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MANAGEMENT OF SWEET CORN PROCESSING WASTES TO PROTECT GROUNDWATER QUALITY

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ABSTRACT

Results from the first 2 years of this study to determine appropriate application rates for sweet corn processing wastes indicate that land application for management of waste materials is a feasible approach. Agronomic responses of field corn to applications of up to 200 tons/acre of sweet corn residue were positive. Plant emergence, plant height, dry matter yields, and grain yields were increased by increasing rates of residue application. Yield responses to residue rate occurred even where there was no response to fertilizer N, suggesting that the residue additions provide beneficial effects other than contributing N. High soil N contributions at the experimental site prevented yield response to added N.

Soil inorganic N measurements throughout the growing season show that sweet corn residues decompose with a relatively rapid release of available N. Based on these results, residue applications in the 50 to 100 tons/acre range probably would not exceed corn N requirements at responsive sites and should not leave excessive amounts of residual nitrate in the soil at the end of the growing season. Data from the residual study show that N mineralization is not complete after the first year of application, but the amount of available N supplied in the second year will not provide the entire corn N need. The residual effects of residue treatments must be considered to avoid excess N applications in the second year after residues are land-applied.

Soil water data indicate that residue treatments in excess of 100 tons/acre can increase soil water nitrate-N concentrations relative to typical corn N fertilizer rates, but by the end of the second growing season soil water nitrate-N concentrations were equal in all treatments including the control (no residue).

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INTRODUCTION

Production of sweet corn for processing in the Midwest is concentrated in Wisconsin, Minnesota, and Illinois with these three states accounting for >60% of the 1991 national production of ~3.3 million tons. The economic contributions of this industry benefits urban and agricultural communities throughout the region. A major problem facing the sweet corn industry is the management of waste materials in a manner consistent with sustained profitably and environmental protection. The residues generated in sweet corn processing are bulky, heavy, expensive to handle, and cause environmental problems unless they are properly managed. Approximately 66% of the weight of harvested corn entering a processing plant must be removed as waste material. This material consists mainly of husks, cobs, and other plant residues generated in canned or frozen sweet corn processing. Based on 1991 Wisconsin, Minnesota, and Illinois sweet corn production, approximately 1.3 million tons of waste materials must be managed annually. Traditionally, much of this residue has been stored in silage stacks and distributed to farmers during the winter months as livestock feed. The reduced demand for sweet corn silage, seepage of acidic high biological oxygen demand (BOD) effluent from the stacks, odors, and regulatory actions against processing companies regarding surface water contamination has lead to an increasing interest in returning the residue to agricultural land immediately after processing. Continuation of the traditional stacking process now requires complex, expensive effluent containment and monitoring facilities. There is little information available to determine appropriate land application rates for sweet corn processing residues or to indicate the environmental and agronomic effects of various residue application strategies.

Objectives of this research included determining:

1. The mineralization/immobilization rates of N from land application of high rates of sweet corn processing residue;
2. The distribution of nitrate over time in the soil profile associated with the treatments;
3. The effects of supplemental fertilizer N additions to these high rates of residue application on mineralization of the residue and nitrate in the profile;
4. The effects of these high loading rate applications on growth and production of succeeding crops;
5. The residual effects of sweet corn residue applications on growth and production of succeeding crops; and
6. The effect sweet corn residue applications have on soil water nitrate-N concentrations below the corn root zone.

METHODS

An experiment designed to accomplish project objectives was conducted at the University of Wisconsin Research Station, Arlington during 1992 and 1993. The soil at the experimental site was a Plano silt loam. Experimental conditions and procedures are summarized in Tables 1 and 2. Sweet corn or field corn was planted in May on the experimental area and the corn was removed as silage or ear corn in mid-August.

