Enhancement of switchgrass (*Panicum virgatum* l.) early growth as affected by composts

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Abstract

Switchgrass (*Panicum virgatum* L.) is a bunchgrass native to North America recently successively cultivated as an energy crop. The use of compost as soil amendment is a universal practice well known for its benefits to soil properties and plant growth. This study aimed to assess the possible benefits of compost addition on the growth parameters of four switchgrass populations, the octaploids *Shelter, Shawnee* and *Dacotah*, and the tetraploid *Alamo*, in pot experiments. Three growing media were prepared by mixing peat (P) with each of three different composts, a green compost (GC), a mixed compost (MC) and a coffee compost (CC), at the percentages of 5%, 10% and 20% (v/v). Results obtained showed that, with respect to the use of P only, all compost mixtures exerted positive effects on root, shoot and primary leaf lengths and on the fresh weight of the different switchgrass populations. In particular, GC/P and MC/P mixtures appeared more efficient at 5% and 10% of compost, whereas CC/P mixtures produced the best results at 10% and 20% of compost. The effects of composts were more evident for the *Shawnee* population and less for the *Shelter* one, thus indicating an involvement of the genotype in the plant response.

Keywords: Switchgrass, growth parameters, plant growing substrate, compost, peat

1. Introduction

Switchgrass (*Panicum virgatum* L.) is a warm-season perennial C_4 grass native to North America where it represents a typical species in the tall grass prairies (Monti *et al.*, 2001). The traditional use of this plant was related to soil conservation and forage production (Bouton, 2007). Since the early 1990s, this crop has been considered by the United States Department of Energy as a model herbaceous energy crop for ethanol and electricity productions (Elbersen *et al.*, 2001).

Since 1991 this grass has been used also in Canada for thermal conversion (electricity and heat) and ethanol and paper pulp productions (Elbersen *et al.*, 2001). Many reasons justify the use of this plant as energy crop, such as its high biomass productivity, the low nutrient requirement, low production costs, high water use efficiency, large range of geographic adaptation, high potential for carbon sequestration in soil, and other potential environmental benefits (Schmer *et al.*, 2008).

Native switchgrass populations occur as two different ecotypes. Upland ecotypes, tipically octaploids and occasionally hexaploids (Lewandowski *et al*., 2003), occur in upland areas that are not subjected to flooding. Lowland ecotypes, generally tetraploids (Lewandowski *et al.*, 2003), are found typically in floodplains and other areas that receive run-on water (Vogel, 2004). Generally, with respect to upland ecotypes, lowland ones have a later heading date and are taller with larger and thicker stems.

Composting is an aerobic treatment aimed at converting organic wastes of various origin and nature into agriculturally useful products, i.e., organic amendments. The main process occurring during composting is the decomposition of organic matter into carbon dioxide, water, inorganic nutrients and a stabilized and mature organic material rich in humic-like substances (Senesi, 1989). For these reasons, the compost is able to improve several soil physical, chemical and biological properties. Further, during appropriate composting pathogens and phytotoxic organic substances are destroyed, and availability of polluting and/or phytotoxic trace metals and organic contaminants originally present in the matrices are reduced (Senesi *et al*., 2007). Proper compost amendment to soil is well known to promote plant growth and reduce root pathogens by competition and parasitism, and shoot pathogens by plant induced resistance (Termorshuizen *et al.*, 2004).

In some cases, however, problems may derive, e.g. due to compost salt content that may negatively affect plant growth (Stamatiadis *et al*., 1999), and by application of immature composts that may inhibit seed germination, reduce plant growth and damage crops by competing for oxygen or causing phytotoxicity to plants (Cooperband *et al*., 2003; Wu *et al*., 2000). Further, the application of high rates of compost may determine an accumulation of trace metals in plants, with dangerous consequences for humans and animals that feed on these plants (Petruzzelli, 1996). Generally, to reduce these risks the amount of compost to be added to growing substrates is limited to approx. 20% (v/v) (Loffredo and Senesi, 2009). Finally, different plant response to compost application have been shown to be related to the different origin and nature of compost, the different dose applied, and the different plant genotype examined (Fornes *et al.*, 2009).

