Crop uptake of nitrogen, phosphorus and potassium from soil amended with chicken manure and green waste compost

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Abstract

Organic amendments can be a useful source of nutrients for vegetable crops. A two-year field trial on a Levin silt loam compared the uptake of nitrogen (N), phosphorus (P) and potassium (K) from uncomposted chicken manure and green waste compost. Each year three crops, (silverbeet, sweetcorn and winter cabbages) were grown in rotation. Two rates of both uncomposted chicken manure (5 and 15 t/ha) and green waste compost (50 and 300 t/ha) was applied annually in a replicated trial. Application of organic amendments increased crop yields. N in uncomposted chicken manure appeared to be more available for plant uptake than N in green waste compost. Applying green waste compost at 300 t/ha increased soil organic carbon content from 2.7% in the control to 3.6%. As the amounts of N, P and K applied in this rate of compost were in excess of crop requirements, a surplus of N, P and K in the soil was generated.

Additional key words: *silverbeet, sweetcorn, winter cabbage*

Introduction

Intensive vegetable production in New Zealand currently covers an area of 50 000 ha. On these soils, two or three vegetable crops are commonly grown each year. Most vegetable crops are grown using very high rates of fertiliser (e.g., 200 - 300 kg N/ha; Wood, 1997). There is interest in using organic amendments as a source of nutrients to lessen the reliance on compound fertilisers, and utilise organic material which is otherwise considered to be a waste product. A further advantage of applying organic amendments is that they add organic matter to the soil. In soils intensively cultivated for vegetable crops, soil organic matter levels are usually relatively low (Haynes and Tregurtha, 1998), and are associated with poor soil structure and low biological activity. If the aim of applying amendments is to increase soil organic matter content, then the amendment must be applied at a very high rate. However, high rates of application can lead to large amounts of nitrate accumulating in the soil and leaching (Leclerc *et al.*, 1995; Nemeth, 1995).

In New Zealand, green waste compost is a potential organic amendment. It is made from garden waste diverted from landfill, shredded and composted for at least nine months. Currently about 50 000 t of green waste compost is produced annually, although the amount is rapidly growing. Another type of waste is fresh chicken manure from battery hen egg production, 50 000 t of which is produced annually. Some growers have started to apply these amendments but little is known about the usefulness of these amendments for vegetable production. A field trial was therefore carried out to measure the effects of green waste compost and chicken manure on vegetable crop production. In this paper the uptake of N, P and K from the amendments by a sequence of vegetable crops is presented. Data on nitrate leaching are presented elsewhere (Spiers *et al.*, 1996).

Materials and Methods

The trial ran for two years from September 1994. The trial was situated adjacent to the Levin Research Centre on a site that had been intensively cropped for vegetables for 30 years. The soil was a Levin silt loam and the preliminary soil test analyses are given in Table 1. Three vegetable crops were grown in rotation each year, silverbeet (Oct-Dec), sweetcorn (Dec-April) and winter cabbages (May-Sept).

The trial design was an incomplete Latin square, with five treatments replicated four times, and a plot size of 10 x 12 m. The five treatments were uncomposted chicken manure applied at two rates, 5 (UCM 5) and 15

(UCM 15) t/ha, green waste compost applied at 50 (GWC 50) and 300 (GWC 300) t/ha, and a control. The moisture and nutrient content of these amendments are shown in Table 2.

The UCM 5, UCM 15 and GWC 50 treatments were used because they represent rates which have been used by growers. The UCM 15 and GWC 50 treatments both supply the same amount of N. The GWC 300 treatment was used because it was considered high enough to increase soil organic matter content.

The treatments were applied each August. The exception was the 300 t/ha of green waste compost which was applied at 100 t/ha prior to planting each of the three crops. The moisture content of the GWC decreased with storage but this was compensated for by reducing the application rate so the equivalent of 100 t/ha at 40% moisture content was applied to each crop.

Table 1. Background soil analyses (0 - 15 cm).

