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Animal Manure Composts as Potting Media for Production of Pepper (*Capsicum annuum*) Transplants

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ABSTRACT

Different types of growing media were evaluated in nursery-produced peppers plants (*Capsicum annuum* L. cv. 'Rouge Long'). Five local composts (C1, C2, C3, C4 and C5), based on animal-manures (chicken, sheep, cattle and horse manure), used alone or in mixture with commercial peat (PT) were tested in this study. A control of 100% PT was compared to PT: compost mixtures at 50: 50 (v/v) and to 100% compost. Various seedling parameters were measured in order to assess the quality of the nursery-produced plants. The carbon: nitrogen ratio (C/N) of the medium decreased considerably as the level of compost increased, while pH increased. Electrical conductivity of all media was high (>3 $dS.m^{-1}$). Despite the quality of the composts used (pH and salinity), growth in media consisting of composts, used at 100% or in a 1: 1 mixture with PT, was more acceptable (stem length and plant dry matter) than growth in peat alone. Although the five composts had different composition, they performed relatively similarly as potting media. No significant difference was observed between seedlings grown in 100% compost and those grown in 50% compost: 50% peat. 100% mature animal-manure composts were horticulturally acceptable as alternatives to 100% peat for pepper transplant production.

Keywords: compost mixture, peat, plant growth, substrate

INTRODUCTION

The objectives of this investigation were to characterize physical characteristics of various mixtures of substrates based on animal manure composts and to test them as a partial or total replacement for commercial peat in pepper transplant production.

Peat is extensively used as a primary component in nurseries for vegetable transplants production (Granberry *et al*. 2001). This is due to its good physical and chemical characteristics: higher organic composition and superior water holding capacity (Leclerc 2001). However, peat is becoming scarcer and more expensive. Moreover, it is generally considered to be a non-renewable resource and can present an environmental problem (Wilson *et al.* 2003; Clark and Cavigelli 2005). Therefore, other organic and inexpensive materials have to be investigated as potential alternatives to peat for use in vegetable transplant production. Many studies showed that composts generated from various kinds of wastes (animal manures, yard waste, pine bark, green waste) had a beneficial effect in nursery crop production systems (Hartz *et al*. 1996; Castillo *et al.* 2004; Clark and Cavigelli 2005; Kahn *et al.* 2005) and can serve as a partial and sometimes as complete substitute for peat in potting medium.

Composts can improve the physical and chemical properties of substrates and stabilise them microbiologically because of the large quantity of organic matter, available micronutrients and beneficial microorganisms (Mustin 1987; Biala and Wynen 1998; Fuchs 2003). Hoitink *et al.* (1997) reported that the use of compost (bark compost) in the nursery decreased production costs, improved plant growth and decreased losses caused by root rot diseases found in nurseries (*Phytophthora* spp. and *Pythium* spp.).

There have been considerable studies of various types of municipal solid waste composts, but few studies have evaluated compost from animal manures. In Tunisia, the use of compost as a horticultural substrate for vegetable transplant production is not yet well known by organic farmers, who still rely heavily on peat.

MATERIALS AND METHODS

The materials evaluated in this study included: 1) five different types of mature composts (C1, C2, C3, C4 and C5; age >1 year), based on animal manure (chicken, horse, cow, cattle) and generated by the composting unit of the Technical Center of Organic Agriculture of Chott Mariem (CTAB), Tunisia; The maturity of the used composts was previously evaluated by a phytotoxicity test carried out on barley seeds (Kerkeni 2008); and 2) a commercial peat-based medium (PT) used as control representing the conventional system used at the nurseries. Treatments were PT mixed with each of the five composts at 50: 50 (v/v) and 100% of each compost. The experiment was conducted on pepper cv. 'Rouge Long'.

Pepper seeds were placed for one week on water-soaked filter paper, in Petri dishes, in the dark at 27°C. After germination, seedlings were transplanted into alveolar flats (cell size 3.5 × 2.5 × 4 cm deep, 104 cells per flat 13 × 8) filled with tested substrates. After the middle of the flat, one row was taped over to allow two

Table 1 Composition of the different composts.

Composts	Composition
C1	50% CM + 25% SM +25% CHM
C2	50% CM + 20% SM + 20% CHM +10% Crushed straw
C3	25% CM + 25% SM + 25% CHM +25% HM
C4	40% CM + 40% SM + 20% vegetable residues
C5	25% CM+25% SM+25% CHM +23.5% HM+1.5% natural phosphate

CM: cattle manure; SM: sheep manure; CHM: chicken-manure; HM: horse manure

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media treatments to be used per flat. Each substrate occupied 48 cells per flat. No fertilizers were added to substrates. Composition of the different composts is given in **Table 1**.

