Pak. J. Bot., 42(1): 527-536, 2010.

ASSESSING NITROGEN SUPPLY POTENTIAL AND INFLUENCE ON GROWTH OF LETTUCE AND *AMARANTHUS* OF DIFFERENT AGED COMPOSTS

M. JAVED AKHTAR[1], I. YOUNG[2], R.J. IRVINE AND C. STURROCK[3]

[1]*Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan.*
[2]*School of Environmental and Rural Science, University of New England, Armidale, NSW, 2350, Australia.*
[3]*Seam Research Centre, Waterford, Institute of Technology, Waterford, Ireland.*
Corresponding author E-mail: drmjavedakhtar@yahoo.com

Abstract

This study assessed the potential of different composts at different maturity stages to supply N and their effect on the vegetative growth of lettuce and *Amaranthus*. Five composts aged 1, 3, 6, 9, and 12 months, were mixed with soil @ 5%, 10% and 15% then seeded with lettuce and *Amaranthus*. Results showed that 1, 3 and 6 month aged composts had a negative effect on plant height of lettuce and *Amaranthus* as 1–15.78% and 4.78 to 29.45% decrease in plant height over control was recorded respectively. On the other hand 9 and 12 month aged composts had a significant positive effect on plant height of lettuce and *Amaranthus* where 43.48% and 34.8% increase over control was recorded with the application of 15% of 12 month aged compost respectively. A similar effect was observed on fresh biomass of both lettuce and *Amaranthus* where a 386% and 59.43% increase over control was recorded with the application of 15% of 12 month aged compost respectively. One and three month aged composts revealed a negative effect on N absorption by lettuce whereas 1, 3, 6 and 9 month aged composts had a negative effect on N absorption by *Amaranthus*. 30.39% and 21.48% increases over control in N absorption by lettuce and *Amaranthus* respectively were recorded with the application of 15% of 12 month aged compost.

Introduction

Compost maturity is an important factor affecting the successful application of composts for agricultural purposes (Inbar *et al*., 1990; Wu & Ma, 2002) and their general marketability (Butler *et al*., 2001). Application of unstable or immature compost may inhibit seed germination, reduce plant growth and damage crops by competing for their oxygen or causing phytotoxicity to plants due to insufficient biodegradation of organic matter (Brewer & Sullivan, 2003; Cooperband *et al*., 2003; Wu *et al*., 200). Therefore, only the use of mature compost can guarantee its employment in agriculture without any damaging effect to both soil and plant.

The ambiguities and uncertainties surrounding compost stability/maturity are in part due to a number of factors that include: (a) the variety of compost systems utilizing mixed microbial populations, (b) the heterogeneous and often unpredictable nature of organic substrates, (c) the variety of applications, potential uses and product compositions and (d) the recent introduction of technologically complex compost systems. Finstein *et al*., (1986) stated that unlike most biotechnologies, the development of sludge composting, and for that matter composting in general, has occurred without the assistance of specific and objective process performance indicators such as decomposition rate and degree of stabilization. Thus, the search for a simple, reliable and inexpensive maturity test continues (Golueke & Diaz, 1996). Numerous research studies have been conducted on the subject but there is no single method available for the assessment of compost stability and maturity.

Growers having negative experiences with compost are usually the victims of immature compost, which can inhibit seed germination and cause rapid nitrogen depletion, root tissue damage or even plant death. For this reason, maturity and quality of a compost are essential facts to be taken into account by producers of compost.

An immature compost that is applied to the soil continues to decompose at the expense of its immediate surroundings, producing odorous gases and products, such as ammonia, that are often toxic to plants. In the presence of this inhibitory environment, plants typically reduce their metabolic rate and build up their resistance to decomposition (Zucconi *et al.*, 1981a).

Immature compost products can cause severe damage to plant growth (Saviozzi *et al.*, 1988) and induce high but unwanted microbial activity and subsequent depletion of oxygen (Beefa *et al*., 1996). It is also reported that immature composts with high carbon : nitrogen (C:N) ratios may cause nitrogen immobilization, starve roots of oxygen due to a high microbial activity, are odoriferous, support growth of pathogens such as *Salmonella* spp., and *Pythium* spp. and create high levels of organic acids (Inbar *et al*., 1990). In addition, immature composts with N content create high ammonia concentrations resulting in ammonium toxicity in plants. Inoko *et al*., (1979) reported that there was much evidence that composted material having a C:N ratio less than 20 caused no N starvation when applied to the soil.