Soil test	Range
pH[1]	6.7 - 7.0
Olsen P (μg/g)[2]	200 - 250
Exchangeable K (me/100g)[3]	1.2 - 1.5
Exchangeable Mg (me/100g)[3]	0.25 - 0.34
Exchangeable Ca (me/100)[3]	10.0 - 11.9

1 In water (1:2.5 soil:water ratio);
2 Blakemore *et al.*, (1972);
3 Extracted with 1M ammonium acetate (1:5 soil:extractant ratio); K, Mg and Ca in the extract were measured by atomic absorption.

Table 2. Nutrient analysis of the soil amendments.

Analysis	Green waste compost	Chicken manure
Total N (%)[1]	1.4	3.8 - 4.9
Total P (%)[1]	0.3 - 0.4	2.2 - 2.3
Total K (%)[2]	1.2 - 1.7	2.2 - 2.4
Total Mg (%)[2]	0.5 - 0.6	0.4 - 0.6
Moisture content %[3]	39 - 45	35 - 43

1 Extracted by sulphuric acid and selenium (1:45 sample:extractant ratio) and measured by auto analyser colorimeter.
2 Extracted by sulphuric acid and selenium (1:45 sample:extractant ratio) and measured by flame photometer.
3 Determined by weight loss after drying at 100°C for 48 hours.

All amendments were cultivated into the soil to a depth of 15 cm prior to planting.

In addition to the organic amendments, nitrogen (N) fertilisers (urea and calcined ammonium nitrate, CAN) were broadcast across all treatments, generally at planting of each of the vegetable crops, and in mid January for the sweetcorn crop. During 1994/95 a total of 300 kg N/ha was applied as urea and CAN, and 150 kg N/ha was applied in 1995/96. This represents normal farming practice for these vegetable crops.

Each time a crop was harvested, all the plant material, including residues, was removed from each plot to determine total crop yield. No attempt was made to measure the crop roots. Plant samples (8 - 14 plants per plot) were taken for dry matter determination and measurement of N, P and K concentration by Kjeldahl digestion (Hutton and Nye, 1958). Nine soil samples were taken from each plot (0 - 15 cm), bulked together and analysed for organic carbon (Blakemore *et al.*, 1972).

Meteorological data were collected at the Levin automatic weather station. Data were analysed using analysis of variance in Genstat.

Results and Discussion

Crop yields

Yields of silverbeet and sweetcorn were typical of crops grown in the area (Table 3). The cabbage yield in the first year was lower than in the second year due to the late sowing of the crop (the first sowing was destroyed by hail). Rainfall for each year (July - June) was 1250 and 1420 mm respectively which were both higher than the annual average of 1110 mm. Rainfall was evenly distributed so summer crops were not drought affected.

Table 3. Fresh yields of the vegetable crops (t/ha).

Crop	Control	UCM 5	UCM 15	GWC 50	GWC 300	SED
Year 1						
Silverbeet	17.8	30.0	33.9	21.6	22.6	2.0
Sweetcorn	16.6	15.3	15.1	17.0	15.3	3.2
Cabbage	0.84	1.21	2.03	2.06	1.60	1.26
Year 2						
Silverbeet	14.0	28.8	44.2	28.9	21.8	6.4
Sweetcorn	8.5	7.9	8.1	9.3	8.9	2.3
Cabbage	2.8	6.2	12.0	12.1	8.7	7.2

The application of the organic amendments increased yields for all crops due to the addition of nutrients in the amendments, particularly N, as P and K were not limited in the soil. The silverbeet crop was particularly responsive to the UCM, with the highest yields obtained from UCM 15. However the carry over effect of this treatment appears to be short lived as there was no difference in sweetcorn and cabbage yields among the organic amendment treatments.

Nitrogen

Although the same amount of N was applied, total plant yield and N uptake (Table 4) for UCM 15 was higher than GWC 50, indicating that N in UCM was more available to plants than N in GWC. For UCM, as the rate of applied N increased, total plant uptake of N also increased due to an increased total plant yield, but for GWC this only occurred at the highest N application rate.

