THE EFFECT OF N SOURCE ON THE COMPOSTING OF GREEN WASTE AND ITS PROPERTIES AS A COMPONENT OF A PEAT GROWING MEDIUM

M. J. Maher[1] and M. Prasad[2]

1.Kinsealy Research Centre, Dublin, Ireland
2. Bord na Mona Research Centre, Newbridge, Co. Kildare, Ireland

1. ABSTRACT

There is interest in using green waste as a component of peat based growing media as it is a renewable resource. The present study investigated the effects on the composting of green waste of two N sources calcium ammonium nitrate (CAN) and poultry manure. The inclusion of peat along with CAN was also studied. Green waste without any addition was the control treatment. The four treatments were composted over a 20 week period. Samples of each treatment were taken at 4 week intervals and stored under refrigeration. During composting there was an increase in pH, N content, CEC and FTIR peak ratio 1485/1056. The C/N ratio and organic matter content declined over time as did available N levels in the treatments where N was added. At the end of the composting period, samples of the four treatments from the five sampling dates were given a N dressing according to analysis and mixed with fertilised peat at rates of 0, 12.5, 25 and 50% by volume. The effects of these treatments on the growth of tomato seedlings was studied. At the 50% rate, plant performance was reduced in green waste composted without additional N and where the composting period was less than 16 weeks. At the lower rates of incorporation these effects were much less. Plant growth was positively related to N content and CEC of the green waste and negatively to the C/N ratio.

2. INTRODUCTION

In Europe in general but particularly in the UK there is strong pressure from environmental groups to replace or dilute peat with a renewable material (Shaw, 2000). In addition the dilution of peat with renewable materials would extend the life of present peat resources. Composted green waste will occupy an increasing proportion of the organic waste stream in Ireland in the future as more local authorities turn to composting as a means of reducing the amount of waste material going to landfill.

There is limited information on the use of green waste as a component of a growing medium. Work in Germany by Fischer (1989), in the Netherlands by Pronk(1995) and in the USA by Bugbee and Frank (1991), Hartz et al. (1996), Speirs et al (2000) and Burger et al. (1997) has indicated that composted green waste can be used as a component of a growing medium. Previous work by Prasad and Maher (2000) concluded that composted green waste could be incorporated with peat as a growing medium at a rate of 20% by volume without adversely affecting plant performance. They found that addition of green waste reduced available N levels in the growing medium and recommended that composting studies particularly with the addition of N should be undertaken. The objectives of the present investigation were, (a) to determine whether the composting of green waste could be improved by the addition of N prior to composting, (b) to study the effect of rate of incorporation of green waste, which had been composted for different lengths of time, into a peat growing medium on plant growth and (c) to measure chemical and spectroscopic parameters of the green waste during composting and to relate these to plant growth and composting time.

3. MATERIALS AND METHODS

3.1 Composting

Fresh green waste material which had been chipped through a 20 mm screen was measured into four stockpiles each with a volume of 10 m^3. Four treatments were compared, (a) a control treatment to which no additions were made before composting, (b) an addition of calcium ammonium nitrate (CAN, 27.5% N) at 1.82 kg/m^3 and ferrous sulphate at 200 g/m^3, (c) the addition of CAN and ferrous sulphate as in treatment b along with the addition of 200 l of peat per m^3 and (d) the addition of poultry manure at 25 kg/m^3. The three N addition treatments all supplied 0.5 kg N per m^3 of green waste material.

The piles were thoroughly mixed and allowed to compost outdoors over a 20 week period. They were turned every two weeks and at each turning a sample of each pile was taken for analysis. At four week intervals a larger sample was taken and stored in a cold room at a temperature of 2°C for a growing experiment at the end of the composting period. The samples were analysed for pH, electrical conductivity (EC), levels of available and total nutrients, cation exchange capacity (CEC) and ash content. Available nutrient levels were determined using a 1‡:1 water extract (Sonneveld et al., 1974). Total nutrients were determined after drying the samples at 105°C (Byrne, 1979). Fourier Transform Infra Red

(FTIR) analysis was carried out (Prasad and O'Shea,1998). Peaks that were selected were 2,800-2,900 m^{-1}, aliphatic, acyclic, 1,600-16,400 m^{-1} aromatic, 1,300-1380 m^{-1} aliphatic acyclic, 1,400-1,465 aliphatic, acyclic, aromatic, 1030-1080, carbohydrate, alcohol and phenol. After drawing a baseline, the heights of the above were measured. The ratios of various peaks were then selected.

