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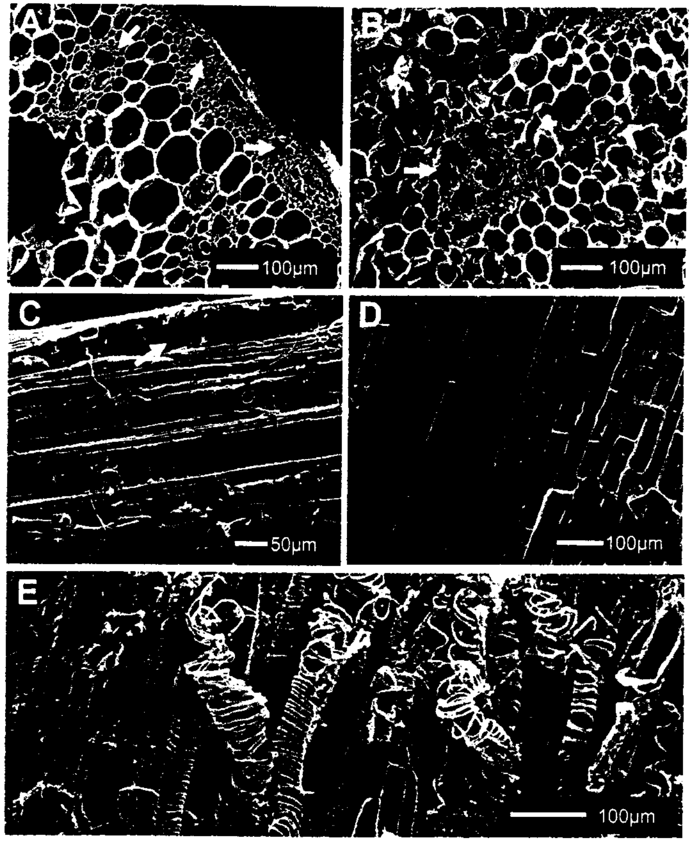

Fig. 1. a) Wheat straw after 1 week of composting. Arrows indicate where the phloem and chlorenchyma have been degraded. b) *Miscanthus* straw after 3 weeks of composting. The arrow indicates the initial signs of degradation of the phloem. c) Longitudinal section of wheat straw after 8 weeks of composting. The arrow indicates the cavity after the chlorenchyma has been degraded. d) Longitudinal section of *Miscanthus* straw after 8 weeks of composting, showing the more rigid structure. e) Longitudinal section of hemp straw after 8 weeks of composting revealing the flexible structure of the xylem secondary wall reinforcements.

Acidification of Composts from Agricultural Wastes to Prepare Nursery Potting Mixtures

C. Carrión, M. Abad, F. Fornes and V. Noguera
Instituto Agroforestal Mediterráneo
Universidad Politécnica de Valencia
Valencia
Spain

R. Puchades and A. Maquieira
Dpto. de Química
Universidad Politécnica de Valencia
Valencia
Spain

S. Botella and R. García
Dpto. de Biotecnología
Universidad Politécnica de Valencia
Valencia
Spain

Keywords: vegetable crop wastes, acidification efficiency, elemental sulfur, ferrous sulfate, microbial ecology

Abstract

The effects of powdered elemental sulfur (S^0) and ferrous sulfate ($FeSO_4.7H_2O$) on the pH of three alkaline composts prepared with residual vegetable crop biomass (melon, C1; pepper, C2 and zucchini, C3) were investigated. Composts reacted differently to the application of the amendments, the acidification efficiency averaging 43%, 50% and 36% for C1, C2 and C3, respectively. S^0 was more efficient than $FeSO_4.7H_2O$ for lowering the pH, and a saturation-like effect was found within the range of amendment rates studied. The pH decrease ranged from 0.24 to 3.03 units. This pH reduction was paralleled by an increase in compost salinity, especially with S^0. pH declined slowly and gradually with S^0, whereas $FeSO_4.7H_2O$ decreased pH soon after its application, followed by a progressive increase and subsequent stabilization. When S^0 was added to the compost, the sulfur-oxidizing bacteria population increased from 10^7 to 10^{10} CFU/g during the first 50 days of incubation, followed by a significant decrease. This initial increase in bacterial population paralleled the pH decrease observed.

