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Full Length Research Paper

Utilizing Composted Agricultural Residues to Enhance Potting Soil Quality

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Four agricultural residues namely, sheath of peanut pods, flax shivers, red sawdust and white sawdust, were composted with different amendments for four months under greenhouse and field conditions. Results emphasized that composting proceeded at different rates and was principally influenced by the type of residues and/or added amendments. Initial bio-fortification of residues with cellulose decomposing microorganisms, exhibited a recognized trend of stimulation and led to a higher rate of organic carbon loss. Percentage losses in organic carbon of the sheath of peanut pods after composting were higher in biofortified treatment. The organic accelerator associated with bio-fortification, led to a loss in the organic carbon amounting to 15.61% of the initial value of flax shivers, after 120 days of composting. Bio-fortification of red sawdust receiving either an organic or a chemical accelerator increased the amounts of bio-oxidized organic carbon to 9.13% in the control and to 16.45 or 12.97% respectively, in amended red sawdust. In white sawdust, the differences in the percentage of oxidized carbon were hardly detectable. The nitrogen (N) concentrations increased in the final compost and the largest amount was found in the sheath of peanut pods, reaching 2.6%. The level of total nitrogen was more or less the same in composts prepared from either flax shivers, red or white sawdust where it was 1.65, 1.63 and 1.5%, respectively. Oxidation of organic matter associated with the increase in nitrogen concentrations, whether initially or during composting, led to a reduction in carbon/nitrogen (C/N) ratios in the final composts. Generally, all biofortified composts had narrower C/N ratios compared to the non-biofortified ones. The lowest organic carbon and total nitrogen contents and consequently C/N ratios were found in sheath of peanut pods compost compared to other residues. Initial neutral pH values of different composted residues were slightly shifted towards acidity before settling around neutrality. Total soluble salts in the final composts varied within the type of agricultural residues used. Nevertheless, values in all composts at the end of the composting did not exceed safe levels.

Key words: Potting soil, bio-fortification, composting, agricultural residues and cellulose decomposing microorganisms.

INTRODUCTION

Potting soil is usually prepared by composting various organic residues and used to grow certain horticulture plants in contained greenhouses. The best potting mixture in which plant can grow well should have proper chemical, biological and physical characters related to their bulk and particle density, particle size distribution and water holding capacity as well as C/N ratio, cation exchange capacity, buffering action, quantity and availability of nutrients and pH value, that furnish a good ecosystem for plant growth. No doubt, microorganisms have a beneficial role both in composting and bio-furnishing potting soils. Saber (1996) confirmed that bio-fortification with a mixed culture of aerobic cellulose decomposing microorganisms, gives rise to composting

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of many agricultural residues to potting soils. The present work aims to maximize the role of cellulose decomposing microorganisms, on composting certain agricultural residues to potting soil.

MATERIALS AND METHODS

Greenhouse trails

Four agricultural residues, that is, shell of peanut pods, flax shivers, red sawdust (inner wood of red cedar tree) and white sawdust (inner wood of spruce tree), were composted to a potting soil in plastic bags under different experimental treatments, including cellulose decomposing bacteria fortification, chemical fortification, chemical and microbial fortification, organic fortification, organic and microbial fortification, as well as the control. Agricultural residues were air-dried, sieved to pass through a 2 mm sieve and moistened to 70% of their water holding capacity. Each residue was composted in association with either a chemical accelerator composed of 7 kg superphosphate, 1.25 kg potassium sulfate, 40 kg ammonium sulfate and 35 kg calcium carbonate and 100 kg fertile soil, with an initial C/N ratio of 13, per ton of dry matter) or an organic accelerator (100 kg of chicken manure, with an initial C/N of 10.3, per ton of dry matter). Control bags received neither chemical nor organic accelerator.

Each treatment, as well as control, was divided into two sub-groups, the first was biofortified with a suspension of cellulose decomposing microorganisms and the second was kept without bio-fortification. Treated and untreated agricultural residues were put in a sufficient number of net plastic bags, containing 1 kg each and were turned off every two weeks. The moisture content during 120 days composting period was kept at a proper level throughout irrigation. Samples from each replicate were collected initially and after 15, 30, 60, 90 and 120 days for chemical and microbiological analyses.