Due to the contamination risks associated with immature compost, the development and adoption of an accurate measure of compost maturity is, therefore critical. To date, no single established method has been developed to measure the relative degree of stabilization effectively and reliably.

Presently, a number of methods to evaluate stability and maturity of compost have been described. However, to date, there is no single method that can be successfully used to evaluate stability and maturity of compost from different organic residues due to the widely different chemical characteristics of organic wastes (Barberis & Nappie, 1996; Bernal *et al*., 1998; Chen *et al*., 1996; Itavaara *et al*., 2002; Wu & Ma, 2002). The utilization of different parameters and indexes that address different properties of composting materials could provide a more complete picture of the degree of transformation achieved by the organic materials. Therefore, the present study was designed to evaluate the N supply potential and influence on plant growth of different aged composts to assess their maturity.

Materials and Methods

Experiments were conducted under controlled conditions i.e. light 350 µM $m^{-1}s^{-1}$ and temperature 27◦C to evaluate composts at different maturity stages for their potential to supply nitrogen (N) and their effect on the vegetative growth of lettuce (*Lactuca sativa*) and *Amaranthus* (*Amaranthus caudatus*).

Five composts were collected from the different aged windrows viz., 1, 3, 6, 9 and 12 months old established at a licenced, open-air composting facility in Fife, Scotland, UK. The windrows were made from feedstocks consisting of shredded and mixed garden botanical wastes. The collected compost samples were air dried (at room temperature), ground and sieved through a 1 mm sieve. Soil was obtained from a plough horizon (15 cm) of a field from Binn Farm, Glenfrag, Perthshire, Scotland. The soil was air dried, ground and sieved to < 2 mm sieve.

The composts at different maturity stages were mixed with soil at 5, 10 and 15% (w/w). Soil of 80g amended with each compost were put into 5 replicate pots for each plant species and then saturated with water to approximately 60 % water holding capacity before adding 4 seeds of each plant species. After seed germination, 2 plants were selected for continued growth for 40 days after which time total fresh biomass and plant height were assessed. Plants were also dried to 60°C, ground and sifted by 0.5 mm to measure the content of total N in plant by the Kjeldah method. Moisture levels were maintained at 60% throughout the course of the study. The data were analyzed statistically according to Steel *et al.* (1997) by using completely randomized design. Means were compared by Duncan's Multiple Range Test at 5% probability (Duncan, 1955).

The chemical characteristics shown in Table 1 of different mixes of compost and soil were: EC (dSm^{-1}), pH, NO_3 ($mg\ kg^{-1}$), NH_4^+ ($mg\ kg^{-1}$) and total N ($mg\ kg^{-1}$) of all composts; organic matter (loss on ignition), total organic Carbon (%), EC ($dSm^{-}1$), pH, NO_3 ($mg\ kg^{-1}$), NH_4^+ ($mg\ kg^{-1}$), total N ($mg\ kg^{-1}$) and erogestrol (Table 2).

Results

Characteristics of different aged composts: Table 2 showed the characteristics of the different aged composts. The analysis revealed that organic matter content decreased from 49.5% in the fresh compost to 26.9% in the 12 month old compost. The pH value of one month aged compost was 6.76 which increased to 8.01 and 8.08 in 3 and 6 month compost, respectively. The pH reduced to 7.77 in 12 month aged compost.

Total N of one month aged compost was 4972.5 $mg\ kg^{-1}$ which decreased to 3878 $mg\ kg^{-1}$ in 12 month aged compost. Nitrate content was 5 $mg\ kg^{-1}$ in one month aged compost which increased to 304.4 $mg\ kg^{-1}$ in 12 month aged compost while ammonia was high at the start which decreased with increased maturity e.g., 432, 155, 212, 118 and 212 $mg\ kg^{-1}$ in 1, 3, 6, 9 and 12 month old compost respectively.

The fungal biomass was high in fresh compost (4618 $\mu g\ kg^{-1}$) which continued to decrease with increasing maturity (833 $\mu g\ kg^{-1}$ in 12 month aged compost).