Soil profile samples (0 to 5 feet) were taken from the four experimental replicates prior to residue application and analyzed for nitrate and exchangeable ammonium-N. Surface samples (0 to 6 inches) were analyzed for pH, organic matter, available P, and exchangeable K. A randomized complete block design, replicated four times, was used. Sweet corn residue application rates applied in fall 1991 were 0, 25, 50, 75, and 100 tons/acre (wet) and fertilizer N rates of 0, 75, and 150 lbs N/acre were applied at the 0, 50, and 100 tons/acre residue rates the following spring. (See Table 12 for a complete list of treatments.) Sweet corn residue was applied in fall 1992 at rates of 0, 25, 50, 100, 150, and 200 tons/acre (wet); fertilizer N rates of 0, 60, 90, 120, and 150 lbs N/acre were applied the following spring. The 60 lbs N/acre rate was applied at the 0, 50, 100, 150, and 200 tons/acre residue rates. Nitrogen rates of 0, 60, 90, 120, and 150 lbs N/acre were applied without sweet corn residue to determine corn response to N at the experimental site. (See Table 13 for a complete list of treatments.) Individual plots were six rows (15 feet) wide and 30 feet long. The residue was weighed, transported, and applied using an end-loader. Garden rakes were used to distribute the residue evenly within the plot areas.

The experimental area was disked 2 days after residue application. Soil temperature measurements were made at the 2-inch depth using a Cole Parmer series 8110 hand held thermometer. Soil moisture was measured gravimetrically at the 0 to 6 inch depth before plowing and at 0 to 1 foot after moldboard plowing. The experimental area was then moldboard plowed and soil samples (0 to 2 feet) were taken and analyzed for nitrate and ammonium-N.

Soil profile samples (0 to 3 feet) were taken in 1-foot increments at five sampling times from April through October and analyzed for nitrate and ammonium-N. Soil temperature, soil moisture, and soil nitrate-N were measured weekly throughout the growing season.

A 104-day relative maturity hybrid (Pioneer brand 3578) was planted on the experimental areas. Seeding rates were adjusted so that stands could be hand thinned to a uniform density of 26,000 plants/acre. Corn emergence rates were determined in each residue treatment twice weekly by counting the number of plants emerged, divided by the total seeds planted in each harvest row. Plant height was measured in late June or early July. At physiological maturity 10 whole plants were harvested from each plot and used to determine dry matter yield and plant N uptake. Grain yields were determined by machine harvest of the middle two rows of each plot. A subsample of grain from each plot was retained for moisture determination.

Soil water was collected at the 4 foot depth throughout the growing season using porous ceramic cup samplers. Samples were collected approximately weekly when water was available, and

Table 1. Experimental conditions and procedures for 1992.

Procedure	Condition
Initial Soil Tests	
pH	7.0
P (ppm)	140.0
K (ppm)	370.0
Organic matter (%)	4.5
Sweet Corn Residue Analysis	
P (%)	0.21
K (%)	0.88
N (%)	1.33
C (%)	45.3
Sweet Corn	
Variety	Zenith
Planting date	15 June 1991
Harvest date	13 August 1991
Sweet Corn Residue	
Application date	20 August 1991
Rates	0, 25, 50, 75, 100 tons/acre
Fertilizer	
Preplant broadcast (urea) rate	0, 75, 150 lb/acre
Application date	5 May 1992
Soil Insecticide	At planting, 6 May 1992 Lorsban (8.7 lb/acre)
Herbicides	Pre-emergence 8 May 1992 Lasso (1.5qt/acre) Bladex 4L (2.5qt/acre)
Soil Sampling	
Profile NO_3-N, NH_4-N dates	15 August 1991 23 April 27 May 1992 30 June 29 July 1992 26 October 1992
Corn	
Hybrid	Pioneer 3578 104 day RM
Planting date	6 May 1992
Row spacing (inches)	30
Plant density (plants/acre)	26,000
Early silage harvest date	29 July 1992
Mature silage harvest date	5 October 1992
Grain harvest date	6 November 1992

Table 2. Experimental conditions and procedures for 1993.

Procedure	Condition
Initial Soil Tests	
pH	6.6
P (ppm)	54.0
K (ppm)	208.0
Organic matter (%)	4.2
Sweet Corn Residue Analysis	
P (%)	0.23
K (%)	0.96
N (%)	1.33
C (%)	42.3
Sweet Corn Residue	
Application date	27 August 1992
Rates	0, 25, 50, 100, 150, 200 tons/acre
Fertilizer	
Preplant broadcast (ammonium nitrate) rate	0, 60, 90, 120, 150 lbs N/acre
Application date	27 April 1993
Soil Insecticide	At planting 30 April 1993 Lorsban (8.7lb/acre)
Herbicides	Pre-emerge 6 May 1993 Prowl (1.5qt/acre) Bladex 4L (2.5qt/acre)
Soil Sampling	
Profile NO_3-N, NH_4-N dates	25 August 1992 26 April 26 May 1993 2 July 29 July 1993 22 October 1993
Corn	
Hybrid	Pioneer 3578 104 day RM
Planting date	30 April 1993
Row spacing (inches)	30
Plant density (plants/acre)	26,000
Mature silage harvest date	27 September 1993
Grain harvest date	27 October 1993