Recent studies conducted by the authors (Traversa *et al.*, 2013) have shown an enhancement of germination of four switchgrass populations by the application at three concentrations of humic acids isolated from three different composts. Schmer *et al.* (2008) have shown that cultivated switchgrass, with respect to wild switchgrass, doubles the quantity of cellulose produced, with significant benefits in terms of biofuel and energy production. To this respect, the cultivation of switchgrass could be extended in other areas, and the possible soil amendment with compost could enhance its beneficial biomass production.

The objective of this study was to verify the possible benefits of the addition of three composts, at three doses, to a peat substrate on the early growth of four populations of switchgrass.

2. Materials and Methods

2.1. Switchgrass populations, peat, composts, and growing substrates

The switchgrass populations examined in this study were *Shelter, Shawnee, Dacotah* and *Alamo*. The first three are octaploid, northern, upland populations. *Alamo* is the most widely diffused tetraploid, southern, lowland population.

The three composts used in this work were a green compost (GC), a mixed compost (MC), and a coffee compost (CC) collected from real scale plants. The GC was obtained by composting for about 120 days in aerated (air-insufflated) piles a mixture of lignocellulosic materials consisting mainly of tree and grass cuttings from urban public and private green. The MC was obtained by composting for 80 days in aerated piles a mixture of 60% lignocellulosic material and 40% of food industry wastes and the organic fraction of municipal solid wastes. The CC was obtained by composting for 120 days in aerated turned piles a mixture of 50% coffee husks and 50% tree cuttings. The peat (P) used as the major component of the potting mixtures is a commercial growing substrate.

The growing substrates used were P only and mixtures of P with each compost (C) at 5%, 10% and 20% (v/v) (C/P 5%, C/P 10%, C/P 20%, respectively). For each substrate, the electrical conductivity and pH values were measured on its suspension in distilled water (1:15, w/v). The total organic carbon (TOC) and total nitrogen (total N) contents of each substrate were measured by using conventional procedures.

2.2. Early growth Experiments

Seeds of each switchgrass population were germinated by previously soaking in distilled water and successively placing in three Petri dishes (20 seeds for each dish) on filter paper under controlled conditions (Traversa *et al*., 2013). The early growth experiments started on the germinated seeds (seedlings) of each switchgrass population collected from Petri dishes after 8 days, when the germination was completed. In particular, five seedlings were collected from each Petri dish and transplanted into plastic pots containing each growing substrate (three pots for each mixture). The pots were then placed in a thermostated chamber where seedlings were allowed to grow for a period of 25 days in the following conditions: 12-h photoperiod, temperature of 23 °C during the illumination period and 18 °C during the dark period, and constant humidity of 65%. Twice in the week, each pot was added with 25 mL of the Nitsch nutrient solution (Nitsch, 1968) diluted 1:1 with distilled water, in order to provide all nutrients, especially nitrogen. At the end of the experiments, root, shoot and primary leaf lengths, and the plant fresh weight of each switchgrass population were measured.

All experiments were conducted in three replicates and data obtained were statistically analysed by ANOVA at 95% confidence level. The mean values obtained for the different treatments were separated by using the Tukey test (HSD).

Further, the correlations existing between some properties of the substrates and the growth parameters of switchgrass were evaluated.

3. Results

3.1. Composts, peat, and growing substrates

The main properties of the C samples used, which were comparatively presented and discussed in Traversa et al. (2010), are summarized in Table 1. The main properties of the P sample and the different mixtures used as potting media are referred in Table 2.

The peat (P) showed lower EC and pH values with respect to all the mixtures examined, in which EC and pH values increased with the C rate in the order: GC/P > MC/P > CC/P. The TOC content was maximum in P and inversely related to the C rate in the growing mixtures, with similar values in GC/P and MC/P mixtures, and higher values in CC/P mixtures. The total N content was minimum in P and increased with the C rate in the growing mixtures, with similar values in GC/P and CC/P mixtures, and slightly higher values in MC/P mixtures. The addition of the Nitsch nutrient solution was necessary in order to increase N% and thus reduce the TOC/N ratio of the mixtures which finally ranged from 69 (CC/P 5%) to 32 (CM/P 20%).