Tests with lettuce and *Amaranthus*

Plant height: Plant height measurements of lettuce at harvest (Fig. 1) revealed that 1, 3 and 6 month aged composts had a negative effect on plant height. The decrease was 1–15.8% compared to the control. Whereas, 9 and 12 month aged composts had a significant ($p \leq 0.05$) positive effect on plant height and a maximum increase (43.5%) was observed with the 15% application rate of 12 month old compost. Similarly, 1 month, 3 month and 6- month- old composts had a significant ($p \leq 0.05$) negative effect on plant height of *Amaranthus* (Fig. 2) and in this case 4.8 to 29.5% decrease in plant height was recorded with 1 and 6- month-old composts. Conversely, 9 and 12 month aged composts displayed a significant ($p \leq 0.05$) positive effect on plant height of *Amaranthus*. A maximum plant height of 70.5 mm (34.8% increases over control) of *Amaranthus* was recorded with the 15% application rate of 12 month aged compost applied to the soil.

Table 1. Chemical characteristics of different mixes of soil and composts.

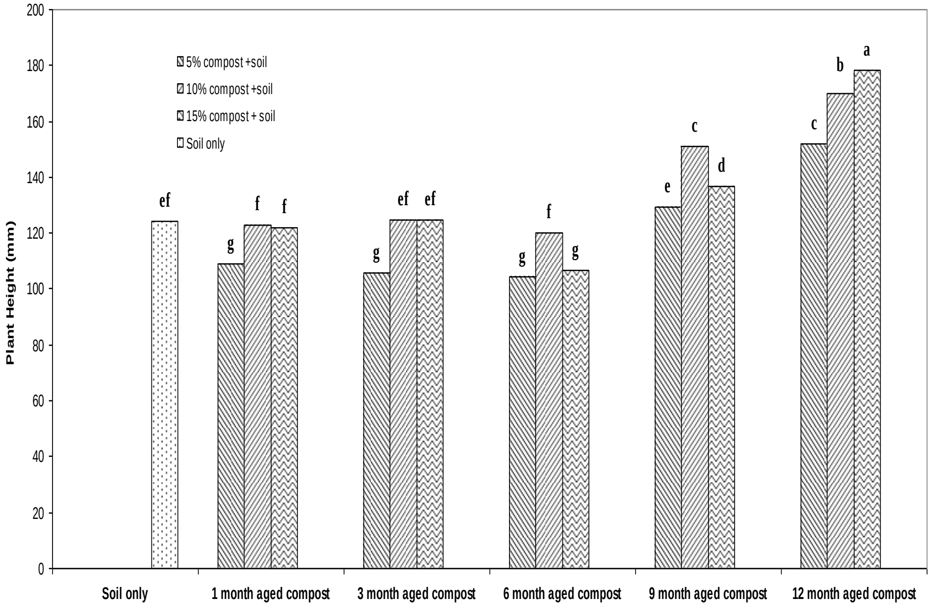
Samples	EC (dSm^{-1}) (1:5 water)	pH (1:5 water)	NO_3 (mg kg^{-1})	NH^+ (mg kg^{-1})	Total N (mg kg^{-1})
Soil	0.06 ± 7.13	5.02 ± 6.78	122 ± 8.24	148 ± 4.79	3750 ±4.78
Soil + 5% 1 month aged compost	0.1 ± 6.59	5.67 ± 5.45	38 ± 7.34	125 ± 6.44	4361 ±6.44
Soil + 10% 1 month aged compost	0.16 ± 8.44	5.82 ± 8.24	60 ± 5.35	164 ± 8.26	4490 ± 5.80
Soil + 15% 1 month aged compost	0.22 ± 7.68	5.85 ± 5.75	142 ±8.12	142 ± 5.44	4513 ± 7.85
Soil + 5 % 3 month aged compost	.096 ± 5.79	5.86 ± 7.66	15 ± 4.78	161 ±7.28	3715 ± 6.42
Soil + 10 % 3 month aged compost	0.14 ± 8.28	5.98 ± 6.48	80 ± 6.59	68 ± 4.86	4005 ± 7.15
Soil + 15 % 3 month aged compost	0.16 ± 6.80	6.1 ± 8.45	73 ± 8.34	79 ± 6.50	4793 ± 5.87
Soil + 5% 6 month aged compost	0.1 ± 4.58	5.8 ± 5.38	38 ± 5.44	60 ± 4.35	4018 ± 6.55
Soil + 10% 6 month aged compost	0.15 ± 7.36	5.9 ± 3.95	38 ± 7.33	201 ± 7.12	4366 ± 8.40
Soil + 15% 6 month aged compost	0.15 ± 6.88	6.32 ± 6.74	25 ± 3.86	133 ± 5.66	4471 ± 4.30
Soil + 5% 9 month aged compost	0.19 ± 5.44	5.59 ± 7.35	56 ± 7.44	172 ± 7.84	4351 ± 8.45
Soil + 10% 9 month aged compost	0.33 ± 8.25	5.69 ± 5.95	95 ± 5.35	60 ± 6.46	4416 ± 7.00
Soil + 15% 9 month aged compost	0.36 ± 7.65	5.79 ± 8.24	109 ±6.77	289 ± 5.68	4606 ± 5.90
Soil + 5% 12 month aged compost	0.24 ± 5.68	5.62 ± 6.45	30 ± 3.75	42 ± 8.24	4445 ± 9.68
Soil + 10% 12 month aged compost	0.29 ± 8.35	5.83 ± 7.86	85 ± 7.54	73 ± 5.78	4924 ± 7.44
Soil + 15% 12 month aged compost	0.49 ± 8.64	6.21 ± 5.12	73 ± 6.95	55 ± 9.65	5430 ± 5.90