analyzed for nitrate-N. Porous cup samplers were installed in each of the four field plot replications of selected treatments. The treatments that were monitored in 1992 were the control (0 residue), 100 tons residue + 0 lbs N, and 100 tons of residue + 150 lbs N/acre. These treatments were also monitored in 1993 to measure second year residual effects of treatments on nitrate-N concentrations. Five treatments were monitored in 1993, including the control (0 residue), 100 tons residue + 0 lbs N, 200 tons residue + 0 lbs N, 50 tons residue + 60 lbs N, and 0 tons residue + 150 lbs N.

A second experiment was conducted during 1993 to determine second year residual effects of sweet corn residue on the amounts of N supplied to corn. The plots used to determine residual effects were those used to determine first year effects of sweet corn residue in 1992. The 150 lb N/acre fertilizer N treatment was repeated in 1993 to measure corn N uptake with adequate N. This treatment received 150 lbs of ammonium nitrate-N/acre in late April. (See Table 16 for a complete list of treatments.) Field corn (Pioneer brand 3578) was planted on the experimental area in late April. Soil profile (0 to 3 feet) samples were taken in late April, June, and October and analyzed for nitrate and ammonium-N. Whole plant samples were taken at physiological maturity from treatments that contained residue with zero added N and the treatment that contained zero residue + 150 lbs N/acre. Grain samples were taken from all treatments.

RESULTS AND DISCUSSION

SOIL TEMPERATURE AND MOISTURE

The effects of residue application rate on soil temperature and moisture following residue application in 1991 and during the 1992 growing season are shown in Figures 1 and 2, respectively. Data in Figure 1a show that soil temperature at a 2-inch depth increased with increasing residue rates at several measurement times during August and September. This effect may be due to increased biological activity promoted by the residue addition or to an insulating effect in which the residue addition slowed heat loss from the soil as temperatures decreased in fall.

Soil moisture (Figure 1b) in 1991 usually increased with increasing residue rates before and after moldboard plowing. The residue treatments probably reduced soil moisture loss before plowing and increased soil moisture holding capacity when the residues were incorporated.

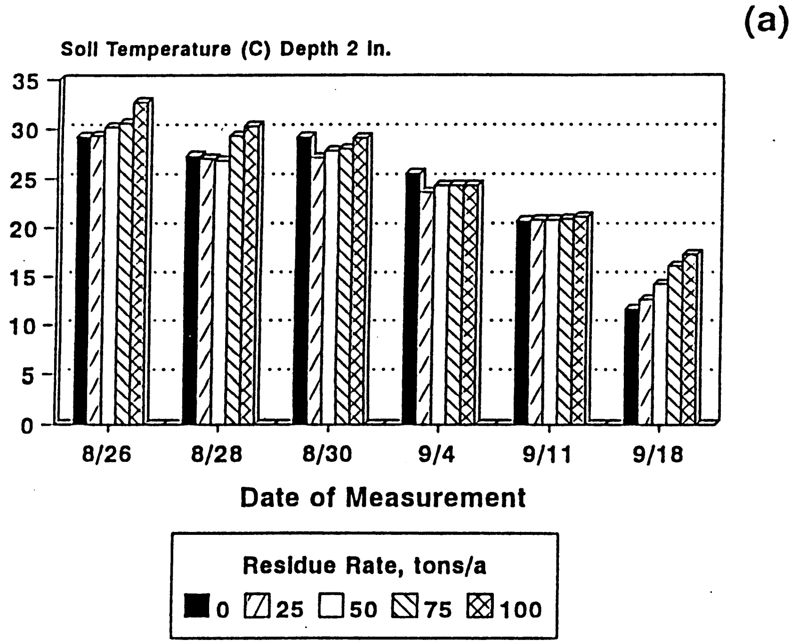
Figure 2a shows the typical changes in soil temperature (8-inch depth) during the 1992 growing season; residue rate had little, if any, effect on soil temperatures. Soil moisture content at the 1-foot depth (Figure 2b) was higher at the higher residue rates during the first 2 to 3 months of the growing season, but this effect was less apparent during the remainder of the year. The higher soil moisture levels at the higher residue rates suggest that residue additions increased soil moisture holding capacity and/or reduced soil moisture loss.