Field trails

Two compost heaps, 500 kg each, using red or white sawdust were built in rows. The agriculture residues were thoroughly mixed with a chemical accelerator at the rate of 40 kg ammonium sulfate, 7 kg superphosphate, 1.25 kg potassium sulfate, 35 kg calcium carbonate and 100 kg fertile soil per ton. The heaps were built in ten successive layers and attention was paid to maintain moisture at a proper level for microbial proliferation. Both heaps were left for a 120 days composting course and were turned over and rebuilt again three times after 15, 30 and 60 days.

Chemical and physical methods

The dry matter was recorded after drying the plant samples at 70°C in a hot air oven until constant weight. Total nitrogen was determined by the semi-microkjeldahl method using H_2SO_4 and H_2O_2, diluted sulfuric acid was used for titration with bromocresol green-methyl red mixture (Horowitz, 1980). Organic matter was determined by loss on ignition in a muffle furnace at 900 + 25°C for h. (Michiels et al., 1979). Values of pH were determined in a paste 1:2.5 soil/water, after standing for 2 h, using the glass electrode method. Electrical conductivity (E.C.) was determined in soil using a conductivity bridge in 1:5 soil/water suspensions. Electrical conductivity of potting soil was determined by weighting 5 g compost in an Erlenmeyer 250 ml and adding 100 ml distilled water, shaking for 1 h, filtering and measuring E.C. in the same way as explained for soil (Michiels et al., 1979). Soil water holding capacity was determined using Keen and Raezkovski box.

RESULTS

Chemical changes took place during composting of the four agricultural residues were followed up for four months. Initial incorporation of chicken manure as an organic accelerator to the different agricultural residues, slightly raised their organic carbon contents. Biological oxidation of organic matter during the composting course led to a persistent decrease in the organic carbon contents in the different composted materials, yet at varied rates. Such decreases exhibit the efficiency of biomass in decomposing the raw materials. Data in Table 1 shows that biofortification of agricultural residues with cellulose decomposing microorganisms, led to a higher rate of organic matter oxidation. The percentage losses in organic carbon of the sheath of peanut pods, after 120 days composting period were higher in biofortified treatments associated with either chemical or organic accelerator. Nevertheless, the differences between the influences of the two accelerators were slight. The final organic carbon contents were 72 and 71% of their initial values in biofortified composts, receiving respectively either chemical or organic accelerator, while it was 83% in control compost.

In the case of flax shivers, bio-fortification with cellulose decomposing microorganisms exhibited the same effect, despite being at a lower rate. Generally, most biofortified composts lost more organic carbon during the composting course compared to non-biofortified ones. Results show that the organic accelerator associated with bio-fortification led to a loss in the organic carbon, amounting to 16% of the initial value after 120 days of flax shivers composting. However, the chemical accelerator associated with bio-fortification resulted in slightly smaller losses in organic carbon, the differences were not appreciable.

Bio-fortification of red sawdust receiving either chicken manure as an organic accelerator or a chemical accelerator, raised the amounts of bio-oxidized organic carbon to 9% in control and 17 or 13% respectively, in both amended raw materials. The amounts of organic carbon lost in the absence of bio-fortification with cellulose decomposing microorganisms, followed the same trend, but were much smaller. White sawdust composting followed the same aforementioned trend but at varied rates. The differences in the percentage of oxidized carbon were small and were more or less within the same range. The rate of organic carbon oxidation during the composting period varied between the four raw materials tested. The greatest losses were reached in biofortified composts receiving chicken manure. The oxidation of organic carbon was greatest in case of sheath of peanut pods, followed by red sawdust and flax shivers and was smallest in case of white sawdust. It was found that 71, 84, 84 and 89% respectively of the initial

Table 1. Effects of different treatments on carbon percentage in the investigated agricultural residues (oven dry basis).

