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Biosolids Compost as Component of Potting Media for Bedding Plants

Kompost aus Bioabfällen als Bestandteil von Topfsubstrat für Beetpflanzen

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Summary

Soilless potting substrates are increasingly used in greenhouse production of bedding plants replacing soil as growth media. These substrates usually consist of a mixture of organic materials like peat or pine bark and inorganic substances such as perlite, vermiculite or sand. Among other possibilities, compost made from municipal and industrial sludges and other solid wastes can effectively replace both peat and soils as they imply little risk to human or to the environment. The objective of this study was to evaluate the effects of different proportions of biosolids compost in substrate mixtures on growth and quality performance for two bedding plants (*Petunia hybrida* and *Vinca* sp.). Pots containing different proportions (0 to 100%) of biosolids compost were used to grow both crops under greenhouse conditions. In plants were determined height, diameter, flower fresh weight, fresh aerial biomass without flowers, leaf area, flower area, number of floral stems, number of flowers, total N, P and K in aerial biomass without flowers. At the end of the experiment particle size distribution, bulk density, degree of compaction, water holding curves, pH, electrical conductivity, total nitrogen and available phosphorus were determined in substrates. Substrates with compost in its composition showed predominance of medium particle distribution. Bulk density and the degree of compaction were higher than the ideal range in treatment 75 to 100% of compost. The treatments 25 to 75% compost, were more adequate for normal water supply to roots. Substrates pH varied between 5.4 and 6.0, and the electrical conductivity (1:10) between 0.14 and 0.43 $dS\,m^{-1}$. Both plants exhibited adequate vegetative and reproductive parameters in substrates composed of different proportion of compost of biosolids. In *Petunia*, the differences in plant parameters found among treatments can be mainly attributed to water availability and substrate salt content. *Vinca* was also related to water availability and substrate pH. Our results indicate that, in horticultural production, peat and soil can be partially replaced by biosolids compost. Considering the different plant parameters, the substrate with 25% of biosolids compost could be selected among those that produce the best plant quality in both studied species. The substrate made up of only compost of biosolids cannot be considered a commercial alternative.

Zusammenfassung

Erdelose Topfsubstrate finden in zunehmendem Maße für die Produktion von Beetpflanzen im Gewächshaus Verwendung und ersetzen Mutterboden als Substrat. Im Allgemeinen enthalten diese Substrate eine Mischung aus organischen Materialien wie Torf oder Kiefernrinde und nicht-organische Substanzen wie Perlite, Vermiculite oder Sand. Als weitere Möglichkeit kann Kompost aus Klärschlamm von Haushalten und Industrie und aus festen Abfällen, Torf und Erden wirkungsvoll ersetzen, sofern sie geringe Risiken für Mensch und Umwelt in sich tragen. Gegenstand dieser Untersuchung ist, die Wirkung von unterschiedlichen Anteilen Kompost aus Bioabfällen auf Wachstum und Qualität von zwei Beetpflanzen (*Petunia hybrida* und *Vinca* sp.) zu ermitteln. Für die Kultur beider Pflanzenarten unter Gewächshausbedingungen wurden Substrate mit unterschiedlichen Anteilen (0 bis 100%) Kompost aus Bioabfällen verwendet. An den Pflanzen wurden Parameter wie Höhe, Durchmesser, Frischgewicht der Blüten und der oberirdischen Pflanzenmasse ohne Blüten, Blattfläche, Anzahl Blütentriebe, Blütenzahl sowie Gesamtmenge N, P und K in der oberirdischen Pflanzenmasse ohne Blüten ermittelt. Am Versuchsende wurde das Substrat hinsichtlich Korngrößenverteilung, Dichte, Volumen, Wasserhaltevermögen, pH, elektrische Leitfähigkeit, Gesamtstickstoff und verfügbarer Phosphor untersucht. Substrate mit Kompost als Bestandteil sind bei der Teilchenverteilung führend. Bei einem Anteil von 75 bis 100% Kompost waren die Massendichte und Grad der Verdichtung höher als die Idealwerte. In den Versuchspartien mit 25 bis 75% Kompost war die Wasserversorgung der Wurzeln angepasster. Der pH-Wert des Substrats variierte zwischen 5.4 und 6.0 und die elektrische Leitfähigkeit (1:10) zwischen 0.14 und 0.43 $dS\,m^{-1}$. Bei allen Substraten mit unterschiedlichen Kompost-Anteilen zeigten beide Pflanzenarten ausreichende vegetative und generative Parameter. Bei *Petunia* können die Unterschiede zwischen den Behandlungen durch die verfügbare Wassermenge und den Salzgehalt des Substrates erklärt werden. Auch bei *Vinca* bestand ein Zusammenhang mit der verfügbaren Wassermenge und dem pH des Substrates. Unsere Ergebnisse zeigen, dass bei der gartenbaulichen Pflanzenproduktion Torf und Erde teilweise durch Kompost aus Bioabfällen ersetzt werden können.

