

# EFFECT OF SUGARBEET PROCESSING BY-PRODUCTS ON WHEAT YIELD, NITROGEN MINERALIZATION, AND RUN-OFF WATER QUALITY

Kuldip Kumar, Carl Rosen, and Satish Gupta  
Department of Soil, Water, and Climate  
University of Minnesota, St. Paul, Minnesota

## 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 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 may cause some environmental problems.

The sugarbeet processing facility generates many solid and liquid by-products resulting from the processing of sugarbeets into sugar. In Minnesota and North Dakota, more than 500,000 acres are planted to sugarbeets each year. The quantity of sugarbeets produced and processed in various facilities in these two states is about 10 million tons annually. Three types of solid wastes are produced as by-products. These include: (i) Spoiled beets – due to a sudden increase in temperature the beets in frozen storage piles thaw and then rot and are no longer fit for sugar processing. The quantity of spoiled beets depends upon the season and may be as high as 100,000 tons in some years; (ii) Beet tailings – these by-products mainly consists of 70-90% weeds, sugarbeet tops, debris, and soil and 10-30% sugarbeets. The quantity of beet tailings varies between 40,000 to 50,000 tons annually. (iii) Beet pulp – this consists of sugarbeet left-overs following juice extraction. The quantity of pulp produced is approximately 475,000 tons annually. Some of the pulp is used as animal feed, but the remainder is land applied.

Studies are being conducted at a field site at East Grand Forks to assess long-term production and environmental impacts of land application of sugarbeet by-products. This paper reports on the effects of application of sugarbeet by-products (pulp and spoiled beets) on first year crop growth, soil nitrogen (N) mineralization, and run-off water quality. Only a part of data is reported in this paper.

## MATERIALS AND METHODS

The field experiments are being conducted on a Bearden soil (Silty clay loam) at East Grand Forks. The soil at the site had pH 7.9, Olsen-P 16 mg/kg, K 260 mg/kg, Total N 0.35% and Organic C 4.93%. At the experimental site, 15 run-off plots (10 x 72') were set up in the fall of 2000. The run-off plots are equipped with a tipping-bucket to measure the run-off volume and a sampling mechanism to sample run-off water. The plots were also equipped with wick lysimeters to sample water and associated nutrients that are percolating through the soil. In the first week of June 2000, a crop of wheat was seeded in these plots, which was harvested in September of 2000. On 27<sup>th</sup> and 28<sup>th</sup> March 2001, by-product treatments were applied to the plots when the soil was still frozen. These treatments were:

- (i) Control (No by-product, no fertilizer)
- (ii) Spoiled beets @ 100 t/acre
- (iii) Spoiled beets @ 200 t/acre
- (iv) Pulp @ 100 t/acre
- (v) Pulp @ 200 t/acre

No N or P fertilizers were applied as soil test for nitrate and P before sowing showed that these nutrients were sufficient for wheat crop. The characteristics of the sugarbeet by-products are presented in Table 1 and the amounts of organic N and total P in these by-products applied are presented in Table 2.

Table 1: Chemical characteristics of the sugarbeet by-products.

By-product	Moisture (%)	Total P (g/kg)	NH <sub>4</sub> -N (mg/kg)	NO <sub>3</sub> -N (mg/kg)	Organic carbon (%)	Total nitrogen (%)	C:N
Pulp	83.76	1.07	255	14	27.8	1.25	22
Spoiled beets	67.60	0.97	8	30	27.4	0.61	45

Table 2: Amount of organic N and total P in the sugarbeet by-products applied.

