MINERALIZATION OF NITROGEN IN SOILS AMENDED WITH SUGARBEET PROCESSING BY-PRODUCTS

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INTRODUCTION

Application of organic industrial wastes and by-products on agricultural land has received considerable attention in recent years not only because of increasing energy requirements for production of synthetic fertilizers, but also because of the cost and environmental problems associated with alternative disposal methods. In this context, nutrient cycling in organic waste treated soils deserves attention as this may affect the use efficiency of applied fertilizers and if over applied, may cause environmental problems. Information on the relative degree of nutrient release (mineralization) and nutrient tie-up (immobilization) in soils treated with various organic waste materials therefore is needed. Therefore, laboratory and field studies were undertaken to (i) assess the mineralization of nitrogen (N) in various sugarbeet processing by-products added to soils, (ii) evaluate the effect of soil types on mineralization of N in these by-products, and (iii) to evaluate the effect of different size of chopped spoiled sugarbeets on N mineralization. Reported here are the results of the laboratory studies to assess nitrogen release and tie-up from the various sugarbeet by-products. A field site at East Grand Forks is currently in progress and will be used to assess long-term production and environmental impacts of land applying sugarbeet by-products.

MATERIALS AND METHODS

Laboratory incubation studies were conducted using the two surface soils varying in texture. Bulk soil samples (0-15 cm depth) of Bearden soil (Silty clay loam) and Angus soil (sandy loam) were collected from Red River Valley area (Table 1). Field moist soil was mixed and stored in coolers before starting the incubation.

Table 1. Chemical characteristics of soil used for incubation.

Soil	pH	Bray-P (ppm)	Olsen-P (ppm)	K (ppm)	OM (%)	Total N (%)	Org. C (%)
Bearden	7.9	18	16	260	7.07	0.35	4.93
Angus	8.2	35	24	115	5.75	0.34	5.36

The treatments consisted of (i) pulp @ 50 t acre^{-1} (ii) pulp @ 100 t acre^{-1}, (iii) pulp @ 200 t acre^{-1}, (iv) tailings @ 100 t acre^{-1}, (v) fresh beet @ 100 t acre^{-1}, (vi) spoiled beets @ 100 t acre^{-1}, (vii) dry sewage sludge @ 200 lbs available N, and (viii) unammended soil as control. The treatments with 3 replications were used for incubation. The chemical characteristics of the by-products and dry sewage sludge are presented in Table 2. Sewage sludge was included as a by-product control.

1308 g of moist Bearden soil and 1246 g of moist Angus soil (equivalent to 1000g dry weight) were mixed with the required amount of by-products according to the treatments into 1.5 gal (13 in. long x 4 in. deep x 8 in. wide) plastic storage boxes. Holes were drilled on the lid and sides of boxes to allow for diffusion of air. These containers were incubated at 30 ^{o}C $\pm$ 2 ^{o}C for a period of 120 days in an incubator.

Table 2 Chemical characteristics of sugarbeet processing by-products and dry sewage sludge.

By-product	**Moisture (%)**	**Total P g kg^{-1}**	**NH_4-N mg kg^{-1}**	**NO_3-N mg kg^{-1}**	**Organic carbon (%)**	**Organic nitrogen (%)**	**C:N**
Pulp	82.50	1.07	255	14	27.8	1.25	22
Tailings	81.52	2.04	234	30	25.2	1.05	24
Spoiled beets	65.07	0.97	8	30	27.4	0.61	45
Fresh beets	70.10	1.04	10	28	28.9	0.51	57
Dry sewage sludge	-	-	1	4099	29.9	5.30	6

Subsamples of soil (6-7 g wet weight) were taken at 0 (initial), 2, 4, 9, 16, 23, 30, 45, 65, 85, 120 days. These samples were extracted with 25 ml of 2*M* KCl by shaking for 30 minutes. The extracts were filtered with 2v fluted filter paper and/or plasma filter and inorganic N (NH_4-N + NO_3-N) was measured by conductimetric techniques (Carlson *et al.*, 1990).