Unter Berücksichtigung der unterschiedlichen Pflanzenparametern konnte das Substrat mit 25 % Kompost-Anteil für beide Pflanzenarten zur Produktion von bester Pflanzenqualität ausgewählt werden. Das Substrat, das ausschließlich aus Kompost aus Bioabfällen bestand, stellt keine wirtschaftliche Alternative dar.

Introduction

In several countries, ornamental plant growers still use soils as a basis for growing media, but soil-less potting substrates are increasingly used in greenhouse production, replacing the soil as growth media. These substrates usually consist of a mixture of organic materials like peat or pine bark and inorganic substances such as perlite, vermiculite or sand (BUNT 1988; NELSON 1991). There is an increasing demand for peat and peat-based mixtures for greenhouse crop production. In northern European countries and in Canada, it is possible to find highly humified peats with excellent features for plant production in containers; however, the harvest rates are not sustainable enough for ecologists (BARBER 1993; BARKHAM 1993, BUCKLAND 1993). Even though the organizations involved in peat removal state that this activity can be performed at a sustainable level (ROBERTSON 1993), they do admit different alternatives must be tried out to replace or complement the product. High quality peat has shown a significant price increase during the last decade (MEEROW 1994) and growers are now using local organic materials to replace *Sphagnum* peat.

There are peats in Argentina whose commercial exploitation is still in its first stages. Most peatlands are located in Rio Grande, Tierra del Fuego and due to its recent exploitation, its agronomic qualities are still unknown.

Among other possibilities, compost made from municipal and industrial sludge and other solid wastes can effectively replace both peat and soils as they imply little risk to human or animal health or to the environment (WARMAN 1999). Compost made from biosolids has been successfully used to grow marigold, *Petunia*, *Chrysanthemum*, *Geranium*, snapdragon and *Impatiens* plants (GOUIN 1985; KLOCK-MOORE 1999). Compost contains substantial amounts of nitrogen and phosphorous that may improve plant growth and reduce the need for fertilizers (BUGBEE & ELLIOT 1998). Besides, composts addition may benefit substrates by improving bulk density, porosity, water-holding capacity and aggregate stability (BARKER 1997).

The objective of this study was to evaluate the effects of different proportions of biosolids compost in substrate mixtures on growth and quality performance for two bedding plants.

Materials and Methods

An experiment was carried out in a greenhouse. *Petunia* and *Vinca* plantlets (*Petunia hybrida* and *Vinca* sp.) were transplanted into pots of 1 l volume and 15 cm diameter. Substrates were obtained from different proportions of peat (from Tierra del Fuego); perlite, soil (Typic Hapludoll, horizon A) and biosolid compost. This compost was prepared with sawdust as bulking agents (2:1, biosolid:sawdust ratio by volume) and biosolids from sewage sludge treatment plant located in the north of Buenos Aires City. Physical and chemical properties of the compost were published elsewhere (ZUBILLAGA and LAVADO 2001). There were 6 treatments with the following proportions by volume:

I. 50 % soil + 25 % peat + 25 % perlite;
II. 100 % compost;
III. 75 % compost + 12.5 % peat + 12.5 % perlite;
IV. 50 % compost + 25 % peat + 25 % perlite;
V. 25 % compost + 3.5 % perlite and
VI. 50 % peat + 50 % perlite.

Pots were arranged in the greenhouse using a randomized design with seven replications. They were maintained around field capacity by means of daily watering with distilled water. Before transplanting the plants, all pots were fertilized with a commercial formula: 16N-7P-12K plus micronutrients at the rate of 0.8 g kg^{-1} substrate. It was not necessary to apply fungicides and insecticides and weeds were removed manually.

Petunias were harvested 61 days and *Vinca* 73 days after transplant when they had reached commercial size. Plant height, plant diameter, flower fresh weight, fresh aerial biomass without flowers, leaf area, flower area, the number of floral stems and the number of flowers were determined. Total N was determined by Kjeldahl method and total P and K were extracted by digestion in HNO_3-HCl and determined by ICP in aerial biomass without flowers. From the plant nutrient contents and the dry aerial biomass without flowers, nutrient uptake was calculated. Leaf and floral area was measured using a LI-3100 Area Meter.