The effects of residue rate on soil temperature and moisture following residue application in 1992 and during the 1993 growing season are shown in Figures 3 and 4, respectively. Data in Figure 3a show that soil temperature at a 2-inch depth was increased by increasing residue rates during early and mid-September measurements. This effect is similar to 1991 data. In contrast, measurements taken in late September and early October showed a decrease in soil temperature with increasing rates of residue. Soil moisture (Figure 3b) in 1992 usually increased with increasing residue rate before and after moldboard plowing.

Figure 4a shows that residue had no effect on changes in soil temperature (8-inch depth) during the 1993 growing season. Soil moisture content at the 1-foot depth (Figure 4b) was higher at the higher residue rates during the first 2 to 3 months of the growing season, but this effect was less apparent during the remainder of the year.

SOIL INORGANIC NITROGEN CONTENT

Extensive measurements of soil inorganic N (ammonium and nitrate) were made throughout the experiment to determine the effects of the sweet corn residue treatments on the rates and amounts of ammonium and nitrate-N produced. These measurements were made to determine the amounts of available N the residue might provide to subsequent crops and to evaluate the risk of possible losses of nitrate-N released from the residue. Exchangeable ammonium-N was measured at all soil sampling times, but residue rate had little effect on the amounts detected. Therefore, exchangeable ammonium values are shown only for the initial sampling prior to residue application.



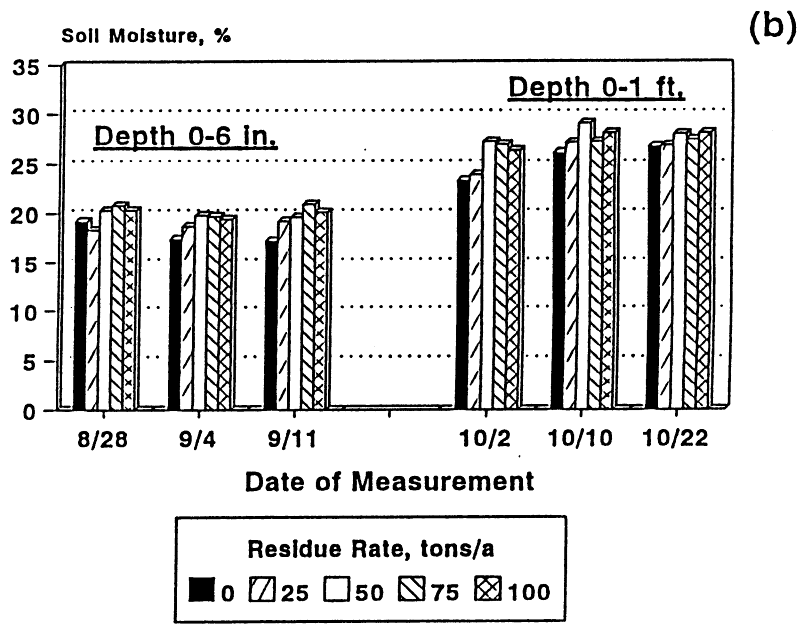
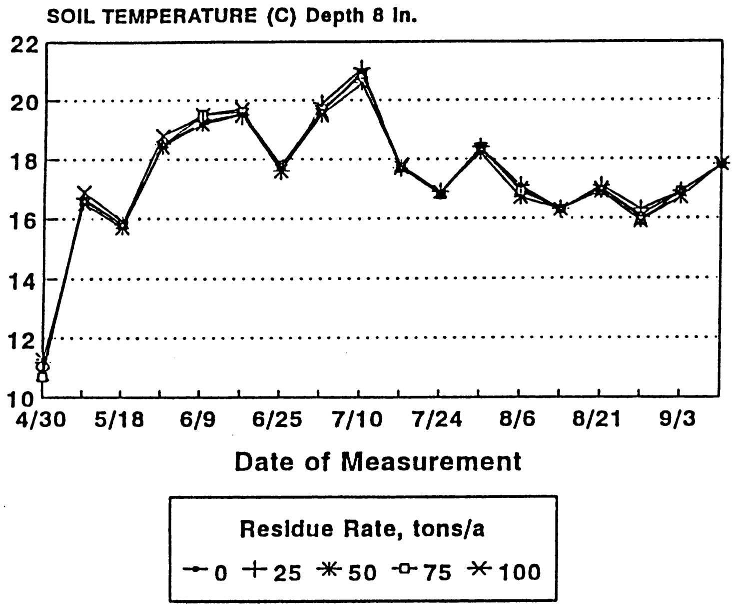