INTRODUCTION

Composts from different sources and characteristics are being widely and successfully used as growing media or as growing media constituents for containerized ornamental crop production (Raviv, 1998, 2005). Nevertheless, most composts cannot be used directly in container media since pH is typically above the desirable range (Abad et al., 2001; Fitzpatrick, 2001). This high pH constitutes a significant limiting factor, particularly in nursery production, since alkaline pH often reduces the availability of nutrient elements to plants.

Composts are alkaline because they contain few exchangeable hydrogen ions and much exchangeable calcium and magnesium and sometimes, sodium. Usually, they also contain calcium and magnesium carbonates and, above pH 8.4, sodium carbonate as well. pH of alkaline composts can be lowered by using different methods: 1) by applying acidifying materials such as elemental S^0 or sulfates before media preparation (Martínez et al., 1988; Marfà et al., 1998), 2) by mixing with acidic materials like *Sphagnum* peat when preparing substrate mixtures (García-Gómez et al., 2002), and 3) by adding nitric or phosphoric acids as sources of nitrogen and phosphorus, respectively during plant growth and development (Raviv et al., 2002).

This study investigated the effects of the addition of elemental S^0 and ferrous sulfate on the pH of three alkaline composts prepared with the residual biomass of different vegetable crops.

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MATERIALS AND METHODS

Composts

Three mature composts prepared with different agricultural wastes were studied. The composts consisted of (composition expressed in% by volume): C1 - melon (75%) + yard trimmings (19%) + almond husk (6%), C2 - pepper (75%) + almond husk (15%) + yard trimmings (10%); and C3 - zucchini (70%) + cucumber (15%) + pepper (15%).

Dilute sulphuric acid and ligno-cellulolytic bacteria were added to mixtures C1 and C2. These mixtures were composted in a pilot plant (University of Almeria, Spain) using a combined system which consisted of the Rutgers static pile, with forced aeration and controlled temperature, plus pile turning- for 45 days. The composts were then left to mature for an additional 135 days. Urea and one enzyme formulae were added to C3 and composted under commercial conditions (Ejido Medio Ambiente S.A.®, Almeria, Spain) using the open windrow system with periodical pile turning. Composting for C3 lasted 60 days and at completion C3 was allowed to mature for another 15 days.

The three composts reached an acceptable degree of maturity, defined as the total organic carbon to total nitrogen (C/N) ratio reaching about 17 and the cress germination index greater than 65% of the control. pH values of 8.18, 9.27 and 9.90 were measured for C1, C2 and C3, respectively.

Titration Curves

The titration curves of the composts were obtained according to Martínez et al. (1988) to determine the dose (D) of amendment required to reach the lowest compost pH value.

Briefly, 200 ml of ferrous sulfate ($FeSO_4.7H_2O$) solutions with 17 different concentrations were added to 50 ml of compost. These solutions were prepared by diluting $FeSO_4.7H_2O$ (2% w/v) with water, the ratios ranging from 0:200 to 200:0 in a final volume of 200 ml. Suspensions (in triplicate) were incubated at room temperature and shaken daily for 45 minutes. From day 4 of incubation, pH of the suspensions was monitored daily until pH stabilized. Suspensions were then filtered and titrated with potassium permanganate.

The final pH reached in each suspension was plotted against the milliequivalents of hydrogen ions that reacted per litre of compost - calculated from the equivalent amount of iron (ferrous) - and then the D of amendment indicated above was appropriately determined.

Acidification Experiment

An acidification experiment with commercial powdered elemental sulfur (S^0, 98.5% w/w purity, particle diameter < 0.6 mm) and ferrous sulfate ($FeSO_4.7H_2O$, 98% w/w purity) was performed. The composts were amended with 0, 0.5, 0.75, 1 and 1.25 times the D determined from the titration curve.

Plastic pots (≈150 ml) were filled with 200 g of the amended composts moistened to container capacity and then incubated at 30°C and constant humidity for 70 (S^0) and 30 days ($FeSO_4.7H_2O$). Each treatment was replicated 3 times. pH and electrical conductivity (EC) of potted media were determined every 2 days during the first 10 days of incubation, and every 10 days from day 11 till pH stabilization. pH was determined via the 1:5 (v:v) water extraction method (UNE-EN 13037; UNE-EN 13038).