Table 2. Characteristics of differently aged composts.

Characteristics	1 Month	3 Month	6 Month	9 Month	12 Month
Organic matter (%)	49.48	29.16	30.22	28.66	26.90
Organic carbon (%)	27.31	16.20	16.79	15.93	14.94
pH (1:5 water)	6.76	8.01	8.08	7.77	7.55
EC (dSm^{-1}) (1:5 water)	1.243	0.785	0.836	0.753	0.783
Total N(mg kg^{-1})	4973	4399	4365	4335	3878
NO_3 (mg kg^{-1})	5	73.8	23.2	30.4	35
NH_4 (mg kg^{-1})	432	155	212	118	42
Ergosterol (µg kg^{-1})	4618	2112	4187	1597	833

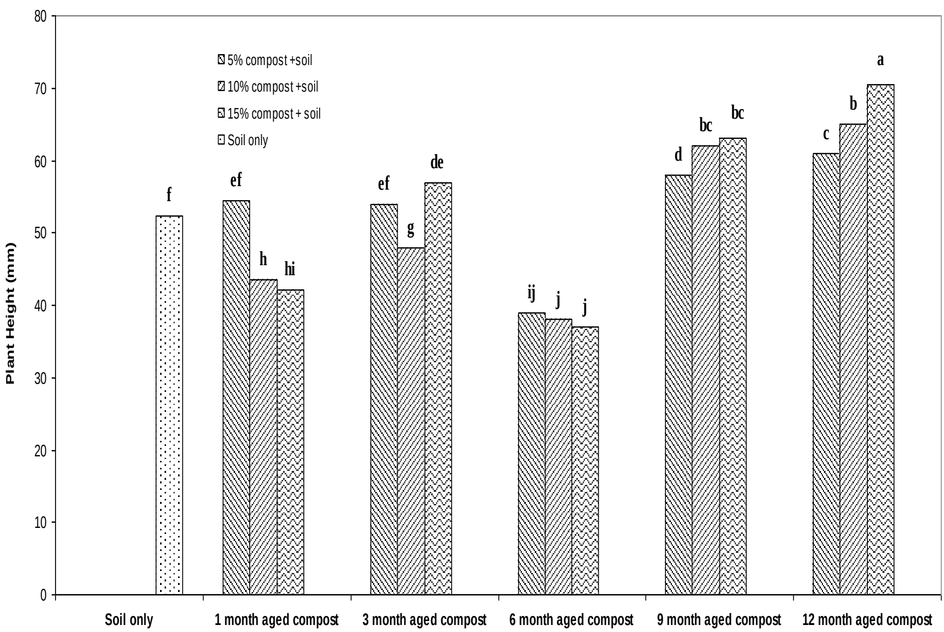
Fresh biomass: 1, 3 and 6 month old composts displayed a significant ($p\leq 0.05$) negative effect on the fresh biomass (wet weight) of lettuce (Fig. 3). Increases in biomass were recorded with 9 and 12 month aged composts when applied to the soil. It was further noted that fresh biomass increased with the higher rates of application of both 9 and 12 month aged composts. The maximum increase (386%) was shown with the15% addition of 12 month aged compost to soil. Fig. 4 shows that 1, 3 and 6 month aged composts also had a significant (($p\leq 0.05$) negative effect on fresh biomass of *Amaranthus*. The maximum decrease (29.45%) in fresh biomass of *Amaranthus* was obtained with the application of 15% 6 month old compost. A continuous increase in *Amaranthus* biomass was recorded with the increased rate of application of 9 and 12 month old composts. The highest level fresh biomass (0.0845 g, 59.43% increase over control) was recorded with the application of 15% of 12 month aged compost.