Figure 1. Effect of residue treatments on soil temperature (a) and soil moisture (b), 1991.

(a)



(b)

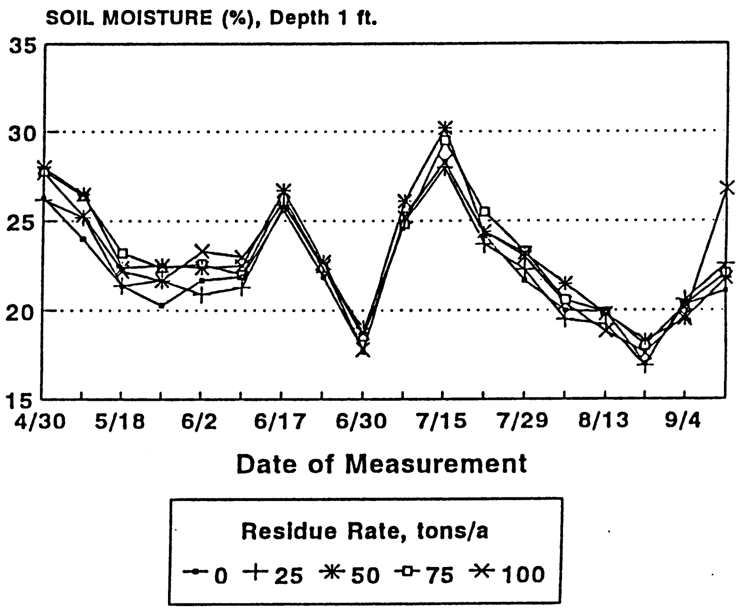


Figure 2. Effect of residue treatments on soil temperature (a) and soil moisture (b), spring and summer 1992.