An acidification efficiency (*ae*,%) index was calculated according to the equation:

$$ae(\%) = \frac{pH_f - pH_i}{pH_e - pH_i} \cdot 100$$

where pH_f is the final pH reached at the end of the experiment, pH_i is the initial compost pH, and pH_e is the final pH to be expected from the titration curve.

Evolution of Microbial Populations

The changes with time in four microbial populations of compost C1 both amended with S^0 (at 1.0 times D) and un-amended (control) during 100 days of incubation under the conditions indicated in the Acidification Experiment were studied.

On each sampling date, 10 g of compost were mixed with 90 ml of sterile distilled water and continuously stirred for 1 hour at 30°C by using a horizontal shaker. Enumeration of microorganisms was carried out on micro plates by serial dilutions on solid media which were incubated at 30°C. Compost pH was simultaneously monitored as described previously.

The microbial populations under study and the media used for their growth were: 1) Plate Count (Difco) for total aerobic bacteria; 2) Medium 126 (Institut Pasteur) for sulfur-oxidizing bacteria; 3) Actinomycete Isolation Agar (Difco) for actinomycete; and, 4) Sabouraud (Difco) for fungi and yeast.

RESULTS AND DISCUSSION

Titration Curves

To lower the pH of the alkaline composts so they may be used for containerized crop production requires the specific titration curve for the compost. From this titration curve, the amount of amendment required to reach an acceptable/optimum pH could be accurately determined. The titration curves obtained for composts C1, C2 and C3 are presented in Fig. 1, where the regression equations and their coefficients of determination (R^2) as well as the minimum pH (pH min) achieved during the titration trial are also indicated. The graph for C1 showed a slope less pronounced than that for C2 and for C3, thus indicating that hydrogen ion requirements of C1 will be higher than for C2 and C3. This relatively greater amount of amendment required for C1 is probably related to the higher buffer capacity (i.e., cation exchange capacity, exchangeable cations as well as calcium, magnesium, and sodium carbonates contents) found in this material compared with that of C2 and C3 (data not shown).

Acidification Experiment

This experiment which was carried out under controlled conditions, i.e., air temperature and compost humidity, studied the mechanism and the acidification efficiency of S^0 and $FeSO_4.7H_2O$.

The final pH (pH_f) achieved at the end of the experiment, the pH decrease (ΔpH) obtained according to the initial compost pH, the final pH to be expected (pH_e) from the titration curve, and the acidification efficiency (*ae*,%) for each of the composts, acidifying materials, and amendment D studied, are presented in Table 1.

Composts reacted differently to the application of the amendments, the acidification efficiency averaging 43%, 50% and 36% for C1, C2 and C3, respectively. In addition, the amendments differed in their ability to reduce pH, S^0 being more efficient than $FeSO_4.7H_2O$. It appears that a saturation-like effect within the range of the amendment D studied occurred and no significant differences between amendment rates higher than 0.75 x D were observed. The *ae* varied between 18% (corresponding to a pH decrease of 0.24 units) and 78% (corresponding to a pH decrease of 3.03 units) for treatments C1 plus 0.5 x D of $FeSO_4.7H_2O$ and C2 plus 1.25 x D of S^0, respectively. No treatments herein reached the final pH expected from the titration curves, however, the extent of pH decrease (ΔpH) increased as the amendment rates increased.

In the three composts studied the pH decrease brought about by the amendments was paralleled by an increase in compost EC, particularly with S^0 (Table 2). In addition, this EC increase was closely and positively related to the D of the amendment, with a saturation-like effect at doses greater than 0.75 x D.

The duration of the acidification experiment varied depending on the amendment used; with S^0 it required 70 days to reach a stable pH, whereas $FeSO_4.7H_2O$ required less than 30 days (Fig. 2). Further, the pattern of compost pH evolution throughout the experiment was highly dependent on the amendment used. pH declined slowly and gradually with S^0, whereas $FeSO_4.7H_2O$ caused a rapid drop in compost pH soon after its application, followed by a progressive increase and subsequent stabilization (from day 15).