Treatments	Time in days					
	0	15	30	60	90	120
	Sheath of peanut pods					
Control	40.73	38.70	36.63	35.86	34.30	33.78
CDB	40.15	36.56	34.80	33.70	33.54	33.14
Chemical	39.17	35.75	34.39	33.36	33.03	32.31
Chemical + CDB	40.11	34.38	32.25	31.00	29.44	29.00
Organic	41.33	36.33	33.78	33.65	33.21	33.25
Organic + CDB	42.00	36.18	33.46	33.14	32.34	30.00
	Flax shivers					
Control	48.05	44.70	43.62	42.92	41.84	41.84
CDB	50.50	47.00	45.99	45.19	44.37	43.98
Chemical	46.90	43.39	42.75	41.68	41.25	40.81
Chemical + CDB	48.82	45.14	44.47	42.98	42.51	42.28
Organic	48.12	43.95	43.18	42.36	41.86	40.56
Organic + CDB	51.53	46.83	46.06	45.29	44.79	43.49
	Red sawdust					
Control	44.64	44.14	43.92	43.50	43.43	42.87
CDB	45.82	44.18	43.39	42.93	42.20	41.64
Chemical	45.63	43.81	43.15	42.72	42.15	41.37
Chemical + CDB	46.57	43.76	42.79	41.84	41.18	40.53
Organic	47.00	44.01	43.50	42.99	42.31	41.93
Organic + CDB	47.31	41.97	41.19	40.50	40.01	39.53
	White sawdust					
Control	46.66	45.77	45.08	44.66	44.32	44.18
CDB	48.63	47.43	46.73	46.09	45.46	44.67
Chemical	48.63	47.43	46.73	46.09	45.46	44.67
Chemical + CDB	48.93	47.50	46.96	46.23	44.91	44.37
Organic	49.00	47.44	46.64	46.16	45.43	44.74
Organic + CDB	49.15	46.05	45.66	44.80	44.13	43.87

CDB= cellulose decomposing microorganisms, Chemical= chemical accelerator, organic accelerator. (Average of four replicates).

values, represented the amounts of organic carbon found after 120 days.

Results exhibited an initial increase in the total nitrogen contents of the different raw materials, as a result of supplementation with either chemical or organic accelerators. The increases in total nitrogen contents proceeded at varying rates throughout the composting course, due to the activation of free living nitrogen-fixing diazotrophs. Also, the decomposition in organic matter through bio-oxidation, raised the percentage of total nitrogen in the composts compared to their initial values. During the composting course of sheath of peanut pods, the total nitrogen values in the different treatments increased by 112 and 127% of their initial values, respectively in non-biofortified and biofortified controls (Table 2). However, the increases recorded in total nitrogen contents in the chemically accelerated sheath of peanut pods, reached 168 and 174% from their initial values, at the end of 120 days composting in non-biofortified and biofortified treatments respectively. The highest increase in total nitrogen, was found in the case of sheath of peanut pods amended with chicken manure, as an organic accelerator. Total nitrogen increased by 194 and 213%, from the initial values in non-biofortified and biofortified composts respectively.

Composting of flax shivers under the different treatments, led to variable increases in total N contents. The greatest increases were recorded in flax shivers composts supplemented with the organic accelerator, followed by those receiving a chemical accelerator. Generally, the increase in total N was greater in biofortified composts even in controls. Bio-fortification

Table 2. Effects of different treatments on nitrogen percentage in the investigated agricultural residues (oven dry basis).

Treatments	Time in days					
	0	15	30	60	90	120
	Sheath of peanut pods					
Control	1.10	1.07	1.10	1.20	1.20	1.23
CDB	1.10	1.00	1.20	1.31	1.33	1.40
Chemical	1.30	1.73	1.78	2.00	2.17	2.19
Chemical + CDB	1.32	1.80	2.00	2.20	2.30	2.30
Organic	1.16	2.10	2.30	2.30	2.31	2.25
Organic + CDB	1.25	2.28	2.43	2.53	2.59	2.66
	Flax shivers					
Control	0.35	0.37	0.38	0.41	0.43	0.42
CDB	0.36	0.38	0.42	0.45	0.45	0.44
Chemical	0.69	0.79	0.98	1.10	1.20	1.20
Chemical +CDB	0.71	0.83	1.00	1.20	1.31	1.30
Organic	0.73	0.87	1.15	1.38	1.53	1.50
Organic + CDB	0.79	0.96	1.26	1.59	1.66	1.65
	Red sawdust					
Control	0.15	0.17	0.23	0.25	0.26	0.25
CDB	0.16	0.19	0.25	0.29	0.33	0.40
Chemical	0.47	0.67	0.88	1.00	1.10	1.00
Chemical + CDB	0.47	0.69	0.91	1.31	1.37	1.35
Organic	0.43	0.71	0.95	1.23	1.29	1.20
Organic +CDB	0.46	0.75	0.99	1.68	1.65	1.63
	White sawdust					
Control	0.11	0.12	0.13	0.15	0.17	0.18
CDB	0.12	0.15	0.21	0.25	0.27	0.25
Chemical	0.48	0.50	0.80	0.91	1.15	1.05
Chemical +CDB	0.49	0.53	0.90	1.00	1.20	1.20
Organic	0.46	0.58	0.87	1.00	1.46	1.43
Organic + CDB	0.46	0.60	0.99	1.30	1.50	1.50