3.2. Early growth parameters

Root and shoot lengths

In no case, the young plants presented visible root and shoot alterations, even when grown at the highest dose of C in the mixtures. Root and shoot lengths measured for the four switchgrass populations after 25-days growth on the various substrates are presented, respectively, in Figures 1 and 2.

Table 1. Main properties of the three composts examineded[a]

Sample	pH	[b] EC (dS m^{-1})	Moisture (g kg^{-1})	Ash (g kg^{-1})	[c] TOC (g kg^{-1})	Total N (g kg^{-1})
GC	8.4	3.73	163	651	184	15.6
MC	8.5	3.64	120	628	196	17.2
CC	9.1	3.30	147	150	424	25.7

[a] Traversa *et al.* (2010) [b]EC: Electrical conductivity [c] TOC: Total organic carbon

Table 2. Some properties of the different growing substrates.

Growing substrates	[a]EC (dS m^{-1})	pH	[b]TOC (g kg^{-1})	Total N (g kg^{-1})
P (control)	0.27	4.3	520	2.0
GC/P 5%	0.82	6.2	482	3.53
GC/P 10%	1.13	6.4	448	4.86
GC/P 20%	1.18	7.0	386	7.43
MC/P 5%	0.60	6.1	483	3.74
MC/P 10%	0.79	6.6	450	5.28
MC/P 20%	1.11	7.1	389	8.14
CC/P 5%	0.66	5.6	514	3.47
CC/P 10%	0.69	5.7	510	4.59
CC/P 20%	0.83	6.1	497	7.66

[a] EC: Electrical conductivity [b]TOC: Total organic carbon

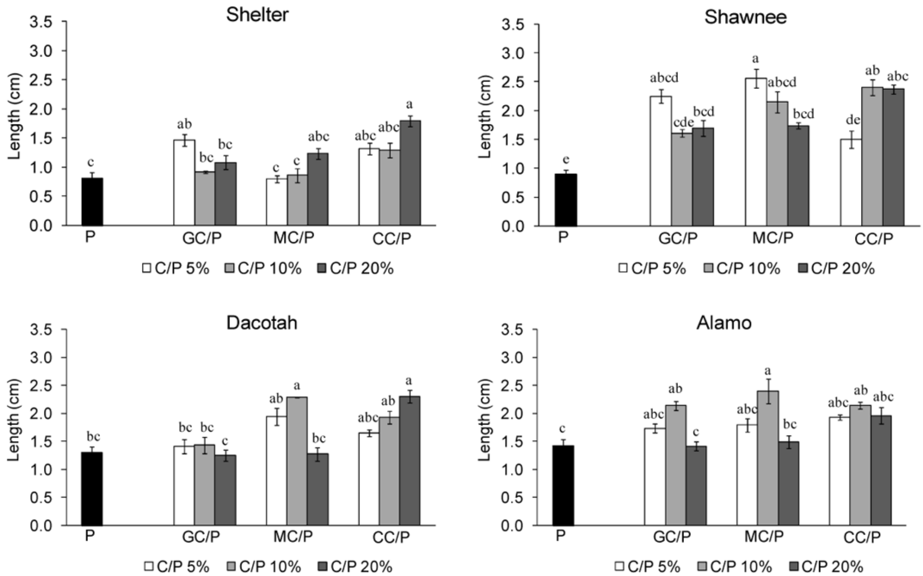

Figure 1. Effect of peat (P) and growing substrates GC/P, MC/P, and CC/P at different percentages of compost (v/v) on the root lengths of the four switchgrass populations measured after 25 days. The vertical line on each bar indicates the standard error for three replicates. The mean values of the different treatments were separated according to the Tukey test.