Changes in Microbial Populations during Compost Acidification

The variation of microbial populations (total aerobic and sulfur-oxidizing bacteria, actinomycete, fungi, and yeast) associated with the biological oxidation of S^0 was investigated.

The addition of S^0 to compost C1 led to a gradual decrease in the pH (from 8.25 to 6.60) during the first 30 days of incubation (Fig. 3b), and then it remained nearly unchanged until day 100. By contrast, pH in the control (no S^0) did not vary significantly during the experiment (Fig. 3a). This differential pH response was probably due to the production of sulphuric acid in the amended compost (data not shown).

In the S^0 amended compost, the sulfur-oxidizing bacteria population increased (from 10^7 to 10^{10} CFU/g) during the first 50 days and decreased subsequently, reaching the initial level after 100 days of incubation (Fig. 3b). The initial increase in this bacterial population paralleled the pH decrease observed. Nevertheless, the other microbial populations studied (total aerobic bacteria, actinomycete, fungi and yeast) remained stable during the experiment. In the un-amended compost, small and non-significant fluctuations in the populations studied were observed (Fig. 3a). In this compost, the sulfur-oxidizing bacteria population decreased from day 50 to day 70.

CONCLUSIONS

Powdered elemental S^0 and ferrous sulfate are two amendments which effectively lower the pH of alkaline composts - from residual vegetable crop biomass - before growing media preparation. Further, elemental S^0 was shown to be more effective than ferrous sulfate in pH correction.

Based on the results obtained from this research, a compost acidification program should be developed under commercial conditions, and the effects of the amended composts on both plant growth and mineral nutrition of containerized ornamental crops should be further investigated. Additionally, whether ferrous sulfate reduces the availability of phosphorus to plants because of the application of large amounts of iron should be studied.

ACKNOWLEDGEMENTS

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Tables

Table 1. Final pH (pH_f) achieved at the end of the acidification experiment, pH decrease (ΔpH) obtained according to the initial compost pH, and acidification efficiency (*ae*,%) for each of the composts, acidifying materials, and amendment doses studied.

			S^0			$FeSO_4 \cdot 7H_2O$		
Compost	Dose	*pHe*	*pHf*	ΔpH	*a.e.*	*pHf*	ΔpH	*a.e.*
C1	0.50xD	6.85	7.66	0.52^{h}	39^{ef}	7.94	0.24^{i}	18^{e}
	0.75xD	6.53	7.30	0.88^{f}	53^{cd}	7.83	0.35^{h}	21^{e}
	1xD	6.22	7.08	1.10^{e}	56^{bc}	7.25	0.93^{e}	48^{a}
	1.25xD	5.93	6.83	1.35^{c}	60^{b}	7.10	1.08^{d}	48^{a}
C2	0.50xD	7.19	8.57	0.70^{g}	34^{f}	8.48	0.79^{f}	38^{c}
	0.75xD	6.66	7.98	1.29^{cd}	50^{d}	8.15	1.12^{d}	43^{b}
	1xD	6.06	7.51	1.76^{b}	55^{bcd}	7.67	1.60^{b}	50^{a}
	1.25xD	5.39	6.24	3.03^{a}	78^{a}	7.37	1.90^{a}	49^{a}
C3	0.50xD	7.59	9.42	0.48^{h}	21^{g}	9.27	0.63^{g}	27^{d}
	0.75xD	7.12	8.73	1.17^{de}	42^{ef}	8.83	1.07^{d}	39^{bc}
	1xD	6.64	8.66	1.24^{cde}	39^{ef}	8.71	1.19^{d}	38^{c}
	1.25xD	6.44	8.55	1.35^{c}	39^{ef}	8.55	1.35^{c}	39^{bc}
P		nd	nd	***	***	nd	***	***

pH_e = final pH to be expected from the titration curve. D = dose of amendment required to reach the lowest compost pH value. P = level of significance. nd = not determined. *** Significant at $P \leq 0.001$. Mean separation within columns by Newman-Keuls' multiple range test at $P = 0.05$.