Plants were observed daily and irrigated when necessary. The effect of the substrate combinations on plant growth was assessed after six weeks.

Physical properties of media

Three replicates of each substrate were initially evaluated for pH, electrical conductivity (EC), percent moisture, total porosity (TP) and C/N (carbon/nitrogen) ratio. Total porosity and percent moisture were determined in the laboratory by pF curves and calculated by the formula of Gras (1982). pH and EC were determined by preparing a suspension of media in distilled water (1: 5); pH was measured with a pH meter (model Mettler-Toledo MP225) and EC with a conductimeter (model Amel 123). Organic matter (OM) was obtained by combustion at 900°C for 2 h and C was estimated by the formula C=OM/1.72 (Reddy *et al.* 2005). N content was determined by the Kjeldahl method (Black *et al.* 1979). Substrate samples were oven-dried for 24 h at 105°C and ground with a ball mill prior to analysis.

Plant growth characteristics

Plant growth characteristics were evaluated after six weeks, the age at which plants reached commercial size. Stem length, shoot and root dry weight and total leaf chlorophyll of 12 plants collected from each substrate, were determined. Stem length was measured from the cotyledon's leaves to the shoot apex. Total leaf chlorophyll content was determined by the method of Arnon (1949) using a BECKMAN DU 640 spectrophotometer (652 nm). Dry weight of plants was determined after heating at 105°C for 24 h.

Nutritional status of pepper plants

To evaluate the nutritional status of pepper plants, 12 plants were collected from each substrate. Leaves already dried and ground to powder were further combusted at 550°C for 4 h. Then ashes were digested in nitritic acid, filtered through Whatman filter paper in a volumetric flask (100 ml) prior to analyses. The concentration of K, Mg, Ca, and Fe was determined by atomic absorption spectroscopy. Phosphorus was determined by the Olsen method (Olsen *et al.* 1954) using a colorimeter. Nitrogen was determined as previously described (Kjeldahl method).

Statistical analyses of data

An analysis of variance (ANOVA) was performed for each measured variable using the SPSS statistical program version 11.0. Mean comparison was performed by the Student-Newman-Keul's (SNK) test at the 5% level.

RESULTS AND DISCUSSION

Physical characteristics of substrates

The volume of compost added to the different substrates has a significant effect on pH. pH values increased as percentage compost increased in peat-based substrates (**Table 2**). pH values ranged from 5.71 (0% compost) to 7.37 and 8.50 in the 50% (C4) and 100% (C5) treatments, respectively. Adding composts to substrates had a variable effect on the electrical conductivity (EC). This parameter was higher than 3 $dS.m^{-1}$ for all media tested. Peat-based media had an initial CE of 4.98. Conductivities of media with 50% compost varied between 3.31 (50%, C1) and 5.63 $dS.m^{-1}$ (50%, C2) while media amended with composts alone had a CE that ranged from 3.49 to 5.56 $dS.m^{-1}$. According to Verdonck (1988), growing substrates for most vegetables should have a slightly acidic pH (5.2-6.3) and a reduced salinity (<3 dSm^{-1}). Above those values, Castillo *et al.* (2004) noted negative effects on germination and emergence of tomato seeds.

The C/N ratio was significantly higher in media containing 100% peat; it decreased significantly with increasing compost. However, the addition of 50 or 100% C3 to the substrate had a similar effect on the C/N ratio (**Table 2**). According to Mustin (1987) and Leclerc (2001), the C/N ratio of good quality compost should range between 8 and 15. Compost with a high C/N ratio (>15) is not so stable to be used as substrate due to N mineralization.

Substrates with 50% compost have superior moisture content than peat-based substrate. Therefore, moisture content of substrates with high compost volume (100%) decreased significantly in comparison to 0 and 50% compost. Moisture content of 100% compost ranged from 66.17 (C3) to 72.35 (C1). This parameter is very important for seeds, which require a high level of moisture during the first hours of germination, corresponding to the imbibition process (Castillo *et al.* 2004).