3.2 Plant growth experiment

Samples of each treatment which had been composted for 4, 8, 12, 16 and 20 weeks were taken from cold storage. Depending on analysed available N levels, CAN was added to bring the N level in each treatment to a calculated 200 mg/l. Each of the 20 combinations of N addition and composting time was incorporated in a peat growing medium at three rates 12.5, 25 band 50% by volume. A control rate with zero addition of green waste was also included. The rate of lime addition to the peat was reduced from 4.0 g/l for the 100% peat control to 3.5, 3.0 and 2.5 g/l where the rate of incorporation of composted green waste was 12.5, 25 and 50%. This was to take account of the high pH of green waste. Similarly, the K addition to the peat was reduced from 300 mg/l to the control to 240, 150 and 0 mg/l for the three rates of green waste incorporation. The resulting 80 treatments were combined in a 5 (composting time) x 4 (N addition before composting) x 4 (rate of green waste addition to the growing medium) factorial design in a plant growth experiment with 6 replications. Each treatment was filled into 6, 11-cm diameter pots which were labelled and laid out in randomised block design on a greenhouse bench. A tomato seedling, cv. Blizzard, was pricked out into each pot. The plants were grown for a four week period at a minimum temperature of 15°C. They were irrigated with plain water. At harvest the fresh weight of each plant was recorded and plant samples were taken for analysis of nutrient concentration.

4. RESULTS AND DISCUSSION

4.1 Composting

The values for the measured parameters after 4, 12 and 20 weeks composting are shown in Table 1 along with the correlation coefficients relating the values to the duration of composting. The pH rose through the composting period in all four composting treatments. In the three treatments where additional N was supplied the EC tended to fall over the composting period. This was probably because the available NH_4-N and NO_3-N were contributing to the EC level early in the experiment but by the end they had reduced to low levels in all three treatments. Available N levels in the control treatment were practically zero throughout the experiment and in this case the end EC was higher than the initial level. Sesay et al. (1997) noted a decline in EC levels during composting of paper pulp sludge but the measurements were rather irregular and EC was not a suitable stability indicator. The final EC level in the treatment supplemented with poultry manure was higher than in the other treatments and this was probably due to higher available K levels.

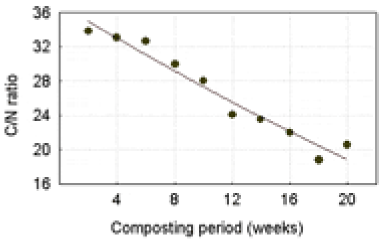

Figure 1. C/N ratio during composting with poultry manure added to green waste.

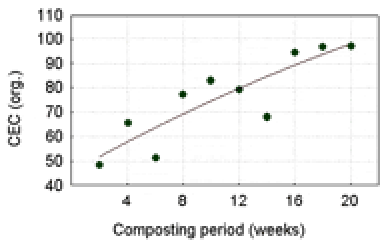

Figure 2. CEC (org.) during composting with poultry manure added to green waste.

The total N content increased as composting proceeded while the C content decreased. Consequently the C/N ratio reduced markedly in all treatments but more rapidly where N had been added. The organic matter content decreased while the CEC (based on organic matter) increased over the composting period. The reduction in C/N ratio and the rise in CEC (org.)

	Composting	N addition before composting			
	time (weeks)	Control	CAN	Peat + CAN	P. manure
pH	4	6.7	6.4	6.3	7.7
	12	7.7	7.0	6.8	7.9
	20	8.1	7.8	7.7	8.1

	R[1]	0.88*	0.92*	0.92*	0.83*
EC (mS/cm)	4	98	183	137	224
	12	95	207	186	150
	20	125	134	73	180
	R	0.00	-0.68	-0.67	-0.68
N (mg/l)	4	0	135	93	124
(available)	12	4	144	120	27
	20	2	18	2	15
	R	0.01	-0.80*	-0.78*	-0.88*
N (g/kg DM)	4	8.2	10.9	10.7	13.2
	12	9.1	15.1	13.5	14.9
	20	13.1	15.9	15.2	16.8
	R	0.84*	0.74*	0.57	0.91*
C (% of DM)	4	45.2	48.9	46.4	43.6
	12	40.8	41.2	42.1	41.8
	20	36.6	35.7	40.4	36.9
	R	-0.84*	-0.67*	0.05	-0.78*
C/N ratio	4	55.1	44.9	43.5	33.0
	12	44.9	27.3	29.9	28.0
	20	28.0	22.2	27.7	22.0
	R	-0.85*	-0.76*	-0.50	-0.98*
% OM	4	81.3	87.1	83.7	78.5
	12	76.4	74.1	75.7	75.2
	20	65.9	64.2	72.8	66.5
	R	-0.84*	-0.86*	0.05	-0.78*
CEC (org)	4	55.9	47.1	53.8	65.6
meq/100 g	12	65.2	71.5	79.2	83.1
	20	81.9	90.2	101.7	94.7
	R	0.76*	0.81*	0.81*	0.87*
FTIR 1485/1056	4	0.46	0.47	0.56	0.52
	12	0.54	0.53	0.53	0.60

	20	0.59	0.61	0.58	0.60
	R	0.76*	0.86*	0.17	0.28

Table 1. Changes in green waste composition during composting
1 Correlation coefficient with time. Figures with an asterisk are significant at p<0.05 where poultry manure was added is shown in Figures 1 and 2. A similar rise in CEC was reported by Namkoong et al. (1998) in composting food waste who noted that it could be a useful index of compost maturity. Sesay et al. (1997) also reported a fall in volatile solids and C/N ratio in composting paper pulp sludge.