Table 2. Treatment main effects of composts (C1, C2 and C3) on the pH decrease (ΔpH) and electrical conductivity increase (ΔEC, dS/m).

Treatment main effect	Compost C1 ΔpH	Compost C1 ΔEC	Compost C2 ΔpH	Compost C2 ΔEC	Compost C3 ΔpH	Compost C3 ΔEC
A. Acidifying material						
S^0	0.97	1.57	1.70	1.09	1.06	1.70
$FeSO_4.7H_2O$	0.64	0.08	1.36	1.31	1.05	1.90
P	***	***	***	***	ns	ns
B. Dose						
0.50xD	0.38^{d}	0.79	0.75^{d}	0.60^{c}	0.56^{d}	0.87^{b}
0.75xD	0.61^{c}	0.69	1.21^{c}	1.48^{a}	1.13^{c}	1.86^{a}
1xD	1.01^{b}	0.69	1.68^{b}	1.38^{b}	1.22^{b}	2.21^{a}
1.25xD	1.21^{a}	1.12	2.47^{a}	1.35^{b}	1.31^{a}	2.26^{a}
P	***	ns	***	***	***	***
C. Interaction AxB						
P	***	ns	***	**	*	ns

D = dose of amendment required to reach the lowest compost pH value. ns, *, ** or *** = not-significant or significant at $P \leq 0.05$, $P \leq 0.01$ or $P \leq 0.001$, respectively. Mean separation within columns by Newman-Keuls' multiple range test at $P \leq 0.05$.

Figures

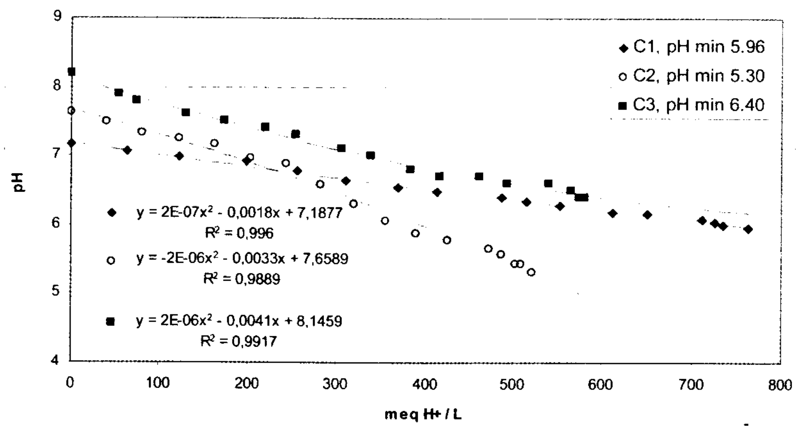

Fig. 1. Titration curves of the composts studied (C1, C2 and C3). pH min = minimum pH reached during the titration trial.