At the end of the experiment, the particle size distribution, bulk density, water holding curves, pH (1:10), electrical conductivity (1:10 extract), (KLUTE 1986), total nitrogen (Kjeldahl) and available phosphorus (Bray and Kurtz), were determined (SPARKS et al., 1996) in substrates. The degree of compaction of substrates, the volume variation percentage between the start and the end of the experiment was also measured. There were no significant differences in substrate characteristics after the growth of each species; therefore the shown data are the average values.

All data were statistically analyzed by ANOVA. All LSD values were tested at a probability level of 5 %. Correlations between substrates and plant parameters were calculated.

Results and Discussion

Substrates characteristics

The particle size distribution varied largely among substrates (Figure 1a). The treatment peat + perlite showed the highest percentage of coarse particles, which allows presuming there was high macroporosity in those containers. Conversely, in the substrate with soil the opposite happened. Substrates with compost in its composition showed predominance of medium particle distribution. Bulk density of some substrates (Figure 1b) were around the ideal range, between 0.15 and 0.5 g cm^{-3} (NAPPI and BARBERIS 1993) but substrates with 75 % and 100 % of compost exceeded this range. An associated measure, the degree of compaction (Figure 1c)

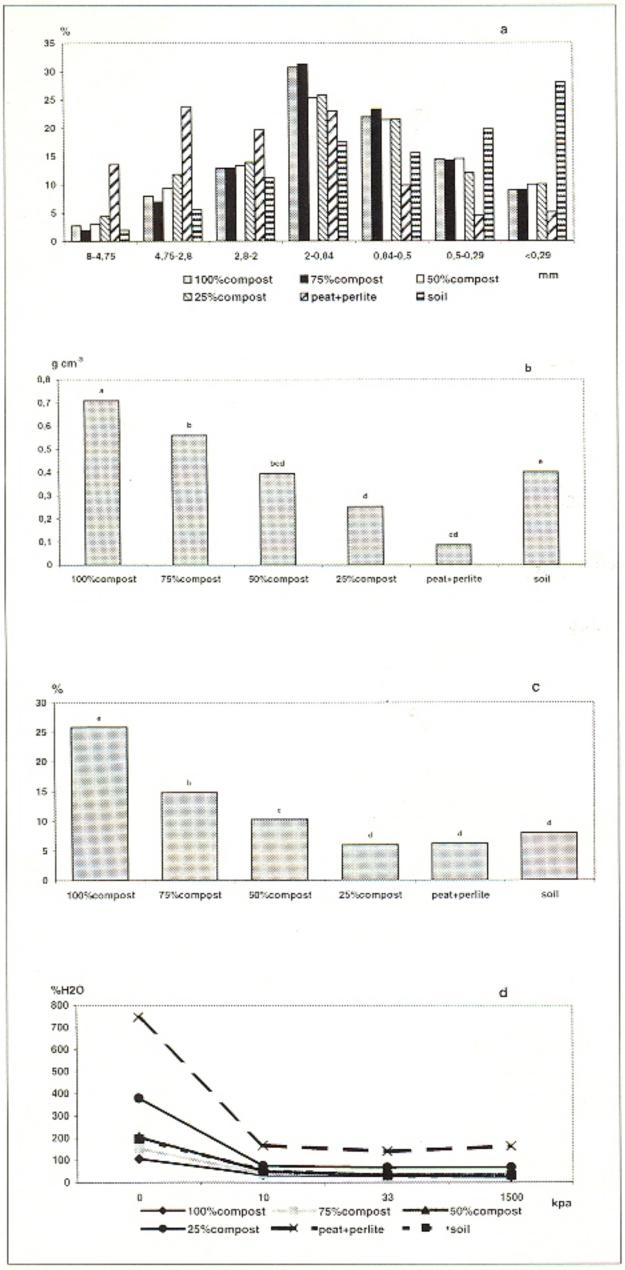

Fig. 1. Characteristics of substrates in the experiment. A) particle size distribution; b) bulk density; c) degree of compaction; d) water holding. Different letters indicate significant differences (LSD, $p < 0.05$)

Merkmale verwendeter Substrate. a) Korngrößenverteilung; b) Dichte; c) Volumen; d) Wassserhaltevermögen. Abweichende Buchstaben bedeuten signifikante Unterschiede (LSD, $p < 0.05$)

shows that the higher the contents of compost, the lower substrates stability.