Total N: The total N absorbed by lettuce from soil only and compost amended soils revealed that compost maturity had a significant ($p\leq 0.05$) effect on absorption of N. Fig. 5 shows that 1 and 3 month old composts revealed a significant negative effect on N absorption by Lettuce with a maximum decrease of - 23.07% over the control. It was observed that as compost maturity was positively correlated with N absorption, with a maximum of 30.39% over control shown with the application of 15% of 12 month aged compost.



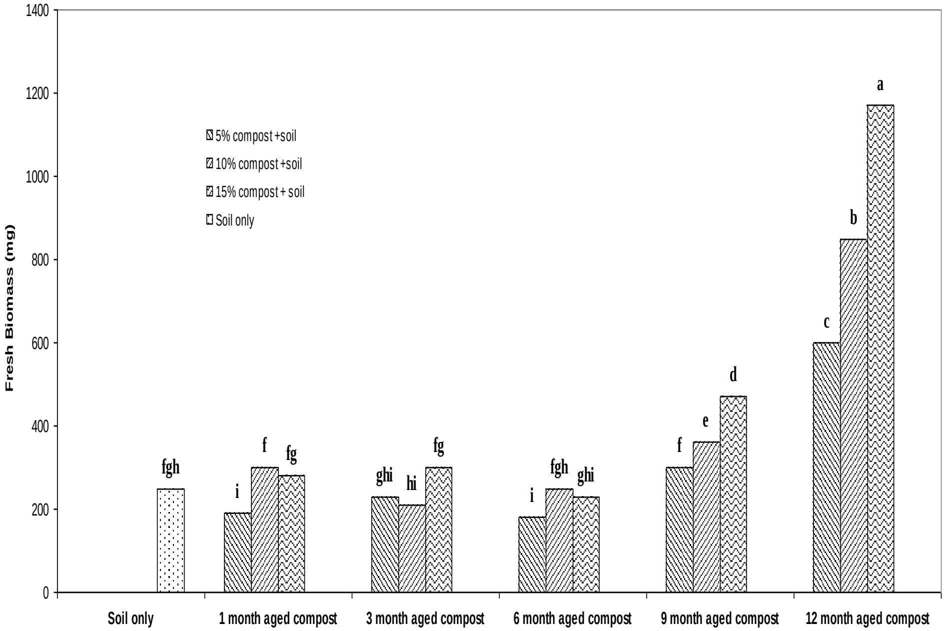
Means sharing the same letter (s) do not differ significantly at p = 0.05

Fig. 1. Effect of different aged composts on plant height of lettuce (mm).