Inbar et al. (1989) reported good correlation between a number of FTIR peak ratios and compost maturation parameters such as length of composting, CEC and C/N ratio in the case of the solid fraction of separated cattle manure. The data of Provenzano et al. (1998) also show changes in FTIR ratios with time in composting of municipal solid wastes. In this study however, the only FTIR peak ratio which displayed a trend over the composting period was 1485/1056 which increased over time in the control treatment and where CAN was added before composting.

Where peat and CAN were added together, the measured values tended to be more variable than the other treatments resulting in lower correlation coefficients for some of the parameters (Table 1).

4.2. Plant growth experiment

The aim of the N additions to the green waste before the growth experiment and of varying the K and lime additions to the peat according to the rate of incorporation of green waste was to follow what was thought to be best horticultural practice for each treatment and to equalise as far as possible the available nutrient status. The mean analysed values of the growing media at the start of the growth experiment are shown in Table 2.

	pH	EC (mS/m)	K (mg/l)[1]	N (mg/l)[1]
Length of composting (weeks)				
4	5.1	163	156	131
8	5.1	149	144	126
12	5.3	146	142	121
16	5.3	149	144	124
20	5.3	152	154	130
N source prior to composting				
Control- none	5.3	146	144	123
CAN	5.2	155	141	130
Peat + CAN	5.1	150	130	131
P. manure	5.3	156	178	120
Rate of addition				
12.5	5.1	156	144	131
25	5.2	149	139	127
50	5.7	149	169	120
100% peat control	4.9	154	140	127

Table 2. Mean values of pH, EC and available K and N at the start of the growth experiment.

1 expressed as mg/l in a 1.5:1 volume water extract

The nutrient levels were substantially the same in all the treatments. The pH where green waste was used at 50% in the growing medium was high at 5.7 indicating that greater reductions in the rate of lime might be warranted. The K level at the 50% rate of green waste was higher than the other treatments even though no K had been added to the peat in this case.

Plant growth was affected by duration of composting, addition of N prior to composting and by the rate of addition of the green waste to the growing medium. There were very significant interactions between these factors and these are shown in Tables 3 and 4 and Figure 2.

N addition	Rate of green waste addition (% volume)			Mean
	12.5	25	50	
Control ñ none	7.21	7.16	5.32	6.56
CAN	7.14	7.33	7.11	7.19
PeatÝ + CAN	6.70	7.27	6.68	6.88
Poultry manure	7.97	7.55	6.68	7.40
Mean	7.26	7.33	6.45	
Peat (100%) control		7.20		

	F-test	s.e.
N addition	***	0.109
Rate of addition	***	0.094
Interaction	***	0.188

Table 3. Effect of N addition to green waste before composting and the rate of green waste addition to the growing medium on the fresh weight of tomato seedlings (g/plant)

Where no N was added to the green waste prior to composting, plant growth was not as good as in the treatments where N was added but only when the green waste was incorporated in the growing medium at a rate of 50% (Table 3). At the lower rates of incorporation, the differences between the N source treatments were much less and performance was as good as the 100% peat control. Plant weight also tended to decrease in the poultry manure treatment when the green waste was incorporated at 50% but this effect was less pronounced than where no N was added.

N retention has been noted as a problem with green compost by Jauch and Fisher (1993) who also reported a reduction in the fresh weight of pot plants when it was used at a rate of 50%. Hartz (1996) also noted N immobilisation by composted green waste. It seems likely that the reduction in plant weight where green waste composted without any additional N and used at the 50% rate was due to this problem. The addition of N prior to composting or the use of lower rates of green waste in the growing medium resulted in plant performance as good as in the 100% peat control.