CDB = cellulose decomposing microorganisms, chemical= Chemical accelerator, organic accelerator. (Average of four replicates).

increased the total N contents in compost from the initial values after 120 days from 120 to 122% in controls, and from 174 to 183% in composts enriched with the chemical accelerator and from 206 to 209% in composts enriched with the organic accelerator.

Both red and white sawdust had low contents of total nitrogen, that is, 0.15 and 0.11% respectively. The initial treatments increased the total N contents several times to 0.47% in the case of red sawdust and to 0.48% in the case of white sawdust. The organic accelerator led, more or less, to the same increases amounting to 0.43% in the case of red sawdust and 0.46% in the case of white sawdust. These increases markedly raised the total N contents at the end of sawdust composting, over those recorded in other local composts. This however, might be ascribed to the initial low contents of total N. Such increases amounted to 167 and 250% from the initial values in non-biofortified and biofortified controls of red sawdust compost respectively. However, the recorded increases in total N contents in red sawdust composts from the initial values, reached 213, 287 and 279, 354% in non-biofortified and biofortified composts receiving either chemical or organic accelerator respectively. More or less the same level of total N contents was recorded in the case of white sawdust composts and the results followed the same trends displayed in the case of red sawdust. The total N contents increased by 164 and 208% from the initial values, in non-biofortified and biofortified control composts respectively. While in composts receiving either chemical or organic accelerator, the increases in total N contents reached 219, 244 and 311, 326%, from the initial values, in

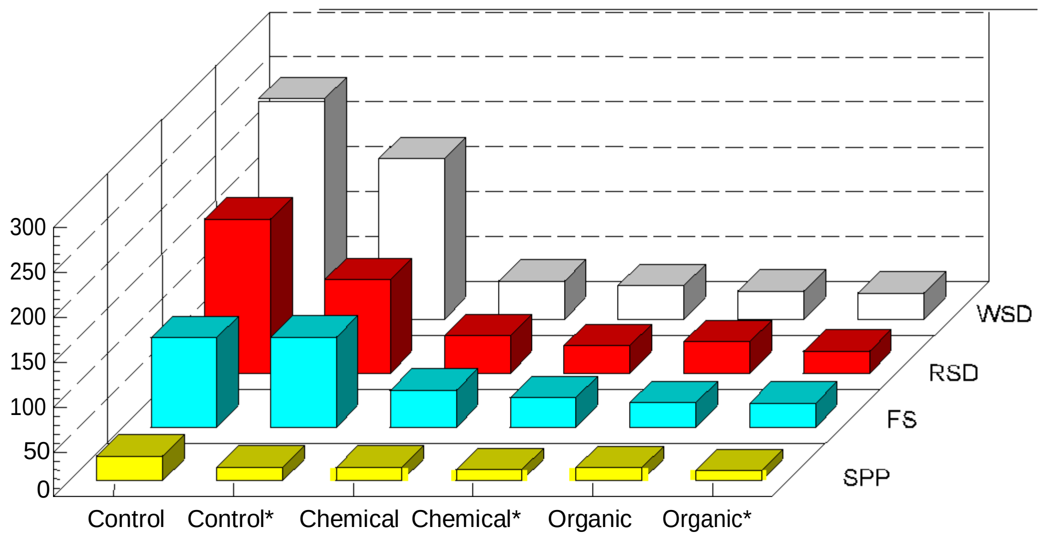

Figure 1. Changes in C/N ratio of different raw materials used during composting. *Biofortified with cellulose decomposing microorganisms; Spp = Sheath of peanut pods, FS= Flax shiver, RSD= Red sawdust, WSD= White sawdust.

Table 3. Effects of different treatments of on pH in the investigated agricultural residues (oven dry basis).