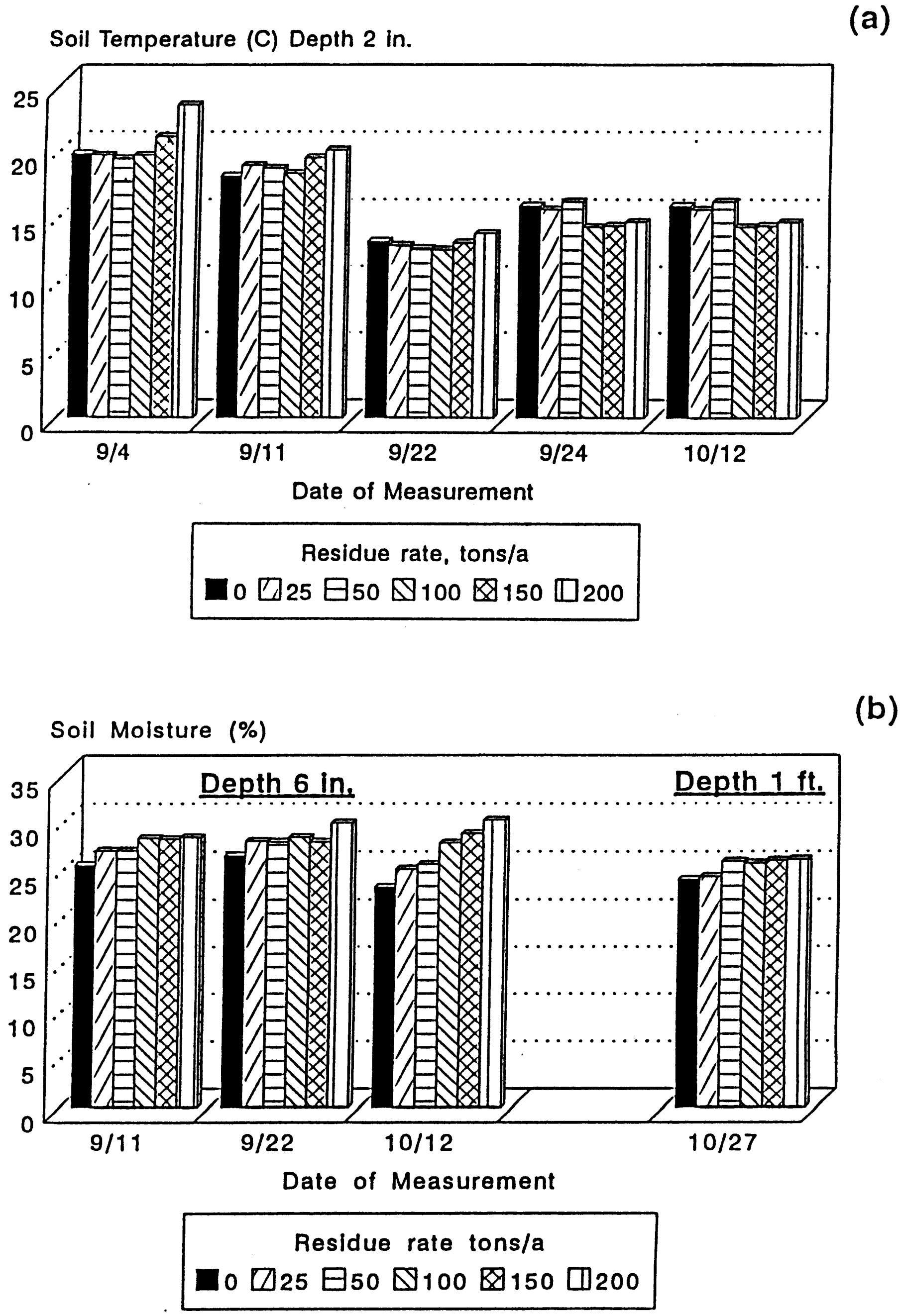
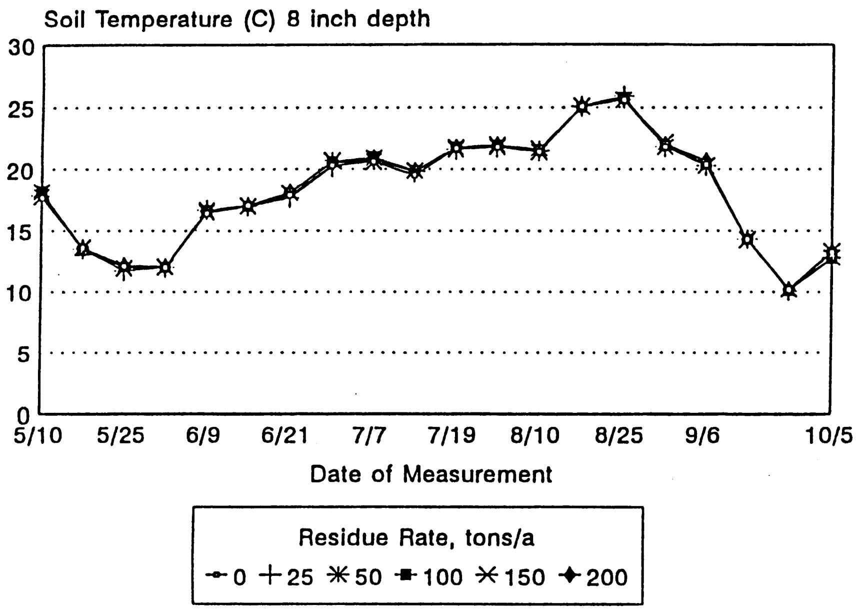


Figure 3. Effect of residue treatments on soil temperature (a) and soil moisture (b), fall 1992.