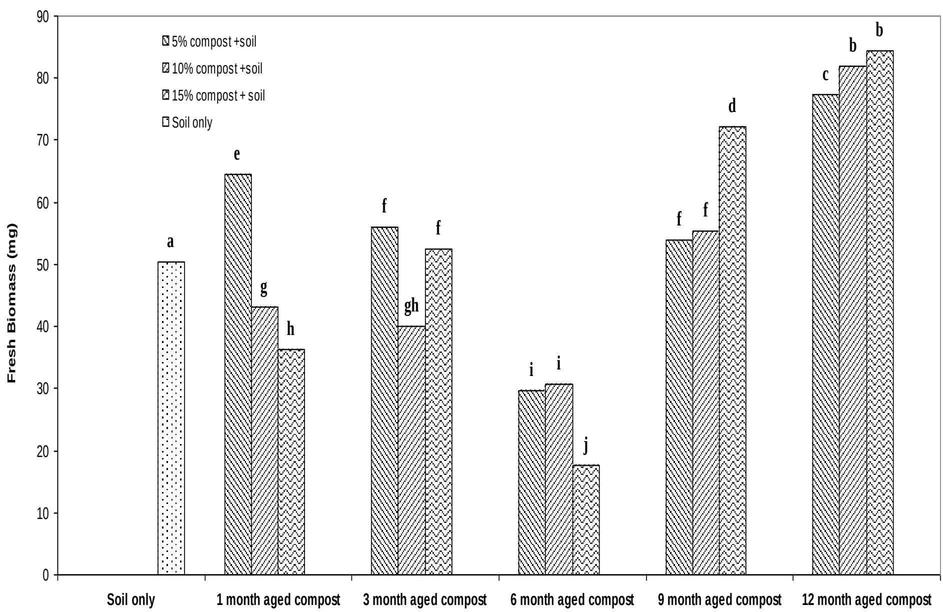
Means sharing the same letter (s) do not differ significantly at p = 0.05

Fig. 2. Effect of different aged composts on plant height of *Amaranthas* (mm).



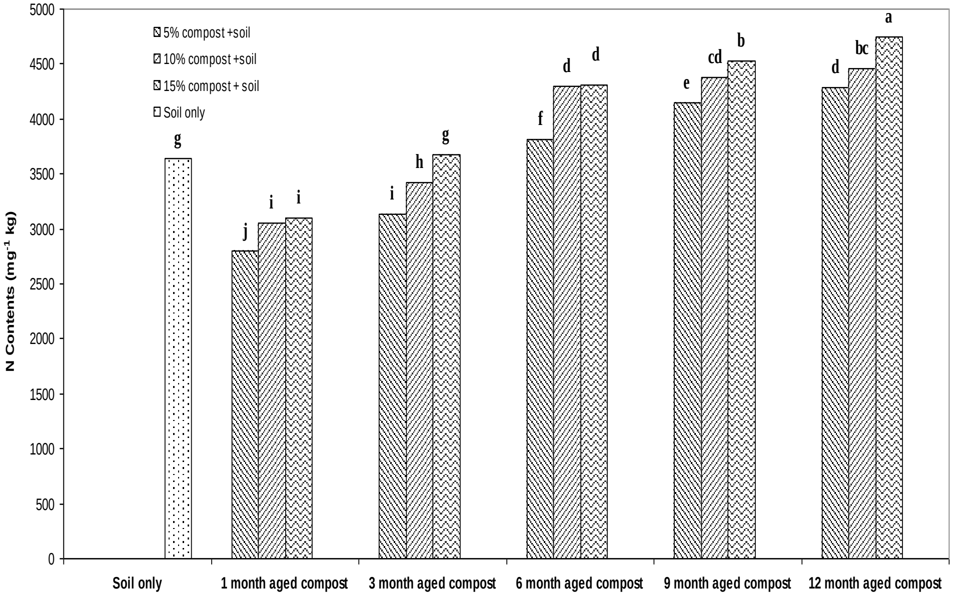
Means sharing the same letter (s) do not differ significantly at p = 0.05

Fig. 3. Effect of different aged composts on fresh biomass of lettuce (mg).



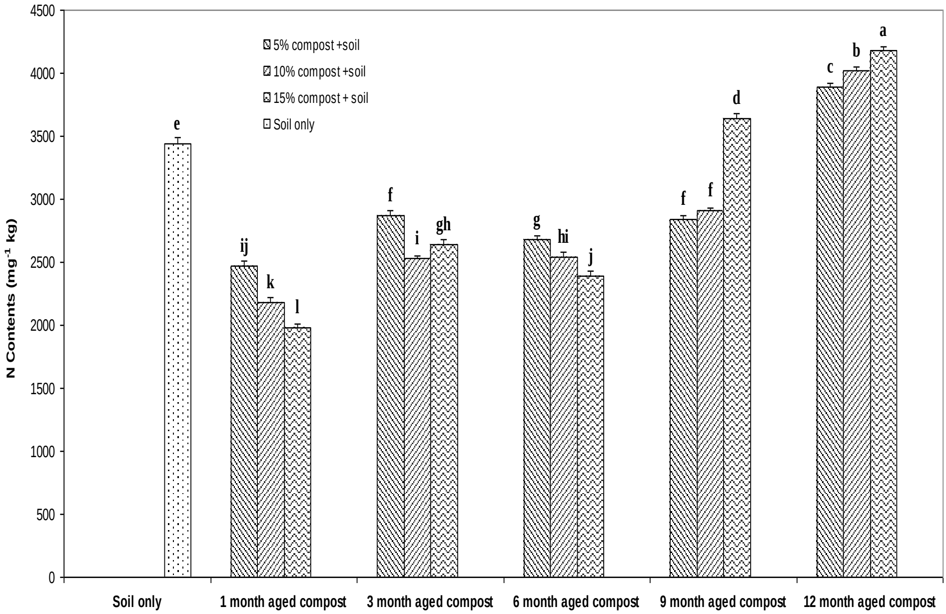
Means sharing the same letter (s) do not differ significantly at p = 0.05