Generally speaking, substrates with good porosity have potentially good aeration and water holding capacity. As regards this matter there are two important parameters: a) water easily available to plants, that is to say, the quantity of water released by the substrate when suction changes from 10 to 50 cm, and b) water reserve, the water still available to plants in case of adverse conditions. This type of water is released by the substrate when suction from 50 to 100 cm (NAPPI and BARBERIS 1993).

Peat has a low hydraulic conductivity at low water potentials and it is prone to evaporation, which decrease the water availability in dry conditions (BEARDSELL et al. 1979; ORLANDER and DUE 1986). Figure 1d shows that the treatment peat + perlite had higher water content retained at suction which was lower than 10 kpa that is the water of easy drainage (ANSORENA MINER 1994). Besides, it also showed the largest water content at higher suction levels not available to plants. Conversely, the treatment with 100 % compost showed the lowest capacity to hold water at low and high suctions; in fact, it had little water available to crops. This behavior has also been found by other authors (CORTI et al., 1998). The other treatments were located in intermediate positions and were more suitable for normal water supply to roots.

Substrate pH (1:10) varied between 5.4 and 6.0, adequate for normal growth of most ornamental plants. The electrical conductivity (1:10) varied between 0.14 and 0.43 dS m^{-1}, a range already found for compost of biosolids (KLOCK-MOORE 1999). The highest electrical conductivity was found in the treatment peat + perlite. Total nitrogen was high in all substrates, varying between 0.30 and 0.47 %. The available P was also very high at the end of the experiment ranging from 302 to 493 µg P g^{-1}.

Crop response

Table 1 shows data concerning both crops quality parameters according to the substrate used. For both species vegetative and reproductive parameters are highly correlated ($P<0,05$), then only all parameters of *Petunia* are shown. For *Vinca* only the data related to height and aerial biomass are shown.

In *Petunia*, the highest heights were found in the substrates with soil and with 25 % to 75 % of compost and the lowest heights were observed in the treatment peat + perlite (Table 1). Plant diameter, leaf area, and aerial biomass without flowers did not show any difference among treatments, except the substrate with peat + perlite. This behavior could be accredited to the higher salt content in this treatment.

The reproductive parameters also exhibited marked differences (Table 1). Substrates with soil and compost contents from 25 % to 75 % showed the highest number of flowers, flowering weight and area. The number of floral stems did not show significant differences among treatments, with the exception of the substrate peat+perlite, which exhibited the lowest data.

For *Vinca* (Table 1) the plant heights and the aerial biomass were significantly higher in all substrates with compost and, as well as with the *Petunia*, the substrate peat + perlite gave significant lower figures. Other authors also observed positive results in plant growth and vegetative development with 25 % and 50 % of compost (GOUIN 1985; NAPPI and BARBERIS 1993).

The N, P and K contents in *Petunia* varied between 1.5–3.6 %; 0.3–0.7 % and 2.2–5.4 % respectively, which

Table 1. Growth parameters in *Petunia* and *Vinca*. Different letters indicate significant differences (LSD, $p < 0.05$)
Wachstumsparameter von Petunia *und* Vinca. *Abweichende Buchstaben geben signifikante Unterschiede an (LSD, $p < 0.05$)*

Treatment	*Petunia*								*Vinca*	
	Height (cm)	Plant diameter (cm)	Leaf area (cm²/pot)	Aerial biomass without flowers (g/pot)	N° flowers per pot	Floral weight (g/pot)	Floral area (cm²/pot)	N° floral stems per pot	Height (cm)	Aerial biomass (g/pot)
100 % compost	24.56 bc	23.53 a	586.39 a	47.41 a	8.25 b	8.37 b	259.58 b	9.88 a	29.86 ab	32.77 a
75 % compost	27.17 ab	23.36 a	548.61 a	41.89 a	12.56 ab	12.07 ab	345.36 ab	10.00 a	30.90 a	32.33 a
50 % compost	28.61 a	26.39 a	566.77 a	44.73 a	12.56 ab	13.19 ab	363.74 ab	10.22 a	30.00 ab	29.37 a
25 % compost	28.50 a	23.83 a	641.33 a	47.67 a	17.67 a	15.25 a	476.05 a	11.00 a	32.30 a	34.08 a
peat +perlite	22.81 c	8.88 b	54.64 b	4.56 b	1.13 c	0.72 c	21.39 c	1.13 b	18.33 c	2.32 b
Soil	28.07 a	24.36 a	664.11 a	49.46 a	16.57 a	10.14 ab	313.35 ab	9.29 a	26.50 b	25.01 a