(a)



(b)

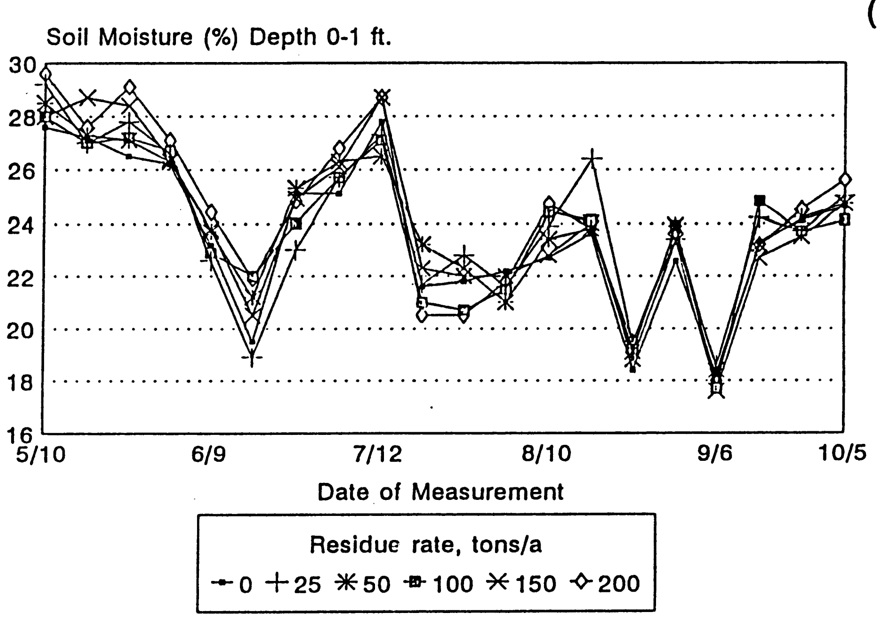


Figure 4. Effect of residue treatments on soil temperature (a) and soil moisture (b), 1993.

Initial inorganic N contents at the experimental sites in 1991 and 1992 (Tables 3 and 4) show significant amounts of nitrate and ammonium-N in the top 5 feet of the soil profile. Soil nitrate measurements after application of residue treatments (Tables 5 and 6) show a general increase in nitrate-N concentrations from most treatments compared to initial amounts in Tables 3 and 4. Soil nitrate-N contents in the fall of 1991 (Table 5) shows higher nitrate-N concentrations at the higher residue rates, suggesting mineralization of organic N from residue applications. Soil nitrate-N contents in the fall of 1992 (Table 6) were lower in the residue treatments than the control (no residue). This trend may be due to immobilization caused by the residue additions.

Measurements of nitrate-N in the top foot of the soil profile throughout the 1992 and 1993 growing season illustrate residue treatment effects on soil nitrate-N contents (Figures 5 and 6). In late April nitrate-N contents in the residue treatments were higher than in the control treatment, indicating that a net mineralization of residue N occurred during the previous fall and winter. In 1992, from the initial April measurement through mid-June, (Figure 5) soil nitrate-N increased dramatically in all treatments as organic N in the residue and in soil organic matter were mineralized. During this period nitrate-N in the top foot of soil increased by about 150 lb N/acre in the 100 ton/acre residue treatment, while nitrate-N in the control treatment increased by about 80 lb N/acre. This is in contrast to 1993 data (Figure 6) where nitrate-N in the top foot of soil increased 5 to 15 lbs. in all treatments during the same period. This may be a result of N loss due to exceptionally high rainfall that occurred in 1993. In both years, between mid-June and late August, soil nitrate-N decreased in all treatments due to N utilization by the corn crop. From late August to the final measurement in late October, soil nitrate-N contents tended to increase in all treatments, especially at the higher residue rates. This data suggests that N-mineralization from the residue treatments is not complete in 1 year. This conclusion is supported by data showing substantial residual effects of previous year residue treatments (see Tables 16 and 17).

The effects of residue rates and fertilizer N treatments on soil profile (0 to 3 feet) nitrate-N contents at several dates during the 1992 and 1993 growing seasons are shown in Tables 7 through 10. These measurements in the residue rate treatments show similar trends, as discussed previously, for the 0 to 1 foot nitrate-N values. Nitrate-N distributions with depth in 1992 (Tables 7 and 8) show that most of the N released from the residue treatments remained in the top foot of the soil profile throughout the growing season, but some increase in nitrate-N in the 1 to 2 foot depth with increasing residue rates is apparent at the late October sampling.