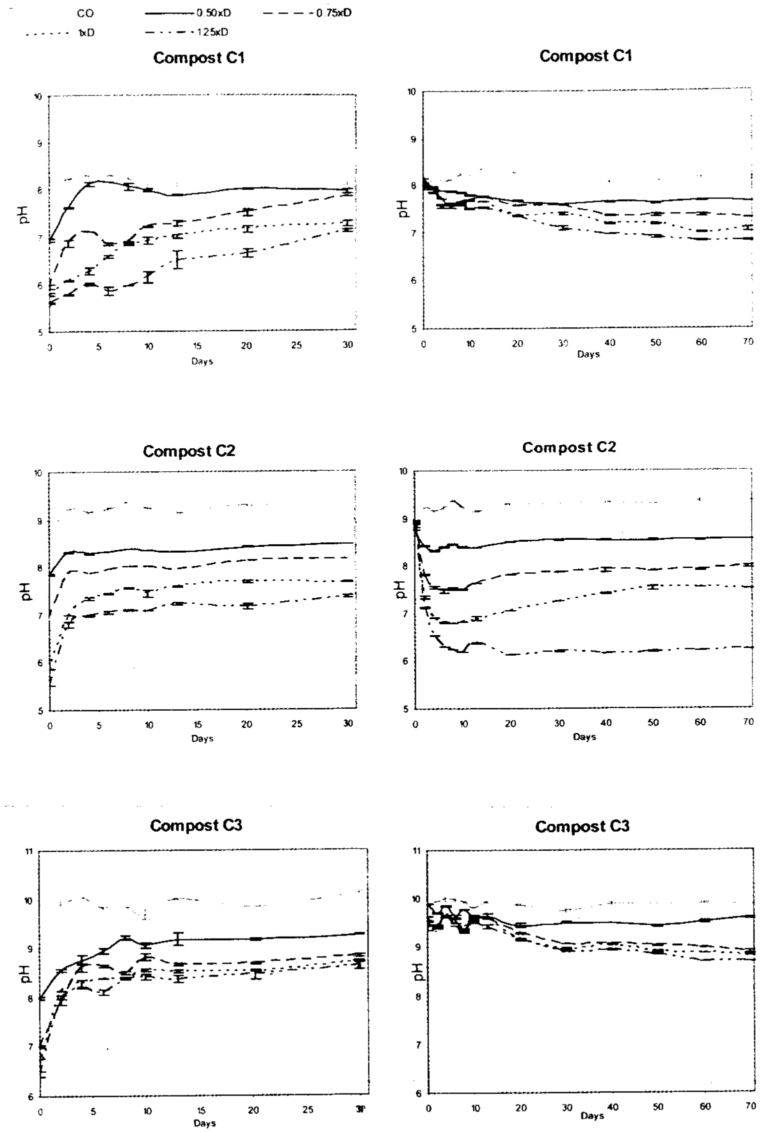

Fig. 2. Evolution of the pH of the composts (C1, C2 and C3) amended with $FeSO_4.7H_2O$ (left column) or S^0 (right column). Vertical bars indicate the standard error of the mean. CO = control (un-amended). D = dose of amendment required to reach the lowest compost pH value.