For the control, the amount of N taken up by the crop was equivalent to 60% of the N applied as fertiliser. For GWC and UCM plant N uptake reached a maximum of 210 - 240 kg N/ha, which was equivalent to 8 - 40% of the N applied. Consequently there was a large accumulation of N in the soil particularly in the GWC 300 treatment (Spiers *et al.*, 1996). Nitrate leaching losses measured over winter when the first cabbage crop was grown showed that 65 - 85 kg N/ha was leached from the amended soils (Spiers *et al.*, 1996). It is possible that leaching losses will continue in future years, particularly from the GWC 300 treatment.

Phosphorus

There were very high levels of soil P at the start of the trial (Olsen P > 200, Table 1), so the differing amounts of P supplied in the treatments had little effect on plant P uptake. Consequently, plant P concentrations were similar in all treatments (data not shown), with differences in plant uptake due to differences in plant yields.

For the UCM 5 treatment, the amount of P applied was similar to that removed by the crop (Table 5). However for the other amendment treatments, considerably more P was applied than was taken up by the crop. The apparent recovery of applied P varied from 65% for GWC 50 to 14% for GWC 300. Surplus P will accumulate in the soil and contribute to further increases in Olsen P.

Potassium

In the control and UCM treatments, plants recovered more K than was applied (Table 6) indicating that the soil was an important source of K. Large quantities of K were applied in both GWC treatments, and more K was applied than was taken up by the plants. The surplus K is likely to accumulate in the soil as exchangeable K and become available to subsequent crops.

Table 4. Mean amount of N applied and taken up by the crops per year.

Treatment	Amount applied (kg N/ha)	Total plant yield (t DM/ha)	Total plant uptake (kg N/ha)
Control	225	6.7	140
UCM 5	350	8.3	200
UCM 15	610	9.7	240
GWC 50	610	8.1	180
GWC 300	2680	9.9	210
$LSD_{(P<0.05)}$		1.8	40

Table 5. Mean amount of P applied and taken up by the crops per year.

Treatment	Amount applied (kg P/ha)	Total plant yield (t DM/ha)	Total plant uptake (kg P/ha)
Control	0	6.7	53
UCM 5	70	8.3	67
UCM 15	200	9.7	80
GWC 50	100	8.1	65
GWC 300	630	9.9	87
$LSD_{P<0.05}$		1.8	17

Table 6. Mean amount of K applied and taken up by the crops per year.

Treatment	Amount applied (kg K/ha)	Total plant yield (t DM/ha)	Total plant uptake (kg K/ha)
Control	0	6.7	200
UCM 5	70	8.3	320
UCM 15	200	9.7	380
GWC 50	390	8.1	270
GWC 300	2530	9.9	340
$LSD_{P<0.05}$		1.8	60

Soil organic carbon

At the end of the experiment, soil organic C content for the UCM 5, UCM 15 and GWC 50 treatments (3.0%) did not differ from that of the control (2.7%). In these treatments the actual amount of organic material applied was small (5 - 50 t/ha per year) and had little effect on total soil organic matter content. However for the GWC 300 treatment, which had a large amount of organic material applied (300 t/ha per year), soil organic C content in the 0-15 cm depth was increased ($P < 0.05$) to 3.6%.

Conclusions

The application of amendments increased crop yields through the supply of N, as other nutrients were not limiting. The N in UCM appeared more plant available than N in GWC, resulting in higher crop yields. The amendments also provided a source of P and K, which if not immediately available to the plants, will be useful for maintaining soil P and K levels. Application of 300 t/ha of GWC provided a small but significant increase in soil organic C content in the short term. The amount of N, P and K applied in this treatment was very high and far in excess of crop requirements, leading to a build up of surplus nutrients in the soil. While the surplus P and K are likely to benefit subsequent crops, the surplus N added is likely to lead to increased nitrate leaching.

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