Table 2. Macronutrients absorption in *Petunia* and *Vinca* (g/pot). Different letters indicate significant differences (LSD, $p < 0.05$)
Makronährstoff-Aufnahme von Petunia *und* Vinca. Abweichende Buchstaben geben signifikante Unterschiede an (LSD., $p < 0.05$)

	Petunia			*Vinca*		
	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
100 % compost	9,94 b	1,87 b	21,88 a	68,26 b	8,63 b	66,41 a
75 % compost	9,19 b	1,92 b	16,80 b	69,39 b	9,05 b	56,46 a
50 % compost	9,77 b	2,24 b	16,44 b	66,46 b	9,11 b	46,85 b
25 % compost	10,82 b	2,63 ab	12,48 b	83,16 a	11,08 ab	48,91 b
peat + perlite	1,89 c	0,40 c	1,21 c	7,84 c	1,15 c	2,95 c
Soil	17,77 a	3,04 a	28,32 a	80,03 ab	11,75 a	61,27 a

corresponded with normal data for these species (MILLS and BENTON JONES Jr. 1998). The absorption of nutrients was significantly higher in plants grown in the substrate with soil (Table 2); while in most cases the substrates with compost showed lower nutrient accumulation. In the substrate peat + perlite the nutrient uptake was the lowest.

In *Vinca*, the contents of N, P and K were between 1.8–3.4%; 0.2–0.7% and 1.1–2.6 respectively and they are also within the normal values for this specie (MILLS and BENTON JONES Jr. 1998). The nutrient absorption was equivalent to *Petunia* and it was the lowest in the substrate peat + perlite.

Both plants absorbed different quantities of nutrients when grown in different substrates but no correlations were found among nutrients and yield parameters. This is an indication that probably plant nutrition was not a limiting factor.

Substrates and plant quality

In *Petunia* there were no significant relationships between most substrates parameters: pH, physical characteristics and nutrient contents with vegetative and reproductive parameters. Water holding data showed a negative and statistically significant correlation ($P<0.05$) with most plant parameters. For instance, models with good adjustment among plant parameters and points of water retention curve are:

- Number of floral stems = 12.63 – 0.013 water retention 0 kpa
  $r = -0.87^{***}$
- Number of floral stems = 12.909 – 0.076 water retention 33 kpa
  $r = -0.90^{***}$

This means that plant growth and development was determined by water availability. Other authors also found high correlations between substrates water holding capacity in containers and yields of several ornamentals (i.e TILT et al. 1987).

Likewise, electrical conductivity values correlated negatively and significantly ($P < 0.05$) with most plant parameters, for example:

- Number of floral stems = 11.80 – 11.002 CE
  $r = -0.43^{*}$

For *Vinca*, there was also a high correlation of plant parameters with water holding capacity at different suctions. Some models are:

- Height = 32.97 – 0.0167 water retention 0 kpa
  $r = -0.79^{**}$
- Height = 33.209 – 0.092 water retention 33 kpa
  $r = -0.79^{**}$
- Fresh weight = 41.66 – 0.25 water retention 0 kpa
  $r = 0.85^{**}$
- Fresh weight= 41.11 – 0.046 water retention 33 kpa
  $r = -0.84^{**}$

Vinca parameters did not correlate with substrates electrical conductivity as *Petunia* did but they showed a positive correlation with pH (even in the short range of pH found in the present study):

- Fresh weight = -42.99 + 13.17 pH
  $r = 0.82^{**}$
- Height = 1.14 + 5.02 pH
  $r = 0.81^{**}$

According to DEVITT and MORRIS (1987) and WILKENSON (1990), the tolerance to salinity and pH is similar for *Petunia* and *Vinca*: both belong to a medium tolerant salt group, with slightly acid ideal pH. However, in this study *Petunia* was more sensitive to charges in electrical conductivity and *Vinca* was more sensitive to changes in the substrate pH value.

Conclusion

The substrates showed different physical and hydrological properties but, as a consequence of basal fertilization, they did not show nutritional differences. Besides, these species exhibited adequate vegetative and reproductive parameters in substrates composed of different proportions of compost of biosolids. The substrate with soil also had good behavior.

In *Petunia*, the differences in plant parameters found among treatments can be mainly attributed to water availability and substrate salt content. *Vinca* was also related to water availability, and to substrate pH.

Our results indicate that, in horticultural production, peat and soil can be partially replaced by biosolids compost. Considering the different plant parameters, the substrate with 25% of biosolids compost could be selected among those that produce the best plant quality in both studied species. The substrate made up of only compost of biosolids cannot be considered a commercial alternative.

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