Treatments	Sheath of peanut pods		Flax shivers		Red sawdust		White sawdust	
	I	F	I	F	I	F	I	F
Control	6.56	6.37	7.10	7.00	6.84	7.00	7.00	7.12
CDB	6.57	6.57	7.00	7.03	6.95	7.00	6.85	7.0
Chemical	6.38	6.38	6.92	7.11	6.70	7.03	6.50	7.00
Chemical + CDB	6.44	6.58	6.97	7.00	6.66	7.01	6.45	6.80
Organic	6.94	6.93	6.80	7.13	6.94	7.01	6.80	7.00
Organic + CDB	6.65	6.65	6.80	6.89	7.11	7.00	6.91	6.57

CDB= cellulose decomposing microorganisms, Chemical = chemical accelerator, Organic accelerator. (Average of four replicates).

non-biofortified and biofortified treatments respectively.

The N contents in the final compost increased according to the type of different raw materials. The largest amount was found to be in the sheath of peanut pods reaching 2.6%. The level of total N was more or less the same in composts prepared from either flax shivers, red or white sawdust where it was 1.65, 1.63 and 1.5%, respectively. The C/N ratio in the final compost is usually used as an indicator for evaluating their suitability and maturity (Figure 1). In case of sheath peanut pods, the C/N ratios in the final composts ranged between 27.00 in non-biofortified controls and 11.28 in biofortified composts receiving organic accelerator. Nevertheless, the chemical accelerator led to more or less the same value of C/N ratio. The final C/N ratios in the flax shivers were 99.6 and 100 in non-biofortified and biofortified composts. On the other hand, the C/N ratios were calculated as 40.81, 32.52 and 26.88, 26.21 in case of biofortified and non-biofortified composts receiving respectively either chemical or organic accelerator.

Incorporation of the chemical accelerator with either red or /and white sawdust resulted in a narrowing in C/N ratios in the final compost 41.37, 30.64 and 42.54, 36.97 in non-biofortified and biofortified red and white sawdust represented the calculated C/N ratios respectively. The influence of the organic accelerator, however, on composting of either red or white sawdust far exceeded that of the chemical one. The calculated C/N ratios in the final compost were 34.24, 24.25 and 31.28, 29.24 respectively, in non-biofortified and biofortified red and white sawdust.

Data in Table 3 reveal that initial pH values of composted material were lowest in case of sheath of peanut pods (6.5) and highest in case of flax shivers (7.1). The incorporation of the chemical or organic accelerator in the presence and absence of

Table 4. Effects of different treatments on EC (dS/cm) in the investigated agricultural residues (oven dry basis).

Treatments	Sheath of peanut pods		Flax shivers		Red sawdust		White sawdust	
	I	F	I	F	I	F	I	F
Control	1.58	1.51	0.47	0.47	0.60	0.59	0.50	0.53
CDB	1.40	1.38	0.65	0.63	0.50	0.50	0.50	0.49
Chemical	3.30	3.27	2.10	2.08	2.43	2.31	2.50	2.43
Chemical + CDB	2.93	2.90	2.26	2.13	2.57	2.40	2.20	2.20
Organic	1.70	1.70	1.08	1.00	1.00	0.93	1.00	1.00
Organic + CDB	1.63	1.65	1.20	1.20	1.00	1.00	1.00	1.00

CDB= cellulose decomposing microorganisms, chemical = chemical accelerator, organic accelerator, I= initial, F=final. (Average of four replicates).

biofortification with cellulose decomposing microorganisms did not show any marked changes in the recorded initial pH values. Nevertheless, the effect of biofortification was small in comparison with that of acceleration with either organic or chemical additives. The initial values of total soluble salts expressed in terms of electrical conductivity units, given in Table 4, were increased as a result of treating the different plant materials with any of the chemical or organic accelerators. The added soluble salts through the chemical accelerator far exceed those added with the organic accelerator. Biofortification did not exert any initial influence on the amounts of total soluble salts. It is worth mentioning that, although the total soluble salts in sheath of peanut pods were at least three fold greater than those measured in flax shivers, red sawdust or white sawdust, yet they did not reach an injurious level (which is 6 dS cm^{-1}).

DISCUSSION

The most important parameters in relation to composting were changes in organic carbon, total nitrogen, C/N ratio and pH value. These changes reflect the extent of the bio-transformations that took place in the different composts in chemical terms. Also, changes in the total soluble salts are of substantial importance in evaluating the quality of the potting soils compost (Fialho et al., 2010). Results obtained emphasized that the composting process proceeded at different rates and was principally influenced by the type of raw materials and/or the type of added amendments.