The moisture content of the mixture was calculated using the moisture percentage of both soil and the wastes. The mass water content of soil at 80% field capacity was determined to be 0.26 ($?_{m80}$, w/w). The wet initial weight and the desired weight at 80% field capacity of the mixture were calculated as;

Mix weight at 80% (Fc) = (dry soil weight + dry waste weight)/(1-$?_{m80}$)
Mix initial weight = (soil dry weight + soil water weight) + (waste dry weight + waste water weight)

?? If the mix initial weight was greater than the mix weight at 80% Fc, water was allowed to evaporate until mix weight reached to 80% Fc.
?? If the mix initial weight was less than the mix weight at 80% Fc, water was added to bring the mix weight to 80% Fc.

The weights were checked every 2-3 days and deionized water was added to bring the moisture content to 0.308 and 0.246 (w/w) respectively for Bearden soil and Angus soils.

A second incubation study was also conducted using the above two soils to evaluate the effect of different sized chunks of chopped beets on N mineralization. The treatments were; (i) ground beets (with a food processor), (ii) chunks of 2.5 mm x 2.5mm (0.1” x 0.1”), (iii) chunks of 5 mm x 5 mm (0.2” x 0.2”), (iv) chunks of 10mm x 10 mm (0.4” x 0.4”), (v) chunks of 20 mm x 20 mm (0.8” x 0.8”), (vi) dry sewage sludge, and (vii) control soil.

CALCULATIONS:

Data on inorganic N (NH_4-N + NO_3-N) on any day (from day 0 to day 120) was corrected by subtracting the inorganic N content of mixture at day 0 (start of incubation) (Fig. 1). The data (points) in Fig. 1 were then fitted to double first order kinetic model (equation i) (see the lines in Fig. 1) to calculate potentially mineralizable N (PMN) (equation ii) from the by-products. This is an estimate of the amount of N that would be released over the course of the incubation.

$$N_{min} = N_1*(1-exp(-k_1*t) + N_2*(1-exp(-k_2*t) \quad (i)$$

$$PMN = N_1 + N_2 \quad (ii)$$

Where N_{min} is the corrected cumulative net ammonium plus nitrate mineralized (measured with time, t), N_1 is the potentially mineralizable N from the active pool or immobilization of soil N, k_1 is the rate of mineralization of active pool or rate of immobilization, N_2 is the mineralization of resistant pool of N and k_2 is the rate of mineralization of resistant pool. These double first order kinetic models were fitted by non-linear methods using Jandel Sigmaplot (1995). The estimated PMN of the unammended soil was subtracted from PMN of each treatment, and the availability index (equation iii) was calculated.

$$\text{Availability index (\%)} = \frac{\text{Corrected PMN}}{\text{Organic N applied}} \qquad \text{(iii)}$$

RESULTS AND DISCUSSION

The results showed that there was an initial phase of immobilization (tie up) of N under all the sugarbeet waste treatments before any net mineralization occurred (Fig. 1). The data of net mineralization/immobilization fitted well to the double first order kinetic model (equation i) which can be used to predict not only the %PMN from these wastes but also the maximum amount of N that would immobilize and the time (days) at which maximum immobilization would occur. The model parameters are presented in Table 3. The %PMN from the pulp treatments varied between 0 – 7 % depending upon the rate of application in Bearden soils and varied from 0 to 17% in Angus soil (Table 3). The values of % PMN for tailings, fresh beets and spoiled beets were approximately 17% in Bearden soil and varied between 10-16% in case of Angus soil (Table 3). The standard dry sewage sludge provided the %PMN values as 32.3% for Bearden soil and 38.9% for Angus soils and these values for sewage sludge are quite close to the values obtained in earlier studies.

The total amount of N mineralized at the end of the incubation is presented in Table 4. Less than 20 lbs acre^{-1} N mineralized from treatments where pulp was applied at 50 or 100t acre^{-1} in both the soils. While at 200t acre^{-1} rate, 76 and 178 lbs of N mineralized from pulp in Bearden and Angus soils, respectively. In the case of tailings, between 73 to 83 lbs N mineralized in both the soils (Table 4). While 72 lbs N mineralized from fresh beets and 112 lbs mineralized from spoiled beets in Bearden soils, the corresponding values were 43 lbs and 105 lbs for Angus soil. A large amount of soil N was immobilized under all the by-product treatments. In general a greater amount of N immobilized under Angus soil compared with Bearden soils, the amounts varied from 50 to 120 lbs in case of Bearden soil and from 68 to 243 lbs in case of Angus soil. The amount of N immobilized was correlated with the amount of carbon added through these by-products (r = 0.77 for Bearden soil and 0.85 for Angus soil).