Treatment	Organic N (Lbs/A)	Total P (Lbs/A)
Pulp @ 100 t	530.2	34.67
Pulp @ 200 t	1060.4	69.33
Spoiled beets @ 100 t	658.1	63.61
Spoiled beets @ 200 t	1316.2	127.22

In June 2001, plots were cultivated with a chisel plow to mix in the by-products and then seeded to wheat. The wheat crop was harvested on 24 August 2001. After harvest, the wheat residues were disked in the field. During each run-off event, water samples were collected and analyzed for water quality parameters. Soil samples were taken from three soil depths (0-6, 6-12, and 12-18”) every 2-3 weeks after the application of by-products. These soil samples were analyzed for mineral-N ( $\text{NH}_4^+$  +  $\text{NO}_3^-$ ). Periodically, plant samples were taken (3 quadrats 1ft<sup>2</sup> area in a plot) to determine wheat dry matter and N concentration. At final harvest, plants were sampled from three random spots (each 1 m<sup>2</sup> quadrat) in each plot for final total dry matter, grain yield, straw yield, and weed dry matter. Grain yield of wheat was adjusted to grain moisture content of 14%.

## RESULT AND DISCUSSION

### Grain yield and dry matter yield:

Grain yield, straw yield, and total dry matter were significantly greater under control treatment compared with treatments where sugarbeet by-products were applied (Table 3). However, differences among by-product treatments were not significant. Grain yields under 100 t/acre rates were higher than in 200 t/acre treatments. In general, weed dry matter was significantly greater under pulp treatments compared to the control and spoiled beets treatments (Table 3).

Table 3: Effect of sugarbeet by-products on grain yields, straw yield, weed dry matter and total dry matter accumulation of wheat crop.

Treatment	Grain yield	Straw Yield	Weed dry matter	Total dry matter
			Lbs/A	
Control	1849 a <sup>†</sup>	2920 a	135 b	4904 a
Spoiled beets 100t	1319 b	1544 b	216 ab	3079 b
Spoiled beets 200t	1046 b	1869 b	166 b	3081 b
Pulp 100t	1327 b	1834 b	457 a	3617 b
Pulp 200t	1140 b	2391 b	326 ab	3856 ab

<sup>†</sup>Data followed by the same letter in column are not significantly different at  $P \leq 0.05$ .

### Nitrogen concentration and N uptake

Nitrogen concentration of wheat grain was significantly higher from pulp 200 t/acre treatments compared to control and other by-products (Table 4). There was no difference in straw N concentration among by-product treatments, but straw N concentration in the control treatment was significantly lower compared to the 200 t/acre pulp treatment. There was no particular trend in weed N concentration (Table 4).

Table 4: Effect of sugarbeet by-products on nitrogen concentration (%) in wheat grains, straw and weeds in wheat crop.

Treatment	Grain	Straw	Weed
Control	2.62 b <sup>†</sup>	0.61 b	1.52 ab
Spoiled Beets 100t	2.64 b	0.87 ab	1.56 a
Spoiled Beets 200t	2.69 b	0.83 ab	1.35 b
Pulp 100t	2.67 b	0.75 ab	1.49 ab
Pulp 200t	2.82 a	1.13 a	1.52 ab

<sup>†</sup>Data followed by the same letter in column are not significantly different at  $P \leq 0.05$ .

There were no differences in total N uptake (crop + weeds) and straw N uptake, however, grain N uptake was significantly greater from the control compared to by-product treatments (Table 5).

Table 5: Effect of sugarbeet by-products on nitrogen uptake by wheat crop.

Treatment	Grain	Straw	Lbs/A		Total
			Weeds		
Control	48.44 a <sup>†</sup>	17.66 a	2.06 b		68.16 a
Spoiled Beets 100t	34.81 b	14.23 a	3.39 ab		52.34 a
Spoiled Beets 200t	28.08 b	15.62 a	2.17 b		45.89 a
Pulp 100t	35.51 b	13.86 a	6.95 a		56.32 a
Pulp 200t	32.07 b	27.40 a	4.99 ab		64.46 a

<sup>†</sup>Data followed by the same letter in column are not significantly different at  $P \leq 0.05$ .

### Soil N mineralization

The data on periodic soil mineral N at three depths after the application of by-products in March and after wheat harvest in August clearly shows that, there was less mineral N in soil under by-product application treatments compared to control only from April to July (Fig. 1). After July differences among treatments were not significant. This was probably due to continuous immobilization of soil N due to the application of the sugarbeet by-products.

