bravo' and *Nicotiana alata* 'Dinamo'.

Cultivars	Growth substrates	Chlorophyll a		Chlorophyll b		Chl a/Chl b ratio	
		Leafing stage	Flowering stage	Leafing stage	Flowering stage	Leafing stage	Flowering stage
		mg g ⁻¹					
<i>Petunia grandiflora</i> 'Bravo'	FS100	6.108b	6.812b	2.871b	2.912b	2.127a	2.339a
	BP30-AP60-P10	8.516a	10.005a	4.009a	4.506a	2.124a	2.220b
	BP60-AP30-P10	8.646a	10.105a	4.105a	4.668a	2.106a	2.164b
	BP33-C33-P33	8.012a	9.814a	4.200a	4.738a	1.907b	2.071c
<i>Nicotiana alata</i> 'Dinamo'	FS100	4.238b	4.844b	1.902b	1.998b	2.228a	2.424b
	BP30-AP60-P10	6.226a	9.014a	3.216a	3.412a	1.935c	2.641a
	BP60-AP30-P10	6.425a	9.221a	3.142a	3.514a	2.044b	2.624a
	BP33-C33-P33	6.315a	9.012a	3.311a	3.662a	1.907c	2.461b

Mean values followed by the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$).

FS100: 100% fallow soil; BP30-AP60-P10: 30% biolan peat + 60% acid peat + 10% perlite; BP60-AP30-P10: 60% biolan peat + 30% acid peat + 10% perlite; and BP33-C33-P33: 33% biolan peat + 33% leaf compost + 33% perlite.

Table 3. Effect of growth substrate on total leaf chlorophyll content, carotenoids (Car), and Chla+b/Car ratio in the leaves of *Petunia grandiflora* 'Bravo' and *Nicotiana alata* 'Dinamo'.

Cultivars	Growth substrates	Total leaf chlorophyll content		Carotenoids		Chla+b/Car ratio	
		Leafing stage	Flowering stage	Leafing stage	Flowering stage	Leafing stage	Flowering stage
		mg g ⁻¹					
<i>Petunia grandiflora</i> 'Bravo'	FS100	8.979c	9.724c	0.723c	0.965 c	12.419a	10.076a
	BP30-AP60-P10	12.525b	14.511b	1.525b	1.942b	8.213ab	7.472bc
	BP60-AP30-P10	12.751a	14.773a	1.755a	2.214a	7.265b	6.672b
	BP33-C33-P33	12.212b	14.552b	1.612b	2.005b	7.575b	7.257bc
<i>Nicotiana alata</i> 'Dinamo'	FS100	6.140c	6.842c	0.778c	0.884c	7.892a	7.739a
	BP30-AP60-P10	9.442b	12.426b	1.233b	1.667b	7.657a	7.454b
	BP60-AP30-P10	9.567a	12.735a	1.589a	2.103a	6.020b	6.055c
	BP33-C33-P33	9.626a	12.674a	1.491b	1.714b	6.456b	7.394b

Mean values followed by the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$).

FS100: 100% fallow soil; BP30-AP60-P10: 30% biolan peat + 60% acid peat + 10% perlite; BP60-AP30-P10: 60% biolan peat + 30% acid peat + 10% perlite; and BP33-C33-P33: 33% biolan peat + 33% leaf compost + 33% perlite.

of *N. alata* plants cultured in BP60-AP30-P10 and BP33-C33-P33 media did not show any significant differences. Regarding the influence of growth media on carotenoid pigments in the studied species, there were no significant differences between applying BP30-AP60-P10 medium and BP33-C33-P33 medium, but we found significant differences between BP60-AP30-P10 media and all other culture media. The Chla+b/Car ratio measured in leaves of *P. grandiflora* 'Bravo' and *N. alata* 'Dinamo' was higher in the medium FS100; the rate of this indicator was reduced by the presence of the BP60-AP30-P10 medium (Table 3).