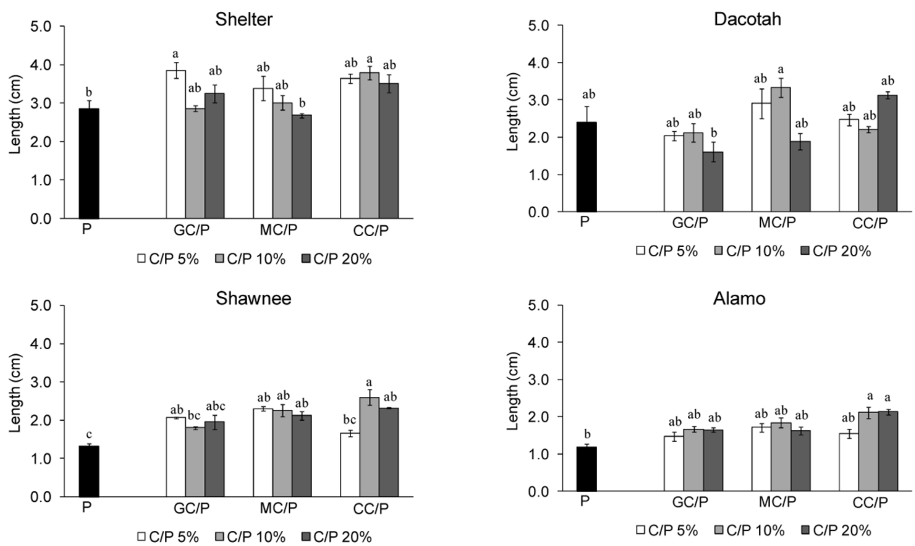

Figure 2. Effect of peat (P) and growing substrates GC/P, MC/P, and CC/P at different percentages of compost (v/v) on the shoot lengths of the four switchgrass populations measured after 25 days. The vertical line on each bar indicates the standard error for three replicates. The mean values of the different treatments were separated according to the Tukey test.

With respect to P: (i) a significant positive effect on the root growth of the *Shelter* population was exerted by GC/P at 5% substrate and CC/P at 20% substrate (Figure 1); and (ii) a significant positive effect was also observed on the shoot growth of this population in presence of GC/P at 5% substrate and CC/P at 10% substrate (Figure 2). In the case of the *Shawnee* population, with respect to P, a significant positive effect on the root growth was exerted by all the substrates used, with the only exception of GC/P at 10% substrate and CC/P at 5% substrate (Figure 1). On the shoot growth of *Shawnee*, a significant stimulation was caused by all treatments, with the exception of GC/P at 10% and 20% and CC/P at 5% substrates (Figure 2). With respect to P, a significant positive effect on the root growth of the *Dacotah* population was exerted by MC/P at 10% and CC/P at 20% substrates (Figure 1). For this population, no statistically significant differences occurred between the shoot lengths measured when grown on P and any growing mixture (Figure 2). In the case of the *Alamo* population, with respect to P: (i) a significant positive effect on the root growth was exerted by the three C/P substrates at 10% (Figure 1); and (ii) a significant positive effect was observed on the shoot growth in presence of CC/P at 10% and 20% substrates (Figure 2).

Comparing the results obtained for the four switchgrass populations, the *Shawnee* population presented the highest and the *Shelter* the lowest values of root growth. In the case of shoot growth, the *Shelter* population showed the highest values and the *Alamo* the lowest ones. In general, with respect to P only, all the mixtures examined appeared to exert positive effects on the root and shoot growth of the four switchgrass populations, especially on the *Shawnee* population.

3.3. Primary leaf length

Primary leaf lengths of the four switchgrass populations after 25-days growth on the different substrates are presented in Figure 3. With respect to P: (i) no significant effect on the primary leaf length of the *Shelter* population was exerted by the different mixtures; (ii) in the case of *Shawnee* population, a significant positive effect was exerted by all the substrates used, with the exception of GC/P and MC/P at 20% substrates and CC/P at 5% substrate; (iii) a significant positive effect was exerted on the *Dacotah* population by MC/P at 5% and 10% substrates and CC/P at 5% and 20% substrates; and (iv) in the case of *Alamo* population, a significant positive effect was exerted by GC/P at 5% substrate, MC/P at 10% substrate and CC/P at 10% and 20% substrates.

Comparing the results obtained for the four populations, the *Shawnee* presented the highest and the *Shelter* the lowest values of primary leaf length, whereas intermediate values were observed for *Dacotah* and *Alamo*.