Initial total porosity was significantly higher in the peat-based substrates than in the 50 or 100% compost substrates (91.5%). It decreased in the substrates as compost content increased (**Table 2**). The higher value of porosity was noted on 50% C1 (84%). According to Verdonck (1988), porosity values measured with compost-amended substrates are not among the norms required for a material used as a substrate. According to this author, porosity should be higher than 85%.

Growth and nutritional status of pepper plants

Despite the higher pH, EC values and porosity, which are under the values recommanded by Verdonck (1988) for compost-amended substrates, significant increase in the growth of pepper plants were observed in those substrates (**Table 3**). Pepper plants grown in compost-based substrates (50 or 100%) were taller than those grown in peat-based substrates. The substrate consisting of 50% C5 improved stem length of plants more than with other combinations.

Table 2 Physical characteristics of peat-based substrates amended with 0, 50 or 100% of five types of composts

Composts (% by vol)	pH	EC ($dS. m^{-1}$)	C/N (ratio)	Moisture (%)	Total porosity (%)
0 (100 % PT)	5.71 c	4.89 ab	42.71 a	73.48 e	91.5 a
50 C1	6.93 b	3.31c	32.04 c	74.53 cb	84.0 b
50 C2	7.08 ab	5.63 a	18.89 e	75.03 b	80.9 c
50 C3	7.17 ab	4.54 abc	19.84 e	73.74 cd	81.6 c
50 C4	7.37 ab	4.33 abc	40.88 b	75.05 b	80.9 c
50 C5	7.15 ab	5.22 a	25.13 d	76.48 a	81.4 c
100 C1	7.87 ab	5.56 a	12.32 g	72.35 e	78.6 d
100 C2	7.80 ab	4.36 abc	9.39 i	68.92 f	75.1 f
100 C3	7.92 ab	5.22 a	19.91 e	66.17 h	75.4 f
100 C4	8.26 a	3.77 bc	10.76 h	68.07 g	73.0 g
100 C5	8.50 a	3.49 c	15.28f	67.65 g	77.3 e

Different letters within columns represent values that are significantly different at $P = 0.05$ based on ANOVA and SNK test. Values are the means of 3 replicates of each substrate.

Table 3 Stem length, shoot dry matter, root dry matter and chlorophyll content of pepper plants grown for six weeks in peat-based substrates amended with 0, 50 or 100% of five types of composts

Composts (% by vol)	Stem length (mm)	Shoot dry matter (%)	Root dry matter (%)	Chlorophyll content (mg/g dry matter)
0 (100%PT)	49.30 c	10.47 b	11.55 de	130.89 bcd
50 C1	70.17 ab	13.61 ab	16.56 cde	92.31 de
50 C2	70.50 ab	13.27 ab	19.69 bcd	84.04 de
50 C3	60.75 b	14.81 ab	31.13 ab	67.51 de
50 C4	63.33 b	13.84 ab	21.07 abcd	108.02 cde
50 C5	74.42 a	15.66 a	7.51 e	51.09 e
100 C1	61.50 b	13.71 ab	23.81 abcd	168.84 abc
100 C2	70.83 ab	13.05 ab	24.57 abc	131.40 bcd
100 C3	66.42 ab	14.99 ab	33.41 a	193.33 ab
100 C4	67.50 ab	13.84 ab	22.43 abcd	184.14 ab
100 C5	67.50 ab	14.06 ab	25.95 abc	206.13 a

Different letters within columns represent values that are significantly different at $P = 0.05$ based on ANOVA and SNK test. Values are the means of 12 plants.

Table 4 Nutrients content of pepper plantlets grown for six weeks in peat-based substrates amended with 0, 50 or 100% of five types of composts.

Composts (% by vol)	N (%)	P_2O_5 (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)
0 (100%PT)	1.20 i	1.21 f	29.59 e	9.91 g	11.36 j	0.31 c
50 C1	1.75 f	3.78 b	43.90 e	14.22 e	23.79 b	0.18 d
50 C2	2.45 b	1.89 e	72.31 cd	18.92 b	20.90 g	0.82 a
50 C3	1.75 f	2.52 d	60.95 d	16.95 c	21.91 f	0.29 c
50 C4	2.05 c	0.89 g	31.99 e	9.41 g	13.02 i	0.21 d
50 C5	1.30 h	2.78 c	97.88 b	22.53 a	23.36 c	0.37 c
100 C1	2.50 a	2.00 e	40.34 e	7.22 h	18.53 h	0.32 c
100 C2	0.85 j	2.94 c	70.10 cd	15.90 d	23.21 c	0.52 b
100 C3	1.50 g	2.10 e	172.10 a	14.38 e	24.58 a	0.37 c
100 C4	2.02 d	4.68 a	90.80 b	17.17 c	22.83 d	0.34 c
100 C5	1.85 e	2.89 c	81.26bc	12.32 f	22.46 e	0.30 c

Different letters within columns represent values that are significantly different at $P = 0.05$ based on ANOVA and SNK test. Values are the means of 12 plants.