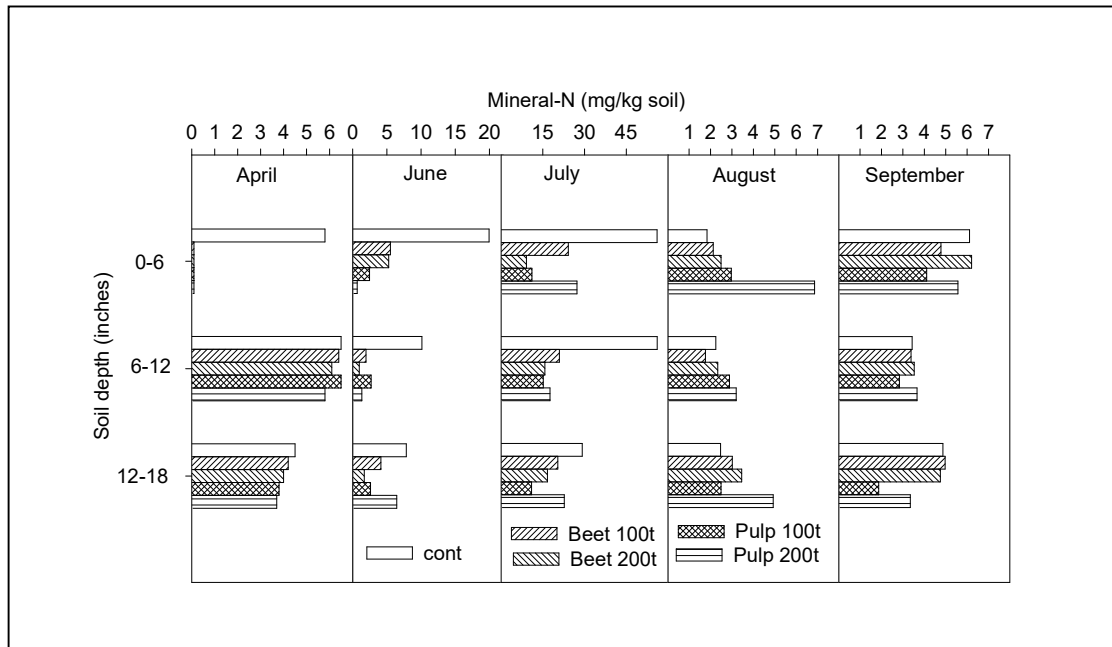
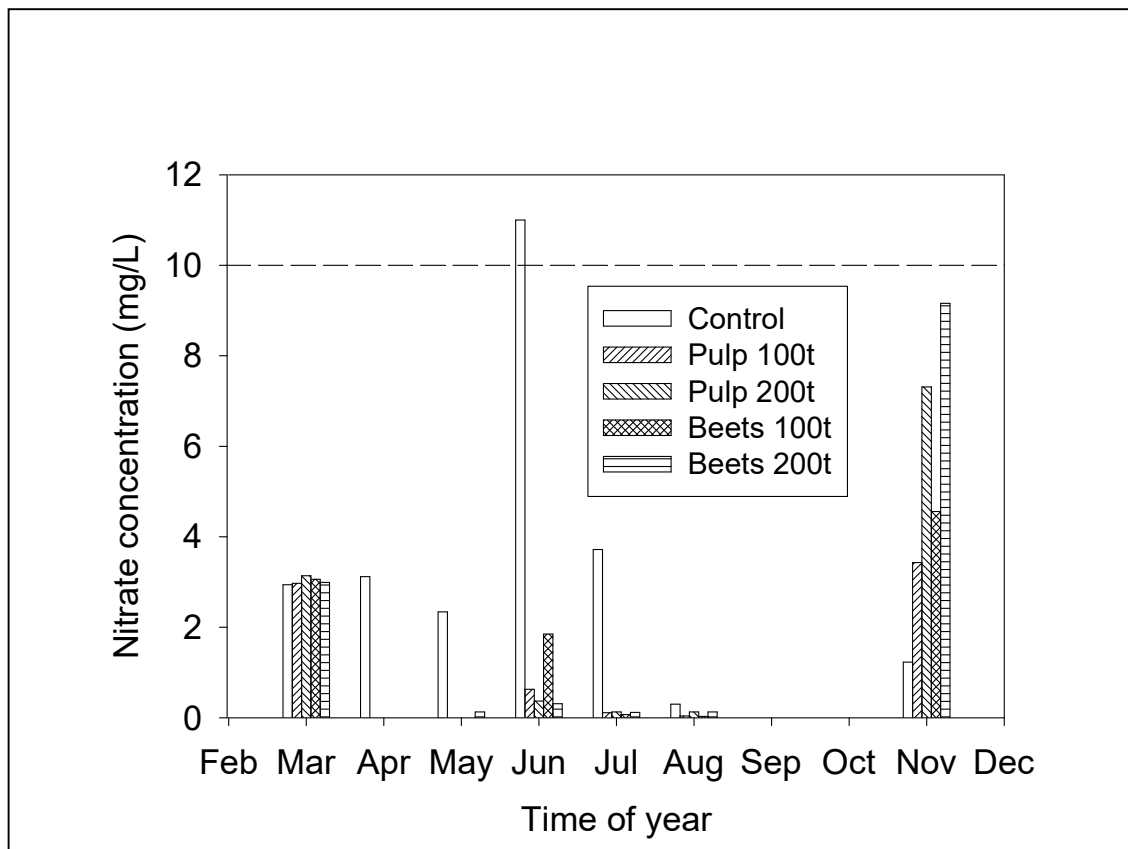