3.4. Plant fresh weight

Plant fresh weights of the four switchgrass populations after 25-days growth on the different substrates are presented in Figure 4. With respect to P: (i) no significant effect on the plant fresh weight of the *Shelter* population was exerted by the different mixtures; (ii) in the case of the *Shawnee* population a significant positive effect was exerted by GC/P at 5% substrate, MC/P at 5% and 10% substrates and CC/P at 10% and 20% substrates; (iii) a significant positive effect was exerted on the *Dacotah* population by MC/P at 5% and 10% substrates and CC/P at 20% substrate; (iv) in the case of the *Alamo* population, a significant positive effect was exerted only by CC/P at 20% substrate. Comparing the results obtained for the four populations, the *Shelter* presented the highest and the *Alamo* the lowest values of fresh weight.

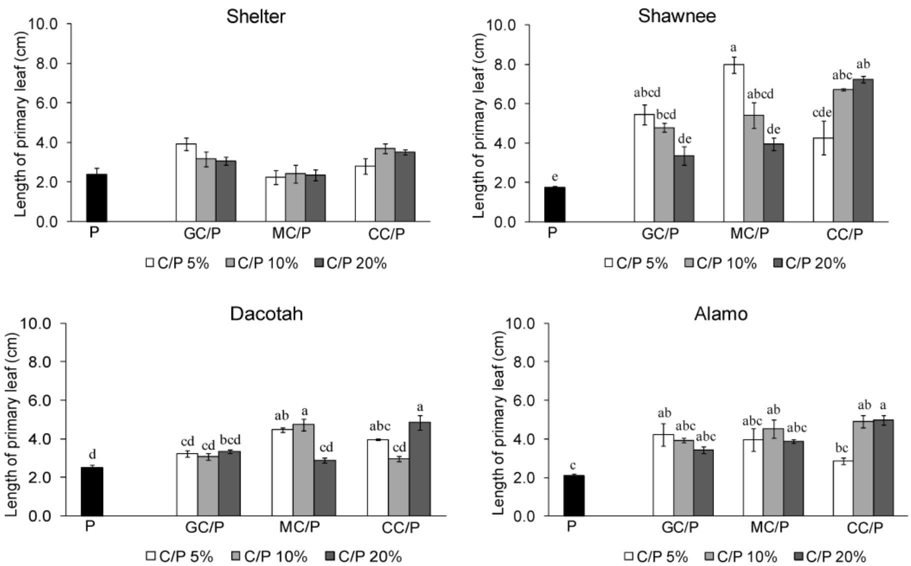

Figure 3. Effect of peat (P) and growing substrates GC/P, MC/P, and CC/P at different percentages of compost (v/v) on the primary leaf lengths of the four switchgrass populations measured after 25 days. The vertical line on each bar indicates the standard error for three replicates. The mean values of the different treatments were separated according to the Tukey test except for *Shelter* whose treatments were not statistically different according to ANOVA analysis.