The maximum vegetative growth potential showed by number of leaves per plant and leaf area was found in plants grown in media BP60-AP30-P10 (Table 4). *Petunia grandiflora* had the lowest number of leaves and leaf area in growth substrates with fallow soil while the BP60-AP30-P10 medium had the biggest effect. In petunias, no significant differences were found in terms of leaf area in the flowering stages between the BP60-AP30-P10 and BP33-C33-P33 media, while significant differences were showed between the BP30-AP60-P10 and FS100 media (Table 4). The ornamental tobacco plant cultured in the BP60-AP30-P10 medium had a higher foliar area, while the lowest foliar area was induced by the medium with

Table 4. Effect of growth substrate on number of leaves per plant and leaf area of *Petunia grandiflora* 'Bravo' and *Nicotiana alata* 'Dinamo'.

Cultivars	Growth substrates	Number of leaves per plant		Leaf area	
		Leafing stage	Flowering stage	Leafing stage	Flowering stage
		dm ²			
<i>Petunia grandiflora</i> 'Bravo'	FS100	10c	14c	0.154c	0.323c
	BP30-AP60-P10	16b	32b	0.659b	1.318b
	BP60-AP30-P10	20a	40a	1.027a	1.766a
	BP33-C33-P33	19ab	33b	0.761b	1.644a
<i>Nicotiana alata</i> 'Dinamo'	FS100	9c	12c	0.307c	0.527c
	BP30-AP60-P10	15b	23b	0.811b	1.744b
	BP60-AP30-P10	17a	36a	1.087ab	2.345a
	BP33-C33-P33	18a	21b	1.200a	2.238a

Mean values followed by the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$).

FS100: 100% fallow soil; BP30-AP60-P10: 30% biolan peat + 60% acid peat + 10% perlite; BP60-AP30-P10: 60% biolan peat + 30% acid peat + 10% perlite; and BP33-C33-P33: 33% biolan peat + 33% leaf compost + 33% perlite.

fallow soil. Significant differences in leaf area were found between the FS100 and BP30-AP60-P10 at flowering stage of *N. alata*. The bigger number of leaves is directly correlated with the leaf area of petunia and ornamental tobacco in all culture substrates (Table 4).

The BP60-AP30-P10 and BP33-C33-P33 substrates were the most adequate for formation of flowers; growth substrates for *P. grandiflora* 'Bravo' did not show significant differences in number of flowers per plant between the BP30-AP60-P10, BP60-AP30-P10 and BP33-C33-P33 media, while for *N. alata* we did not find significant differences between BP30-AP60-P10 and BP33-C33-P33 media (Table 5).

Leaf area/flowers ratio is an important tool that can characterize the ornamental value and the flowering potential according to the foliar surface of the plant. Analyzing the leaf area/flowers ratio, in this study we observed significant differences between the FS100, BP30-AP60-P10, and BP33-C33-P33 media in the case of *P. grandiflora* 'Bravo'. *Petunia grandiflora* 'Bravo' registered the highest value of leaf area/flowers ratio in the BP33-C33-P33 growing medium and the lowest value in the FS100 growth substrates. Growth substrates with 30% or 60% peat proportion for *P. grandiflora* 'Bravo' did not show significant differences. The higher value of leaf area/flowers ratio was induced by plants of *N. alata* cultured in FS100 media, while the lower value of leaf

Table 5. Effect of growth substrate on number of flowers per plant and leaf area/flowers ratio of *Petunia grandiflora* 'Bravo' and *Nicotiana alata* 'Dinamo'.

Cultivars	Growth substrates	Number of flowers per plant	Leaf area/flowers ratio
<i>Petunia grandiflora</i> 'Bravo'	FS100	2b	0.161c
	BP30-AP60-P10	5a	0.263b
	BP60-AP30-P10	6a	0.294b
	BP33-C33-P33	5a	0.328a
<i>Nicotiana alata</i> 'Dinamo'	FS100	3c	0.175a
	BP30-AP60-P10	12b	0.145ab
	BP60-AP30-P10	22a	0.106c
	BP33-C33-P33	16b	0.139b

Mean values followed by the same letter are not significantly different according to Duncan's multiple range test ($P < 0.05$).