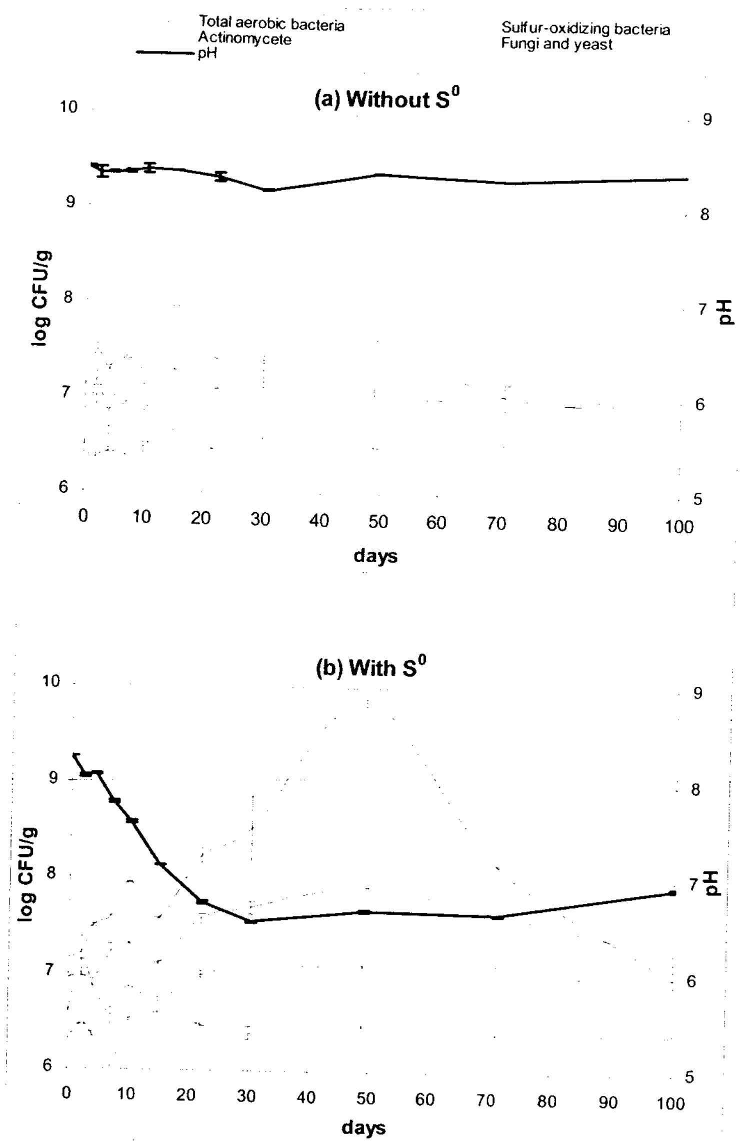

Fig. 3. Evolution of the pH and the microbial populations in compost C1. (a) Without S^0 (control). (b) With S^0. Vertical bars indicate the standard error of the mean.

Effect of Organic Mulches on the Growth of Tomato Plants and Quality of Fruits in Organic Cultivation

I. Bender and M. Raudseping
Jõgeva Plant Breeding Institute
Jõgeva
Estonia

S. Vabrit
Institute of Agricultural and Environmental Sciences
Estonian University of Life Sciences
Tartu
Estonia

Keywords: cracking, length of roots, soil-root sample, unheated greenhouse, vegetative growth

Abstract

Organic mulch covers are easily available and cheap in Estonia. Therefore, investigations into their suitability for tomato cultivation in organic conditions were carried out. The trial was set up in unheated plastic greenhouse in the soil. The influence of mulches made of tree leaves, red clover green mass and grass green mass on plant growth height and fruit cracking was studied. The mulches were spread one month after the planting of tomatoes in a 10 cm thick layer. The treatment without mulch cover was used as control. The height of the plants was measured once a week and a total of five times before harvesting. To find relationship between treatment and root parameters, soil samples were taken from depth of 0–10 cm and 11–20 cm. From the trial data, it can be concluded that the share of cracked fruits was significantly (P=0.05) lower only in red clover treatment of one variety among five. Grass mulch caused significantly negative effect on cracking of 4 varieties probably because of lower covering ability of this material. There were bigger differences between varieties than mulch treatments in the height of tomato plants. In all the mulch treatments the roots located more in upper soil layers compared with control. Differences in root parameters were discovered depending on the mulch type.

INTRODUCTION

Tomato cultivation among the other vegetables faces challenges in producing crops without chemicals for weeds control. Use of several kinds of mulches gives the opportunity effectively control weeds, regulate soil temperature and also evaporation from the soil (Schonbeck and Evanylo, 1998; Bleyaert, 1990; Kristiansen et al., 2003; Guerineau et al., 2004; Radics and Bognar, 2004).

Organic mulching materials may be a viable option for vegetable growing (Grassbaugh et al., 2004). Several studies have described how mulches influence tomato vegetative top growth (Wien et al., 1993; Agele et al., 1999; Hudu et al., 2002; Guerineau et al., 2004; Parris et al., 2004). Mulching may improve quality of fruits by decreasing of cracking (Bleyaert, 1990; Schonbeck et al., 1995). Mulch cover facilitates root proliferation and root length (Gutal et al., 1992; Agele et al., 1999).

Use of organic mulches as moisture retainers and temperature regulators in tomato organic cultivation have been studied in low level in Estonia. Therefore the topic of the study is necessary. Herbal material and tree leaves are easily available and cheap for use as mulches in unheated greenhouses for weed control. The objective of the present research was finding out influence of several kinds of organic mulch covers on growth, share of cracked fruits, root parameters and distribution of roots in the soil.

MATERIALS AND METHODS

Data was collected from organic cultivation in unheated plastic greenhouse (9 x 26 m) at Jõgeva, Estonia, in 2004. Soil was fertilized with cattle manure. Tomato plants were irrigated through the tubes in the soil once or twice per week. Tomatoes were planted in double rows (90 x 40 cm) at spacing of 40 cm, 6 plants per plot in the middle of May. Tomatoes were grown without any mineral fertilizers and pesticides.

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Executive Director of ISHS
Ir. J. Van Assche

Secretariat of ISHS
PO Box 500
3001 Leuven 1
Belgium

Phone: +32.16.22 94 27
Fax: +32.16.22 94 50
E-mail: info@ishs.org
Internet: www.ishs.org

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