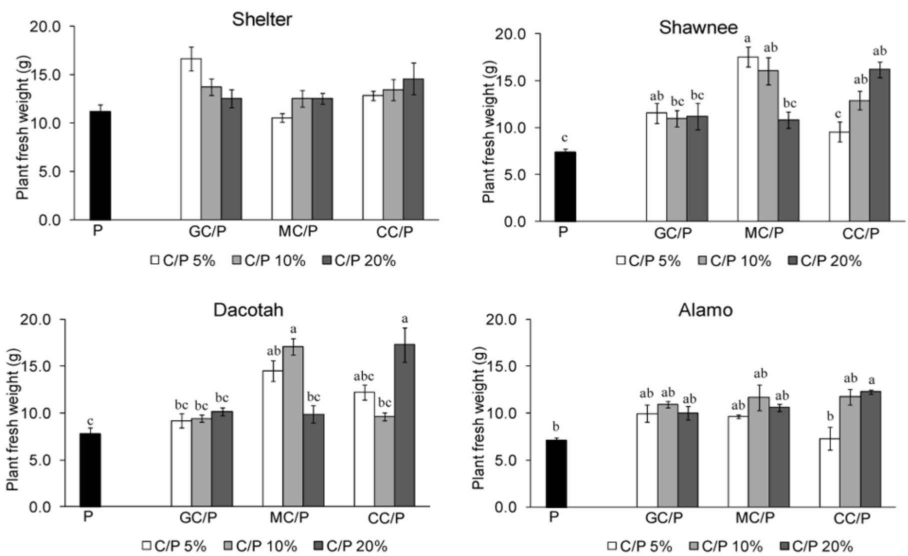

Figure 4. Effect of peat (P) and growing substrates GC/P, MC/P, and CC/P at different percentages of compost (v/v) on the fresh weight of the four switchgrass populations measured after 25 days. The vertical line on each bar indicates the standard error for three replicates. The mean values of the different treatments were separated according to the Tukey test except for *Shelter* whose treatments were not statistically different according to ANOVA analysis.

3.5. Activity-properties relationships

In order to evaluate the effects of the different substrates on the growth of switchgrass populations, the correlation coefficients were calculated between the average variations (%) of each growth parameter for the four populations and the properties of each growing substrate (Table 3).

The growth of shoot and primary leaf and the fresh weight of switchgrass populations were negatively correlated to the pH value of mixtures with the highest dose of compost ($p \leq 0.05$). For mixtures with an intermediate dose of compost, the growth of root and shoot of switchgrass populations were negatively correlated with the EC values of the mixtures ($p \leq 0.05$). All growth parameters of switchgrass populations were positively correlated to the TOC content in the mixtures with the highest dose of compost ($p \leq 0.05$ for root length and fresh weight, and $p \leq 0.01$ for shoot and primary leaf lengths). Differently, the elongation of root resulted negatively correlated to the TOC content ($p \leq 0.01$) in the mixtures with the lowest dose of compost, for which the growth of shoot appeared positively correlated with the N content ($p \leq 0.05$).

4. Discussion

It is reported in the literature that, generally, lowland ecotypes, such as *Alamo*, are taller, have fewer and larger tillers, longer and wider leaves, thicker stems and higher biomass production than upland ecotypes (Alexopoulou *et al*., 2008; Casler, 2012; Fike *et al*., 2006; Stroup *et al*., 2003). In particular, Lemus *et al*. (2002), in a study conducted on farm, found that *Alamo* population presented greater biomass and yield than the two very similar *Shawnee* and *Shelter* populations. Conversely, in the present study *Alamo* did not show the best growth performance. Thus, we can assume that the climatic parameters adopted in our experiments were not the optimum for *Alamo*.

The addition of different percentages of each compost to peat determined changes of EC, pH, TOC and total N, with respect to peat only, which resulted generally beneficial to the early growth of switchgrass. Many growing substrates prepared by mixing compost and peat favoured the elongation of roots and shoots of this plant, particularly in the case of Shawnee population. The results confirmed those of previous works, in which a partial (20%, v/v) replacement of peat with compost enhanced the health and vegetative status of the ornamental plants impatiens and China aster (Loffredo and Senesi, 2009) and philodendron (Loffredo *et al*., 2012). In the latter studies, the authors attributed the beneficial effects of compost addition to both an enrichment of nutrients and an inhibition of pathogens. Using a mixture of peat and compost from solid waste at 30% (v/v), Manios (2004) measured an increasing growth of various plants, whereas the use of highest volume % of compost caused phytotoxic effects, inhibiting both root and shoot development. Soumaré *et al*. (2003) showed a positive effect of a municipal solid waste compost on ryegrass (*Lolium perenne* L.) grown in two tropical soils. Ostos *et al.* (2008) observed positive effects on the height of *Pistacia lentiscus* L. grown on peat mixed with a municipal solid waste/sewage sludge compost. In a study using a mixture of composts and soil, Lima *et al.* (2004) measured an increase of 54% in height of corn (*Zea mays* L.) compared to the control. Similar results are reported by Roy *et al.* (2010), who found increased root and shoot lengths of corn in the presence of compost, with respect to the control.

Table 3. Correlation coefficients calculated between the average variations (%) of growth parameters of switchgrass populations and the properties of growing substrates.