Ultimately the immobilized N would be released and for these by-products, this amount was much less (< 20%) as compared to the dry sewage sludge used for comparison and also much less than the reported values in literature (between 20 to 34%) for leguminous crop residues (Kumar and Goh, 2000).

The results of study on different sized chunks of beets on N mineralization were interesting and showed that there was relatively greater immobilization of N when ground or smaller sizes of chopped beets were used compared with the bigger size. However, at the end of the incubation (120 days) there were no differences in amount of N released among different sized beets.

CONCLUSIONS

The results obtained in this study have direct implications for the farmers and environment managers. The results clearly show that when these wastes are applied to soil initial immobilization of soil N occurs and thus there is a need to supplement this immobilized N with inorganic fertilizer N to meet the crop N demands. Using the tillage practices that leave bigger chunks of beets in soils rather than those practices that would finely chop and mix the beets with soil can reduce the amount of soil N immobilized by spoiled beets. The fate of the N that would ultimately mineralize is beyond the scope of this laboratory study, but the results of field studies being conducted at East Grand Forks under this project will provide additional information that will address long-term nitrogen release.

FUTURE WORK

Apart from field studies already in progress to study the fate of mineralized N from these by-products, more laboratory incubation studies are being conducted to study the mineralization of N from these by-products in the presence of inorganic fertilizer nitrogen.