Other studies (Kahn *et al.* 2005) showed, in contrast, that the addition of more than 40% of an 18 days old-compost to a peat-based media can have a negative effect on cauliflower seedlings height. This difference could be attributed to the maturity of composts used in this study, in comparison with the 18-day old-compost. In fact, our composts were aged of more than 1 year and mature enough according to the test of phytotoxicity (Kerkeni 2008). They did not affect the height of pepper seedlings.

As compost content increased in the substrate, shoot and root dry matters of pepper plants increased in comparison to those grown in peat-based substrate. All composts used at 50 or 100% caused a similar increase in shoot dry matter. For root dry matter, adding compost to the substrates showed a greater effect than shoots. Plants grown in substrates amended with 100% compost had higher root dry matter than those grown in 50% compost. Among substrates, 100% C3 improved significantly root dry matter in comparison to the control (100% peat). The increase in the total seedling dry matter content may have a positive effect in enhancing the quality of transplants. According to Tesi (1987), plants with higher dry matter content are more resistant to stress caused by transplantation and subsequent field production. This suggests that the pepper seedlings from 100 or 50% compost will have sufficient capacity to complete the transplant with better subsequent production.

Chlorophyll content increased in substrates amended with composts alone. The use of 100% C5 increased significantly leaves'chlorophyll content in comparison to control. Plants grown in 50% compost had lower chlorophyll content than those grown in peat and compost-based substrates. The same result was found by Wilson *et al.* (2003), who showed that the use of a mixture of 50% of yard trimmings compost and 50% peat decrease chlorophyll content of *Salvia* plants compared to 100% peat. Chung and Wang (2000) found a positive correlation between total chlorophyll concentrations and shoot yield of Chinese mustard. Bahmanyar and Piradshti (2008) showed that a greater concentration of chlorophyll in rice leaves, after treatment with compost, leads to a higher biomass, in comparison to non-treated plants.

Addition of composts to substrates increased N, P_2O_5 and Mg contents in pepper plants (**Table 4**) in comparison to peat-based substrate. Use of 100 or 50% compost had a different effect on these three elements. Plants grown on compost-based substrates (50 or 100%) had higher K and Ca contents than the control, except for C1 and C4. These two doses similarly affected the content of K except for C3 and C4 and affected Ca content differently. Use of 50% compost improved Ca content. Those results confirm those of Hartz *et al.* (1996), who demonstrate that macronutrient content of tomato plants grown in compost was substantially higher than that of plants grown in peat. They suggested that compost supplies some chemical elements such as N, P and K for plant uptake. Regardless of the percentage of compost added to the substrate, the majority of pepper plants had comparable leaf Fe content. Basic pH in our case seems to have no effect on the assimilation of mineral nutrients and their availability for transplantation.

All substrates tested here, according to Verdonck (1988), do not have the chemical properties required for nursery substrates; in fact, this author proposed high nutrient content as 3-10 ppm P, 60-249 ppm K, 80-200 ppm Ca and 30-70 ppm Mg. Only the needs of K were satisfied here by some substrates (50% C2, 50% C3, 50% C5, 100% C2, 100% C3, 100% C4 and 100% C5).

Despite high salinity (>3 dS. m^{-1}) and basic pH of the composts used in this study, pepper seedlings grown in 100 or 50% compost showed better growth parameters (stem length and dry matter) than those grown in 100% peat, the standard substrate usually used by farmers in nurseries. Pepper seedlings grown in 100% compost were similar to those grown in 50% compost. In contrast to other studies, showing negative effects on growth by the use of high rates of composts (>40%) in substrates, the use here of compost as the only substrate (100%) was performed better than peat and did not affect pepper growth parameters.

Dry matter content and growth parameters measured in this study (stem length, chlorophyll content, and mineral nutrition) display the capacity of pepper seedlings obtained in 100% compost, to complete the transplant with good subsequent development.

Animal-manure composts used as single substrates can be used as a cheaper substitute for the conventional system previously used at nurseries: peat, which is an expensive and non-renewable resource.

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