FS100: 100% fallow soil; BP30-AP60-P10: 30% biolan peat + 60% acid peat + 10% perlite; BP60-AP30-P10: 60% biolan peat + 30% acid peat + 10% perlite; and BP33-C33-P33: 33% biolan peat + 33% leaf compost + 33% perlite.

area/flowers ratio was produced by plants of *N. alata* growing in BP60-AP30-P10 media. The FS100, BP60-AP30-P10, and BP33-C33-P33 media had a significant effect on the leaf area/flowers ratio of *N. alata* 'Dinamo' (Table 5).

DISCUSSION

Studies regarding soilless substrates have been performed on many important floricultural plants such as petunias (Arancon et al., 2008), begonias, tagetes (Grigatti et al., 2007), impatiens (Chavez et al., 2008), roses (Nazari et al., 2009), poinsettias (Papafotiou et al., 2004), gladioli (Ahmad et al., 2013) and antirrhinums (Mehmood et al., 2013). Growth substrates influenced the photosynthetic capacity, leaf area, and flowering potential, which play an important role in growth and development processes of plants. A very important aspect in the production of potted ornamental plants is the controlled and induced vegetative and floral growth by horticultural practices. Many studies on the use of organic or inorganic components for enhanced growth in soilless cultures have been reported by researchers (Ribeiro et al., 2007; Zaller, 2007; Arancon et al., 2008; Bustamante et al., 2008; Bachman and Metzger, 2008; Medina et al., 2009; Hernández et al., 2010; Ntoulas et al., 2011). Arancon et al. (2008) reported that petunia seeds germinated faster in growth substrates with larger amounts of vermicomposts. Petunias grown in substitutions of 20%, 30%, and 40% of food waste vermicomposts into a soilless growth medium, in substitutions of 20%, 30%, and 40% cattle manure vermicompost or in a mixture of 40% paper waste vermicompost and 60% commercial soilless growth medium produced significantly more flowers (Arancon et al., 2008). Grigatti et al. (2007) investigated the potential effect of growing substrates with white peat and 25-50-75-100% green waste and sewage sludge (80% + 20% v/v) compost for *Begonia semperflorens* 'Bellavista F1', *Salvia splendens* 'Maestro' and *Tagetepatula × erecta* 'Zenith Lemon Yellow' and noted that the medium with 25% compost produced the highest number of flowers in all the species. Chavez et al. (2008) studied the influence on plant growth of alternative soilless media based on river waste and *Sphagnum* spp. and *Carex* spp. from Argentinean peatlands with different proportions of perlite and vermiculite in *Petunia × hybrida* and *Impatiens wallerana*. They reported that river waste and *Carex* peat are adequate alternatives to *Sphagnum* peat from the Northern Hemisphere to grow high quality plants. The highest dry weight of *I. wallerana* was observed in plants cultured in media containing *Carex* peat (70%) + Perlite (20%) + Vermiculite (10%), while in *Petunia* hybrid, at harvest time (65 d from transplant), the highest dry weight was induced by growing media with *Carex* peat (40%) + river waste (40%) + perlite (10%) + vermiculite (10%) (Chavez et al., 2008).

Medina et al. (2009) showed the possibility of using spent mushroom substrates in the production of horticultural seedlings replacing part of the peat in the growing media. Papafotiou et al. (2005) reported the behavior of *Syngonium podophyllum*, *Codiaeum variegatum* and *Ficus benjamina* on media containing olive-mill waste compost, sphagnum peat, and perlite in different formulas and suggested that olive-mill waste compost can replace 25% of peat in a potting media for *S. podophyllum* and 75% of peat in *C. variegatum* and *F. benjamina*. Benito et al. (2006) evaluated the use of pruning wastes compost for ornamental plants production of *Lolium perenne* L. and *Cupressus sempervirens* L. by preparing six growth substrates containing pruning wastes compost, peat, ground leaves, sand, and spent mushroom compost in different proportions and concluded that the pruning wastes compost could be used as a growing media component. The addition of 10% and 20% vermicompost of pig manure origin into a commercial potting substrate had positive effects in dry shoot tissue and leaf area of marigolds, tomatoes, green peppers, and cornflowers (Bachman and Metzger, 2008).

Four different formula substrates with compost obtained from forestry wastes and solid phase of pig slurry and peat were tested to evaluate the capacity of plant growth media for the production of tomato and lettuce seedlings. The presence of compost contributed to earlier seed emergence; the greatest root dry weight and number of leaves occurred on media with 100% compost obtained from forestry wastes and solid phase of pig slurry substrate (Ribeiro et al., 2007).