Fig. 4. Effect of different aged composts on fresh biomass of *Amaranthas* (mg).



Means sharing the same letter (s) do not differ significantly at p = 0.05

Fig. 5. Effect of different aged composts on total N contents of lettuce after harvest (mg/kg).



Means sharing the same letter (s) do not differ significantly at p = 0.05

Fig. 6. Effect of different aged composts on total N contents of *Amaranthas* after harvest (mg/kg).

In the case of *Amaranthus*, it was shown that compost maturity had more of an effect on N content as compared to the lettuce. Composts 1, 3, 6 and 9 month aged had a negative effect on N content of *Amaranthus*. Only the application of 12 month aged compost had a positive effect on N content of *Amaranthus* where the maximum increase (21.48%) over the control was shown with the application of 15% of 12 month aged compost (Fig. 6).

Discussion

Composts 1, 3 and 6 month aged exhibited negative effect on height and fresh biomass of lettuce and *Amaranthus* plants. These results may be due to the lack of maturity of the materials of composts in those stages having high C/N ratio and the high content of N-NH_4^+. The incorporation of composts in early stages of the process (bioxidative or initial phase) can activate the microbial mass of the soil and the incorporated material, causing diminution in the content of organic matter (Paschal *et al*., 1998) which ultimately limits the availability of N. This study and previous work (Hartz & Schrader, 1996), demonstrate that short-term release of N is unpredictable, with immature compost typically immobilizing N rather than releasing it. This effect was quantified by Benito *et al*., (2003) who determined that during the bioxidativ stage there was a 76% loss of organic matter, whereas in the phase of maturation only 4% of the same one were lost. It was also observed that the application of mature compost had a positive effect on plant height which is similar to the findings recorded by Akhtar *et al*., 2009.

In contrast to the younger composts (1-6 month), 9 and 12 month samples had a positive effect on plant height and fresh biomass of Lettuce and *Amaranthus*. Such results may be due to more availability of N because more mature composts have less NH_4-N, more NO_3-N and less phytotoxic organic compounds, and is less likely to immobilize significant amounts of N (Hoitink *et al*., 1993).

Nitrogen uptake by Lettuce from the soil alone was higher than from the soil amended with 1 and 3 month aged composts. This may be due to more microbial activity resulting in immobilization of N. Similar results were found by Bernal *et al*., (1998). On the other hand- 9 and 12 month old compost when mixed with soil enhanced N absorption. This is likely to be related to lower ammonium and higher nitrate levels found typically in mature composts (Hoitink *et al*., 1993; Zahir *et al*., 2007). In the case of *Amaranthus*, only 12 month aged compost improved N absorption which indicated that *Amaranthus* was more sensitive to the phytotoxic effects of immature composts as compared to lettuce.

The potential of differently aged composts to supply N and their effect on growth and yield of Lettuce and *Amaranthus* was studied for the growth period of 40 days. It is suggested that this study should be conducted for a longer period because the mineralization of immature composts mixed with soil for a longer period could supply more nitrogen resulting in a positive effect on growth and yield. This study demonstrated that *Amaranthus* is more sensitive to compost maturity than lettuce; therefore studies conducted on *Amaranthus* for a longer period could be more valuable to assess compost maturity.

Acknowledgements

Mr. Alistair Cook, Director of Andrew Cook Ltd., for the supply of compost samples and to Mr. Alan Macgregor of Binn Farm, Perthshire for the supply of soil samples.

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(Received for publication 26 June 2009)