The effects of N source prior to composting and the duration of composting time on the subsequent growth of tomato seedlings are shown in Table 4. There is an overall effect of plant growth improving as the length of the composting period increases for all N sources including the control. After a composting period of four weeks the addition of CAN prior to

Composting	N addition				Mean
Time (weeks)	Control	CAN	Peat + CAN	Poultry manure	
4	6.21	6.97	6.08	6.36	6.41
8	6.89	6.53	6.58	7.02	6.75
12	5.78	7.55	7.20	7.17	6.93
16	6.98	7.43	6.96	8.38	7.44
20	6.97	7.49	7.61	8.07	7.53

Mean	6.56	7.19	6.88	7.40

Peat (100%) control	7.20

	F-test	s.e.
Composting time	***	0.122
N addition	***	0.109
Interaction	***	0.243

Table 4. Effect of composting time and N addition to green waste before composting on the fresh weight of tomato seedlings (g/plant)

composting resulted in the heaviest plants. The control treatment i.e. no N addition prior to composting gave poor results after 12 weeks composting. Growth was best after 16 and 20 weeks composting and the fresh weights of the seedlings were now greater than those in the 100% peat control treatment. After this length of composting the addition of poultry manure prior to composting was giving the best plant performance.

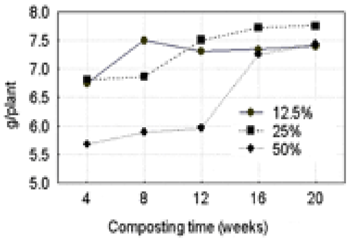

Figure 3. Interaction between composting time and rate of incorporation into the growing medium on the fresh weight of tomato seedlings (significant at p<0.01).

The interaction between the duration of composting and the rate of incorporation of green waste into the growing medium on the growth of tomato seedlings is illustrated in Figure 3. Where green waste was incorporated into the growing medium at 12.5 or 25% by volume there was only a small loss of plant performance when the composting period was short. When a rate of 50% green waste was used, however, composting periods shorter than 16 weeks resulted in a serious reduction in plant fresh weight. This could be due to N immobilisation or phytotoxicity in the relatively fresh material (Hartz et al., 1996).

These results underline the problems of incorporating green waste into a growing medium at high rates. Only when supplementary N was added prior to composting and an adequate composting period applied did the plants perform as well as the 100% peat control. It should be noted that the growth experiment was carried out immediately after fertilising and mixing with peat. It would be desirable to carry out storage experiments to determine whether indeed the green waste was fully stabilised. Another approach would be to use fertigation as Hartz et al.(1996) recommend.

Correlation coefficients between plant fresh weight at each of the incorporation rates and the measures parameters of the composting treatments and these are shown in Table 5. When the incorporation rate was 12.5% there was little correlation between the composted green waste properties and growth of the tomato seedlings. However when the rate was increased to 25% and again to 50% the coefficients increased and became significant.

Parameter	Rate of green waste addition (% by volume)		
	12.5	25	50
N content	0.43	0.58*	0.67*
C/N ratio	-0.28	-0.53*	-0.60*
CEC	0.15	0.49*	0.60*
FTIR 1485/1056	0.25	0.37	0.51*
% Organic matter	-0.21	-0.55*	-0.34

Table 5. Correlation coefficients between measured parameters during composting and plant growth (g/plant) at three rates of green waste addition to the growing medium.
* Figures marked by an asterisk are significant at $p<0.05$

The relationships between plant fresh weight when green waste was incorporated at 50% and the green waste N content and the C/N ratio are shown in Figures 4 and 5. These parameters along with CEC were the best indicators of plant performance.

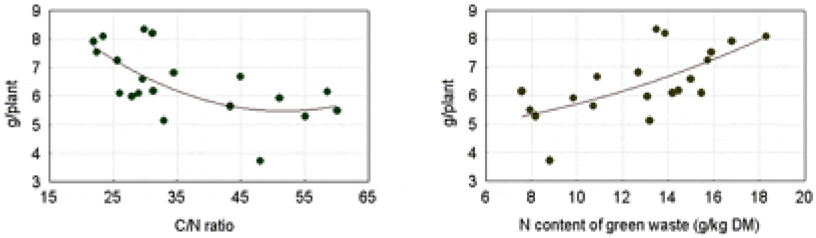

Figure 4. Relationship between plant fresh weight and the C/N ratio of green waste incorporated into the growing medium at 50%.

5. CONCLUSIONS

Composted green waste could be used as a peat replacement in growing media at a rate of 50% without reducing plant performance but only where supplementary N was applied to the green waste prior to composting and where an adequate duration (16 weeks) of composting was given.

Where green waste is used at rates of 12.5 and 25%, the sensitivity to composting time and N supplementation is much less.

During composting of green waste there was an increase in pH, N content, CEC and FTIR peak ratio 1485/1056. There was a reduction in organic matter content and C/N ratio.

When green waste was incorporated into the growing medium at 25 and 50% by volume, plant growth was positively correlated to N content and CEC and negatively to C/N ratio. These compost parameters were the best indicators of plant performance.

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