CONCLUSIONS

The growth substrates used in this study influenced physiological parameters, vegetative and flowering phenological stages, flowering precocity and ornamental value. In this research we found a positive correlation between the number of flowers and the leaf area. The parameters studied were significantly influenced by the type of growing components and the proportion in the mixture. Petunia and ornamental tobacco plants grown in media with 60% biolan peat, 30% acid peat and 10% perlite seem to be high-value ornamental plants, while the value of the plants cultured in media containing fallow soil is too low to be profitable.

LITERATURE CITED

- Ahmad, I., R.U. Saquib, M. Qasim, M. Saleem, A.S. Khan, and M. Yaseen. 2013. Humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. *Chilean Journal of Agricultural Research* 73:339-344.
- Arancon, N.Q., C.A. Edwards, A. Babenko, J. Cannon, P. Galvis, and J.D. Metzger. 2008. Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Applied Soil Ecology* 39:91-99.

- Arancon, N.Q., C.A. Edwards, S. Lee, and R. Byrne. 2006. Effects of humic acids from vermicomposts on plant growth. *European Journal of Soil Biology* 46:65-69.
- Atiyeh, R.M., C.A. Edwards, J.D. Metzger, S. Lee, and N.Q. Arancon. 2002. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresource Technology* 84:7-14.
- Bachman, G.R., and J.D. Metzger. 2008. Growth of bedding plants in commercial potting substrate amended with vermicompost. *Bioresource Technology* 99:3155-3161.
- Benito, M., A. Masaguer, A. Moliner, and R.D. Antonia. 2006. Chemical and physical properties of pruning waste compost and their seasonal variability. *Bioresource Technology* 97:2071-2076.
- Bustamante, M.A., C. Paredes, R. Moral, E. Agulló, M.D. Pérez-Murcia, and M. Abad. 2008. Composts from distillery wastes as peat substitutes for transplant production. *Resources, Conservation and Recycling* 52:792-799.
- Campitelli, P., and S. Ceppi. 2008. Effects of composting technologies on the chemical and physicochemical properties of humic acids. *Geoderma* 144:325-333.
- Castaldi, P., G. Alberti, R. Merella, and P. Melis. 2005. Study of the organic matter evolution during municipal solid waste composting aimed at identifying suitable parameters for the evaluation of compost maturity. *Waste Management* 25:209-213.
- Chavez, W., A. Di Benedetto, G. Civeira, and R. Lavado. 2008. Alternative soilless media for growing *Petunia xhybrida* and *Impatiens wallerana*: Physical behavior, effect of fertilization and nitrate losses. *Bioresource Technology* 99:8082-8087.
- Civeira, G. 2010. Influence of municipal solid waste compost on soil properties and plant reestablishment in peri-urban environments. *Chilean Journal of Agricultural Research* 70:446-453.
- Di Benedetto, A., J.C. Petracchi, G. Marcella, P. Montaron, and W. Chavez. 2006. Evaluation of alternative substrates for bedding plants. *International Journal of Agricultural Research* 1:545-554.
- Dole, J.M., and H.F. Wilkins. 2004. *Floriculture: Principles and species*. 2nd ed. Prentice Hall, Upper Saddle River, New Jersey, USA.
- Francescangeli, N., and A. Zagabria. 2008. Paclobutrazol for height control of petunias. *Chilean Journal of Agricultural Research* 68:309-314.
- García-Gomez, A., M.P. Bernal, and A. Roig. 2002. Growth of ornamental plants in two composts prepared from agroindustrial wastes. *Bioresource Technology* 83:81-87.
- Gaspar, Y.M., J.A. McKenna, B.S. McGinness, J. Hinch, S. Poon, A.A. Connelly, et al. 2014. Field resistance to *Fusarium oxysporum* and *Verticillium dahliae* in transgenic cotton expressing the plant defensin *NaD1*. *Journal of Experimental Botany* 65:1541-1550.