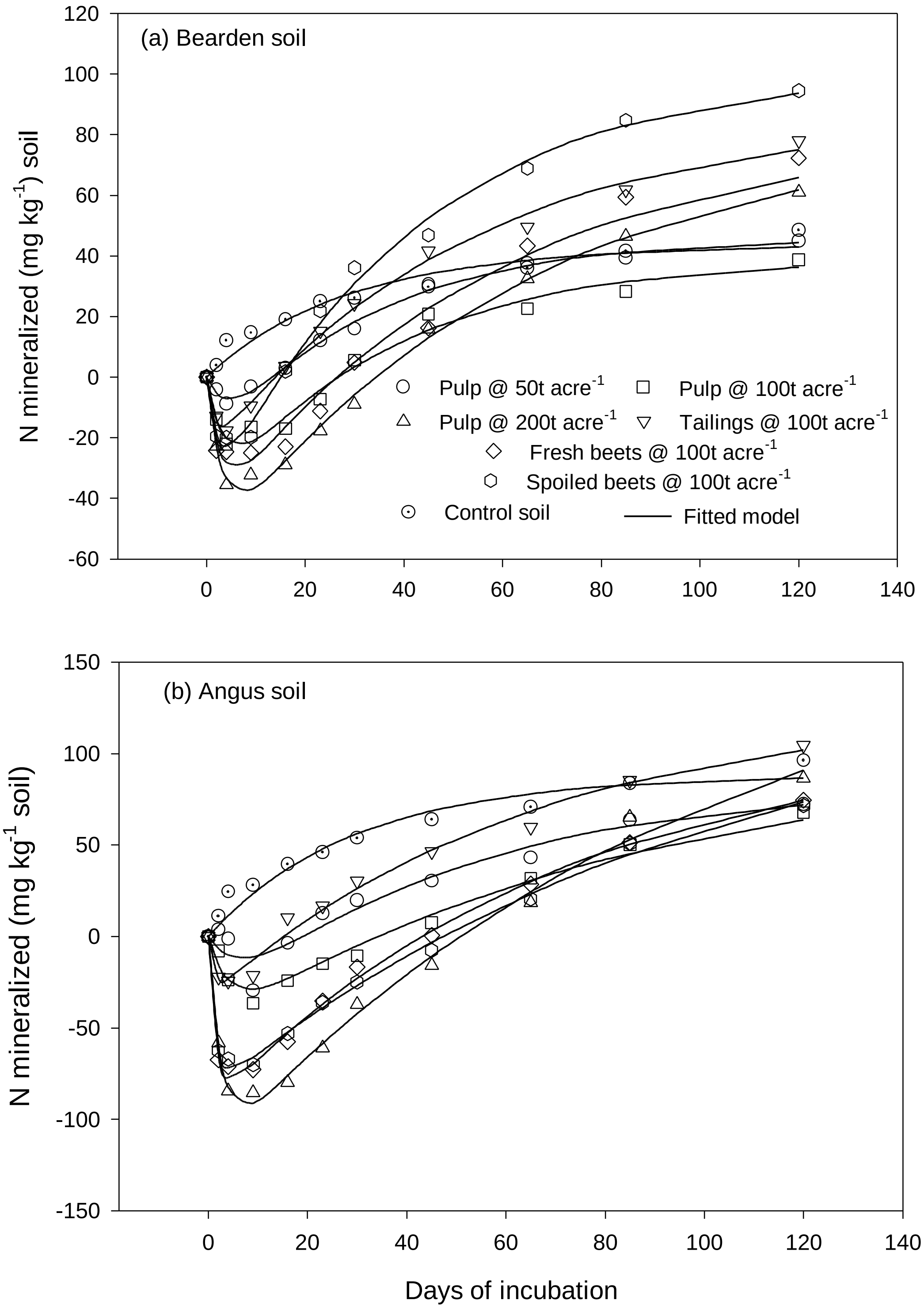

Fig. 1: Amount of N mineralized from (a) Bearden soil and (b) Angus soil amended with different sugarbeet prcocessing by-products and the un-amended control soils.

Table 3: Estimation of potential N mineralization (PNM) and immobilization from Bearden and Angus soils amended with different sugarbeet processing by-products.

	N_1	N_2	k_1	k_2	PMN (N_1+N_2) mg kg^{-1}soil	Corrected PMN† mg kg^{-1}soil
Bearden soil						
Pulp@50t/acre	-25.6	71.5	0.233	0.032	45.9	0.7
Pulp@100t/acre	-43.2	82.5	0.274	0.028	39.3	-5.9
Pulp@200t/acre	-60.3	143.3	0.299	0.016	83.0	37.8
Tailings@100t/acre	-26.4	112.9	0.594	0.019	86.5	41.3
Fresh beets@100t/acre	-48.6	130.0	0.357	0.018	81.4	36.2
Spoiled beets@100t/acre	-45.1	146.6	0.408	0.024	101.5	56.3
Dry sewage sludge	151.3	60.0	0.063	0.012	211.3	166.1
Control soil	35.1	10.1	0.040	0.014	45.2	-
Angus soil						
Pulp@50t/acre	-41.4	124.4	0.161	0.020	83.0	-7.1
Pulp@100t/acre	-50.0	150.0	0.235	0.012	100.0	9.9
Pulp@200t/acre	-121.6	301.0	0.375	0.010	179.4	89.3
Tailings@100t/acre	-34.0	160.4	0.844	0.016	126.4	36.3
Fresh beets@100t/acre	-95.0	206.6	0.673	0.014	111.6	21.5
Spoiled beets@100t/acre	-86.0	228.7	0.702	0.010	142.7	52.6
Dry sewage sludge	200.0	90.0	0.265	0.018	290.0	199.9
Control soil	80.1	10.0	0.036	0.012	90.1	-

†Corrected PMN = PMN for by-product – PMN control soil

Table 4: Amount of organic N applied, availability index, amount of N mineralized, days and amount of maximum N immobilized for different sugarbeet processing by-products.

	Organic N applied (lbs/acre)	Availability index (%)	Amount of N mineralized (lbs/acre)	Maximum amount of N immobilized (lbs/acre)	Days for maximum immobilization
Bearden soil					
Pulp@50t/acre	265.1	0.53	1.40	51.14	2
Pulp@100t/acre	530.2	0.00	0.00	86.31	7
Pulp@200t/acre	1060.4	7.12	75.50	120.47	7
Tailings@100t/acre	476.1	17.33	82.51	52.74	3
Fresh beets@100t/acre	433.2	16.69	72.30	97.09	6
Spoiled beets@100t/acre	658.1	17.09	112.47	90.10	4
Dry sewage sludge	1030.0	32.20	331.66	-	-
Angus soil					
Pulp@50t/acre	265.1	0.00	0.00	82.71	7
Pulp@100t/acre	530.2	3.73	19.77	99.89	8
Pulp@200t/acre	1060.4	16.82	178.35	242.94	7
Tailings@100t/acre	476.1	15.24	72.55	67.93	3
Fresh beets@100t/acre	433.2	9.91	42.93	189.79	5
Spoiled beets@100t/acre	658.1	15.96	105.03	171.82	5
Dry sewage sludge	1030.0	38.90	400.67	-	-

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