Fig. 1: Periodic mineral-N content at different depths as affected by sugarbeet by-products application treatments (multiply mineral N values by 2 to convert approximately to lbs/acre).

### Run-off water quality

Only data on nitrate-N, total P, soluble P and biochemical oxygen demand (BOD) are presented here.

**Nitrate-N:** In general nitrate-N concentrations in runoff water from control plots were higher than the sugarbeet by-product treatments (Fig. 2). Most of the time, runoff nitrate-N concentration were lower than 10 mg/L nitrate-N drinking water standard (USEPA, 1973), except in the control treatment during a June runoff event which occurred just after the cultivation to mix the surface applied by-products and seeding of wheat crop. In fall 2001, there was some increase in nitrate N concentration of run-off waters especially under 200 t/acre treatments of pulp and spoiled beets (Fig. 2).

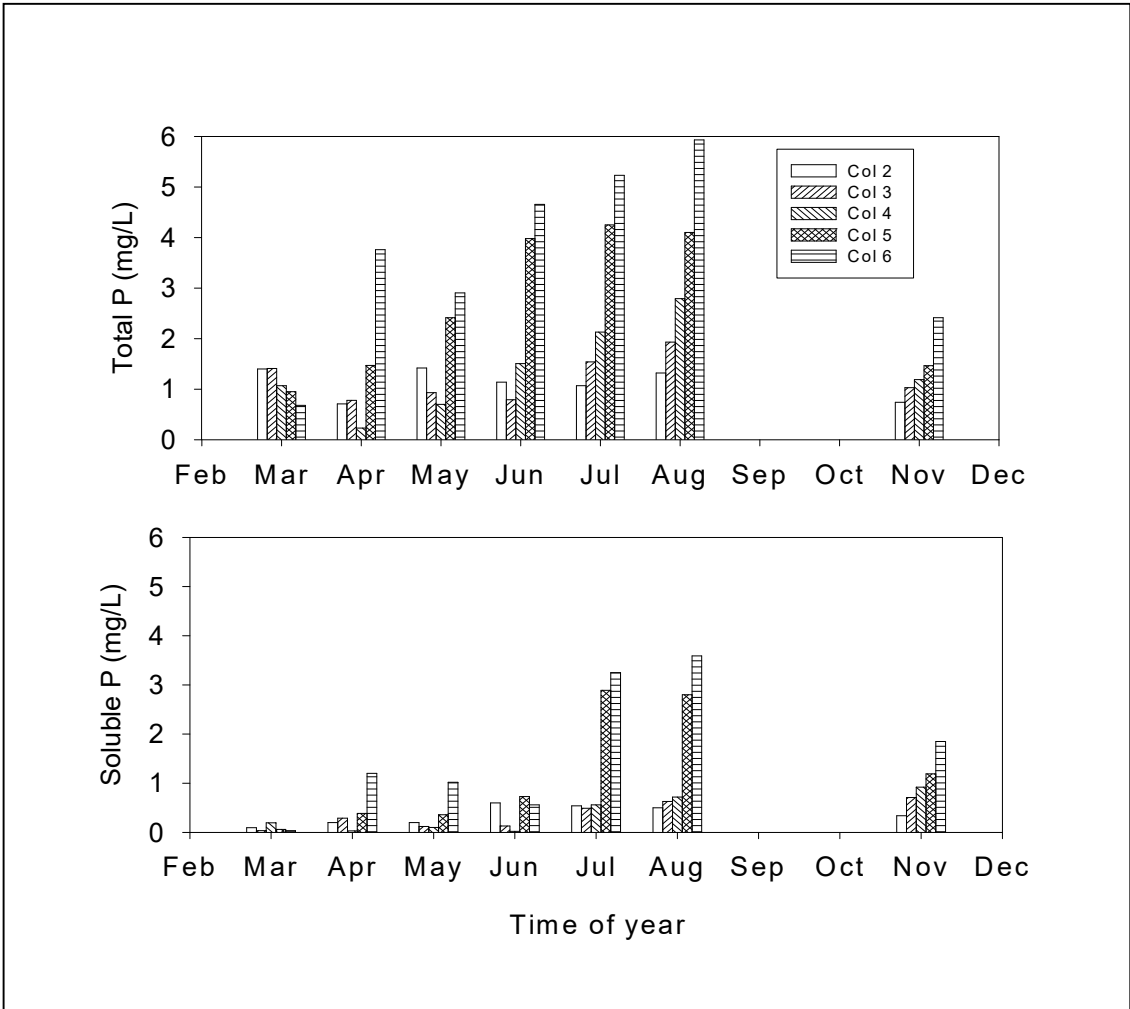


**Fig. 2: Nitrate-N concentration in runoff as affected by sugarbeet by-product application treatments.**

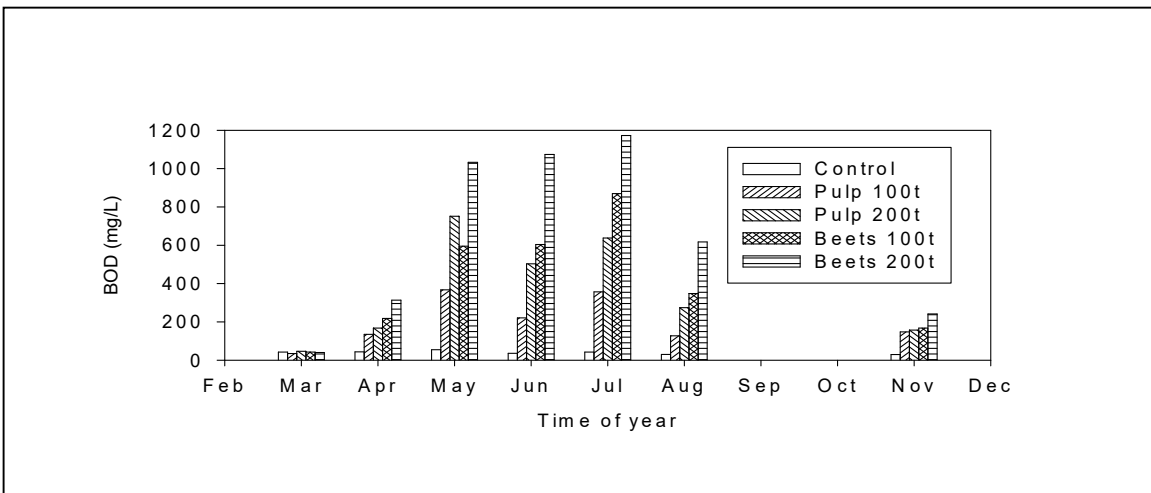
**Phosphorus:** The concentration of both total P and soluble P in runoff waters increased after the application of sugarbeet by-products (Fig. 3). Total P concentration in the runoff water varied from 0.5 to 5.9 mg/L (Fig. 3). These total P concentrations were higher than the 0.02 mg/L limit for accelerated eutrophication of lakes and impoundments (Sharpley *et al.*, 1987). The concentrations of soluble P varied from 0.01 to 3.6 mg/L, while the critical limit for eutrophication of lakes and impoundments for soluble P is only 0.01 mg/L (Sharpley *et al.*, 1987). The concentration of both total P and soluble P was in general, more than double under spoiled beet treatments compared to pulp treatments (Fig. 3). The concentrations were higher under 200 t/acre spoiled beets treatments compared to 100 t/acre treatments. This may be due to a higher amount of total P applied in the spoiled sugarbeet (63.6 and 127.2 lbs/acre, respectively in 100 t and 200 t/acre, Table 2) compared to the pulp treatments (34.7 and 69.4 lbs/acre respectively in 100 t and 200t/acre treatments, Table 2).