Biofortification with cellulose-decomposing microorganisms stimulated the rate of bio- oxidation of organic matter. Percentage losses in organic carbon after 120 days composting period were greater in biofortified treatments associated with either chemical or organic accelerators. Nevertheless, the differences between the influences of the two types of accelerators were slight. Biofortification exerted substantial differences in C/N ratios in the final compost as achieved by Kostov et al. (1991) who found that sawdust had greater microbial biomass, greater CO_2 evolution, greater ammonification and more actinomycetes but less nitrification and fewer fungi compared with bark. All groups and activities were greater in sawdust and bark compared with the soil used as the substrate. They stated that cellulose decomposing strains of *Bacillus sp., Cephalosporium sp*. and *Streptomyces sp*. sometimes increased these activities but only marginally. Generally, all biofortified composts have had narrower C/N ratios compared to the non-biofortified ones. However, this holds true for all the four tested raw materials. Otherwise, an immobilization of nitrogen and other macro- and/or micronutrient elements, might be expected in soil with small amounts of available nitrogen, receiving compost having a wide C/N ratio (Zeng et al., 2010).

As given in Table 1, the oxidation of organic carbon was highest in the case of the sheath of peanut pods, followed by red sawdust and flax shivers and was lowest in white sawdust. Atanasova et al. (1990) studied the mineralization of carbon and nitrogen during the composting of sawdust and bark associated with organic manure and found that decomposition of sawdust was more rapid than that of bark. Also, N'dayegamiye and Isfan (1991) carried comparative composting trials with wood shavings, sawdust and peat moss under field conditions. In each trial, the fresh material was mixed with cattle manure at 2:1 ratio by volume. The C/N ratio decreased after 36 months from 43 to 17 in WS pile and from 48 to 35 in peat moss pile. Tsai and Huany (1994) examined the use of chicken sawdust-rice straw and dairy- sawdust-rice straw, under three aeration rates (0.0, 6.6 ± 0.5 and 25.9 ± 1.9 l/min) and recorded a decrease in carbon content and an increase in N, P and K contents during composting.

After the initial increase in total nitrogen contents, a result of the amendments, total nitrogen continued to increase during composting due to the activity of free living nitrogen-fixing diazotrophs, together with the decrease in organic carbon contents in the final composts (Tsai, 1994 and Bueno et al., 2008). The highest total nitrogen content in mature composts was recorded in the sheath of peanut pods, 2.66%. However, total nitrogen contents in other composts ranged around 1.6%.

The C/N ratio is usually used as an indicator for maturity, suitability, potential nitrogen immobilization and stability of potting soils. Most of the published papers revealed that a C/N ratio of about 1:25 is proper for land application and characterizes a high grade of compost (Alexander, 1977 and Stevenson, 1982). Both organic carbon decreases and total nitrogen increases were reflected in narrowing C/N ratios in the final composts, as previously stated by Singh et al. (1992) and Tsai (1994). In order to prepare a potting soil from agricultural residue with a wide initial C/N ratio (>100), nitrogen is provided in the form of conventional organic manure and/or mineral fertilizers. The composting process results in softening initial differences in C/N ratios among various raw materials.

As a result of the bio-oxidation process during the different stages of composting, an obvious decrease in the pH values was observed in the case of the sheath of peanut pods. Thereafter, the pH values under all treatments were probably affected by the high buffering capacity of the organic colloidal fraction present therein.

Furthermore, the neutralizing effect of calcium ion, added through the chemical accelerator may play a marked buffering role, besides the decomposition of the organic acids that took place throughout the late stage of composting. Generally, the final pH values in all composted materials at the end of the experiment were around neutrality (Avnimelech et al., 1996) which is considered suitable for a high grade compost potting soil. Most plants can survive at a wide range of substrate pH (4 to 8) without suffering significant physiological disorders, as long as all the nutrients are provided in available forms. However, growth rate and plant performance might be slowed down at extreme acid or alkaline conditions. The main effects of pH are exerted on nutrients availability, CEC and biological activity. Total soluble salts in the final composts varied mainly within the type of raw materials used in composting. Recorded values for the total soluble salts in all composts at the end of the composting, however, did not exceed the safe level. It seems reasonable to state that both pH (Poole et al., 1981) and E.C. values in the final composts fulfilled the approved levels of a high-grade potting soil, mentioned in the literature. Peat usually satisfies these requirements and hence is widely used as potting soil.