- Gerats, T., and M. Vandenbussche. 2005. A model system for comparative research: *Petunia*. *Trends in Plant Sciences* 10:251-256.
- Grigatti, M., M.E. Giorgioni, and C. Ciavatta. 2007. Compost-based growing media: Influence on growth and nutrient use of bedding plants. *Bioresource Technology* 98:3526-3534.
- Hernández, A., H. Castillo, D. Ojeda, A. Arras, J. López, and E. Sánchez. 2010. Effect of vermicompost and compost on lettuce production. *Chilean Journal of Agricultural Research* 70:583-589.
- Holm, G. 1954. Chlorophyll mutations in barley. *Acta Agriculturae Scandinavica* 4:457-471.
- Medina, E., C. Paredes, M.D. Pérez-Murcia, M.A. Bustamante, and R. Moral. 2009. Spent mushroom substrates as component of growing media for germination and growth of horticultural plants. *Bioresource Technology* 100:4227-4232.
- Mehmood, T., W. Ahmad, K.S. Ahmad, J. Shafi, M.A. Shehzad, and M.A. Sarwar. 2013. Comparative effect of different potting media on vegetative and reproductive growth of floral shower (*Antirrhinum majus* L.) *Universal Journal of Plant Science* 1:104-111.
- Meier, U. 2001. Growth stages of mono- and dicotyledonous plants. BBCH monograph. German Federal Biological Research Centre for Agriculture and Forestry, Berlin, Germany.
- Nazari, F., M. Khosh-Khui, and H. Salehi. 2009. Growth and flower quality of four *Rosa hybrida* L. cultivars in response to propagation by stenting or cutting in soilless culture. *Scientia Horticulturae* 119:302-305.
- Nishijima, T., H. Miyaki, K. Sasaki, and T. Okazawa. 2006. Cultivar and anatomical analysis of corolla enlargement of *petunia* (*Petunia hybrida* Vilm.) by cytokinin application. *Scientia Horticulturae* 111:49-55.
- Ntoulas, N., P.A. Nektarios, and G. Gogoula. 2011. Evaluation of olive mill waste compost as a soil amendment for *Cynodon dactylon* turf establishment, growth, and anchorage. *HortScience* 46:937-945.
- Papafotiou, M., G. Kargas, and I. Lytra. 2005. Olive mill waste compost as a growth medium component for foliage potted plants. *HortScience* 40:1746-1750.
- Papafotiou, M., M. Phsyhalou, G. Kargas, I. Chatzipavlidis, and J. Chronopoulos. 2004. Olive-mill wastes compost as growing medium component for the production of poinsettias. *Scientia Horticulturae* 102:167-175.
- Ribeiro, H.M., A.M. Romero, H. Pereira, P. Borges, F. Cabral, and E. Vasconcelos. 2007. Evaluation of a compost obtained from forestry wastes and solid phase of pig slurry as a substrate for seedlings production. *Bioresource Technology* 98:3294-3297.
- Tognetti, C., M.J. Mazzarino, and F. Laos. 2007. Composting biosolids and municipal organic waste: effects of process management on stabilization and quality. *Biology and Fertility of Soils* 43:387-397.
- Warner, R.M. 2010. Temperature and photoperiod influence flowering and morphology of four *Petunia* spp. *HortScience* 45:365-368.
- Watharkar, A.D., R.V. Khandare, A.A. Kamble, A.Y. Mulla, S.P. Govindwar, and J.P. Jadhav. 2013. Phytoremediation potential of *Petunia grandiflora* Juss., an ornamental plant to degrade a disperse, disulfonated triphenylmethane textile dye Brilliant Blue G. *Environmental Science and Pollution Research International* 20:939-949.
- Xu, G., R. Huo, and Y. Guo. 2010. Growth and development performance of different *Petunia hybrida* varieties in Yinchuan region. *Journal of Anhui Agricultural Sciences* 38:16833-16835.
- Zaller, J.G. 2007. Vermicompost as a substitute for peat in potting media: effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. *Scientia Horticulturae* 112:191-199.
- Zhanga, W., X. Li, F. Chenb, and J. Lua. 2012. Accumulation and distribution characteristics for nitrogen, phosphorus and potassium in different cultivars of *Petunia hybrida* Vilm. *Scientia Horticulturae* 141:83-90.