**Biological oxygen demand:** Biochemical oxygen demand or sometimes referred to as biological oxygen demand, is a quantitative expression of microbes ability to deplete the oxygen content of a wastewater. High levels of BOD in streams cause the dissolved oxygen content of the water to drop. If the dissolved oxygen drops below a critical level fish, zooplankton etc. start to die.

The values of BOD of runoff water also showed the same trend as total P and soluble P. The BOD values of runoff water from the by-product treatments were higher than those of control treatment (Fig. 4). The BOD values of runoff waters from spoiled beets treatments were much greater than under pulp treatments. The BOD values of runoff water from control treatments varied between 30 to 55 mg/L, while from spoiled beets @ 200 t/acre treatments were as high as 1174 mg/L. In general the BOD values for lake waters are between 20-30 mg/L while those of sewage water may range from 500-1000 mg/L and those of waste waters from food processing plants may range from 1500-3000 mg/L



**Fig. 3: Concentration of total P and soluble P in runoff as affected by sugarbeet by-product application treatments.**



**Fig. 4: Effect of sugarbeet by-products application on BOD of runoff.**

## **CONCLUSIONS**

The results of this field study show that application of spoiled beets and pulp causes significant reduction in grain yield of crops in the first year. This is due to immobilization of soil inorganic N during the period of crop growth. The earlier laboratory experiments with the same by-products have shown that these by-products have potential to immobilize as much as 240 lbs N/acre. Subsequently the N from these by-products would be released slowly and increasing nitrate-N concentration of runoff water in fall of 2001 provided an indication that N was being released. Although nitrate concentration of runoff waters was below the 10mg/L limit, higher total P, soluble P and higher BOD values may cause some concern depending upon the runoff volumes from the fields and its delivery to surface water bodies and impoundments. Based on these results, it is suggested that care should be taken to minimize the runoff from sugarbeet by-products applied fields.

## **WORK IN PROGRESS**

Total losses of nutrients as runoff and leaching are being estimated. Our future plans include continuing water and soil sampling from the plots. Next spring (2002) we plan on establishing a crop (possibly beets) and then continue monitoring runoff and leaching for relevant water quality parameters and soil for release of mineral-N.

## **REFERENCES**

Sharpley, A.N., Smith, S.J., and Naney, J.W. (1987). Environmental impact of agricultural nitrogen and phosphorous use. *J. Agric. Food Chem.*, 35: 812-817.

USEPA. (1973). Water quality criteria. EPA-R3-73-033. U.S. Gov. Print. Office, Washington, DC.