However, it should be examined carefully before use as peat is diverse in nature and may vary even within the same deposit (Hadar, 1986). Many organic materials have been tested as alternatives to peat according to the characteristics discussed above. Although peat seems to be the best of all the growth media tested, the ability of peat substitutes to promote the survival of targeted microorganisms, justifies their development as an alternative to peat.

In conclusion, results show that the proper organic carbon and total nitrogen contents and consequently C/N ratios, were found in the sheath of peanut pods compost compared to other raw materials.

REFERENCES

Alexander M (1977). Introduction to Soil Microbiology. John Wiley & Sons Inc., pp. 96-105.

Atanasova G, Kostov O, Rankov V (1990). Microbiological processes during the composting of wastes from the wood-processing industry. Pochvoznanie. i. Agrokhimiya, 25(2): 64-72.

Avnimelech Y, Bruner M, Ezrony I, Sela R, Kochba M (1996). Stability indexes for municipal sold waste compost. Compost Sci. Util., 4(2): 12-20.

Bueno P, Tapias R, López F,Díaz M (2008). Optimizing composting parameters for nitrogen conservation in composting. Bioresour. Technol., 99(11): 5069–5077.

Fialho L, Silva W, Milori D, Simões M, Martin L (2010). Characterization of organic matter from composting of different residues by physicochemical and spectroscopic methods. Bioresour. Technol., 101(6): 1927–1934.

Hadar Y (1986). The role of organic matter in the introduction of biofertilizers and biocontrol agents to soil. In: Chen Y and Avnimelech Y (eds). The Role Of Organic Matter In Modern Agriculture. Martins Nijhoff Pub., Dordrecht, Netherlands, pp. 169-176.

Horowitz W (1980). Official Methods of Analysis. 13th Eden-Association of Official Analytical Chemists, Washington, D.C., p. 1018.

Kostov O, Rankov V, Atanacova G,Lynch JM (1991). Decomposition of sawdust and bark treated with cellulose-decomposing microorganisms. Biol. Fert. Soils, 11(2): 105-110.

Michiels J, Verdonck O, DeVieeschauwer D (1979). CompostAnalysis. Laboratorium Handleiding Lab. Voor Bodenfysica, Bodemkonditionering en Tuinbouwbodemkunde. Fac. Landbo ww.,Rijksuniv. Gent, Belgium.

N'dayegamiye A, Isfan D (1991). Chemical and biological changes in compost of wood shavings, sawdust and peat moss. Can. J. Soil Sci., 71(4): 475-484.

Poole RT, Conover CA, Joiner JN (1981). Soils and potting mixtures. In Foliage Plant Production. Ed. J.N. Joiner. Prentice-Hall Inc., Englewood Cliffs, N.J., pp. 179-202.

Saber M (1996). Biofortified farming systems for sustainable agriculture and improved environment. Global Environmental Biotechnology Approaching the Year 2000. International Society for Environmental Biotechnology, Third International Symposium, July 15-20, Boston, Massachusetts, USA.

Singh S, Mishra MM, Sneh G, Kapoor KK (1992). Legume-cereal straw compost enriched with Mussoorie rock phosphate as a substitute of inorganic N and P fertilizers. Int. J. Trop. Agric., 10(3): 226-232.

Stevenson FJ (1982). Humus Chemistry. John Wiley & Sons Inc. St-

Johan TV, Voleman DC,Reid CP (1983). Association of VA mycorrhizal hyphae with the soil organic particles. Ecology, 64(4): 957-959.

Tsai YF (1994). Production of compost from mushroom wastes. Bull. Taichung District Agric. Improvement Station, 44: 13-21.

Tsai YF, Huany HC (1994). Effects of different organic wastes and aeration rates on the nutrients contents in composts. Bull. Taichung District Agric. Improvment Station, 43: 25-33.

Zeng GM, Chen Y, Huang D, Zhang J, Huang H, Jiang RZ (2010). Effects of inoculation with *Phanerochaete chrysosporium* at various time points on enzyme activities during agricultural waste composting. Bioresour. Technol., 101(1): 222–227.