[a]**Growing substrate properties**	C/P 5%				C/P 10%				C/P 20%			
	Root	Shoot	Primary leaf	Fresh weigh t	Root	Shoot	Primary leaf	Fresh weight	Root	Shoot	Primary leaf	Fresh weight
pH	+								-	-0.997 *	-0.997 *	-0.998 *
[b]EC					-0.9994 *	-0.9998 *	-		-	-	-	-
[c]TOC	-0.9999 **								0.997 *	0.99994 **	0.99998 **	0.9997 *
Total N		0.9990 *		+								

[a] Data in Table 2. [b] EC: Electrical conductivity. [c] TOC: Total organic carbon. - Negative correlation coefficient, absolute value between 0.95 and 0.99. + Positive correlation coefficient, absolute value between 0.95 and 0.99. [*]: Statistically significant at $p \leq 0.05$ (n=3; *df,* 1); **: Statistically significant at $p \leq 0.01$ (n=3; *df,* 1)

Positive effects of the mixtures of compost with peat were also observed on the primary leaf length of switchgrass plants, especially for *Shawnee, Dacotah* and *Alamo* populations. Similar stimulating effects on leaf growth were observed by the authors on plants of impatiens and China aster (Loffredo and Senesi, 2009) and philodendron (Loffredo *et al.*, 2012) whose leaves resulted increased in number and size when a mixture of compost and peat (20%, v/v) was adopted as growing substrates, with respect to peat alone. In an experiment with different tannery sludge composts, Silva *et al.* (2010) showed a significant increase in the number of leaves and fruits and stem length and chlorophyll content of capsicum plants. Beneficial effects of coir pith compost (25 g/kg of soil) were observed on the growth and quality of leaves of the mulberry plant *Morus alba* L. (Prince *et al*., 2000). Lima *et al*. (1997a) found a significant increase of leaf area and biomass production of radish (*Raphanus* sp.) as affected by the use of a urban waste compost.

An appreciable increase of fresh biomass was observed for the three populations *Shawnee, Dacotah* and *Alamo*. In several studies, the authors have observed the positive effects of the use of compost on the weight of different plants. For example, Smith *et al.* (2001) observed that the addition of compost from market and garden refuses at rates of 25% and 50% (v/v) to sandy soil improved significantly the total leaf fresh mass of Swiss chard (*Beta vulgaris* L. var. *flavescens*). Ostos *et al.* (2008) showed positive effects of the use of compost on the weight of *Pistacia lentiscus* L. In greenhouse experiments, Bernal-Vicente *et al.* (2008) found positive effects exerted by citrus compost on the weight of melon plants. Using a green compost as soil amendment, Roy *et al*. (2010) showed increased biomasses of *Zea mays*, *Phaseolus vulgaris* and *Abelmoschus esculentus*. Testing the effects of compost-based growing media on the dry weight of some bedding plants, Grigliatti *et al*. (2007) found the best results when compost was added in the growing media at rates from 25 to 50%. The observed effects were likely due to the same nutritional and protective effects reported above.

Finally, when the variations (average variation obtained for the four populations) of each growth parameter were correlated with the properties of the substrates adopted, it resulted that plant growth stimulation appeared related to some properties of composts, especially pH and TOC when an higher C/P rate was used. The negative correlations observed between plant growth and pH at the highest dose of compost could be ascribed to the high pH values of these mixtures that are greater than the pH range (pH 5.3-6.5) suggested by Abad *et al.* (2001). The positive influence of TOC of the mixtures at the highest C/P rate may be possibly related to the increased retention of water and nutrients.

5. Conclusions

The growth of the four switchgrass populations appeared generally influenced positively by the replacement of a percentage of peat with compost in the growing media. These effects depended significantly on the compost properties and dose, and on the population and plant organ considered. In particular, the lowest and intermediate doses of compost appeared more efficient for GC/P and MC/P mixtures, whereas the intermediate and the highest doses of compost showed the best results for CC/P mixtures. The beneficial effects of the compost were very evident for the *Shawnee* population, and less evident for the *Shelter* population. These results confirm the beneficial action of compost on switchgrass growth, and encourage its use as soil amendment in areas where this plant grows naturally or is cultivated. In conclusion, the application of compost could partially reduce the problem related to waste disposal, reduce the use of peat and related costs, and increase the biomass production of switchgrass populations.

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