In 1993 (Tables 9 and 10) nitrate-N distributions with depth show that most of the N released from the residue treatments remained in the top foot of soil until early June, when nitrate-N accumulations were more uniformly distributed throughout the profile. This is probably due to the excessive amount of rainfall that occurred during the growing season which promoted nitrate-N leaching. In the last sampling most of the nitrate-N was found in the top foot of soil for both years, probably due to N mineralization from the residue and soil organic matter after the corn reached maturity. As expected, fertilizer N applications alone and in addition to residue treatments increased soil profile nitrate-N contents (Tables 8 and 10). Where fertilizer N was applied in addition to sweet corn residue, substantially more nitrate-N was found in the 1 to 2 and 2 to 3 foot depths at the October sampling date for both years, indicating more leaching of N in these treatments.

Table 3. Initial soil NO_3-N and NH_4-N contents (0 to 5 feet), 15 August 1991.

Residue tons/acre	Soil depth (feet) 0-1	1-2	2-3	3-4	4-5	0-3	0-4	0-5
	NO_3-N (lb/acre)							
0	34	13	22	31	37	69	99	136
	NH_4-N (lb/acre)							
0	17	14	18	17	14	49	66	80

Table 4. Initial soil NO_3-N and NH_4-N contents (0 to 5 feet), 25 August 1992.

Residue tons/acre	Soil depth (feet) 0-1	1-2	2-3	3-4	4-5	0-3	0-4	0-5
	NO_3-N (lb/acre)							
0	81	31	24	18	12	136	154	166
	NH_4-N (lb/acre)							
0	16	12	13	11	10	41	52	62

Table 5. Soil NO_3-N contents (0 to 1 foot), 9 September 1991, and (0 to 2 feet), 20 October 1991.

Residue tons/acre	9 September Depth (feet) 0-1	20 October Depth (feet) 0-1	1-2	0-2
	NO_3-N, lb/acre	NO_3-N, lb/acre		
0	69	74	46	120
25	49	54	36	90
50	57	74	51	125
75	59	77	56	133
100	64	87	54	141

Table 6. Soil NO_3-N contents (0 to 2 feet), 27 October 1992.

Residue tons/acre	Depth (feet) 0-1	1-2	0-2
	NO_3-N (lb/acre)		
0	78	75	153
25	60	50	110
50	55	58	113
100	58	38	96
150	70	73	143
200	72	70	142

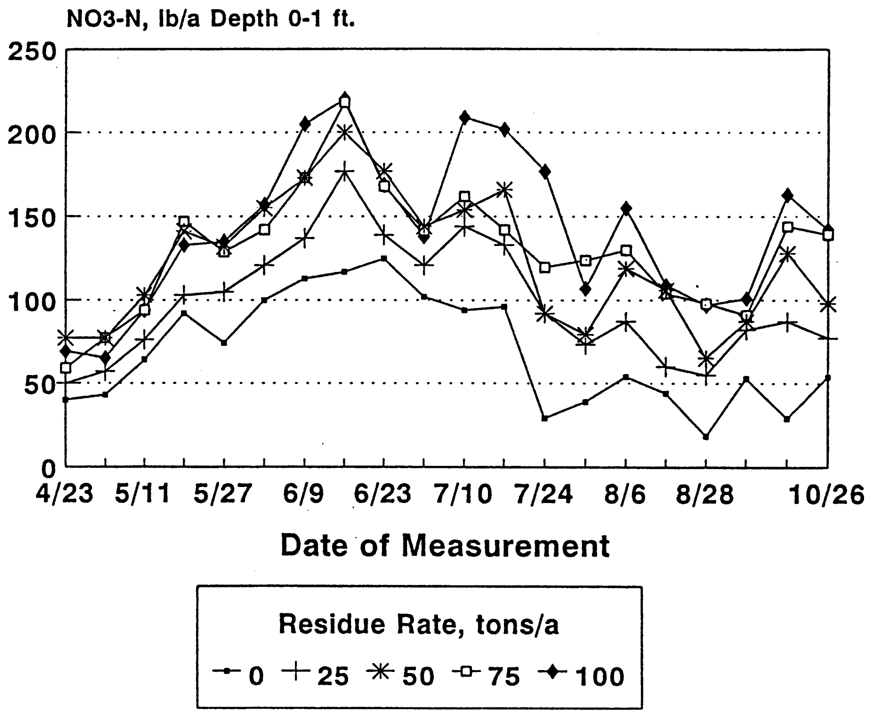


Figure 5. Effect of residue treatments on soil nitrate-N concentrations, 1992.

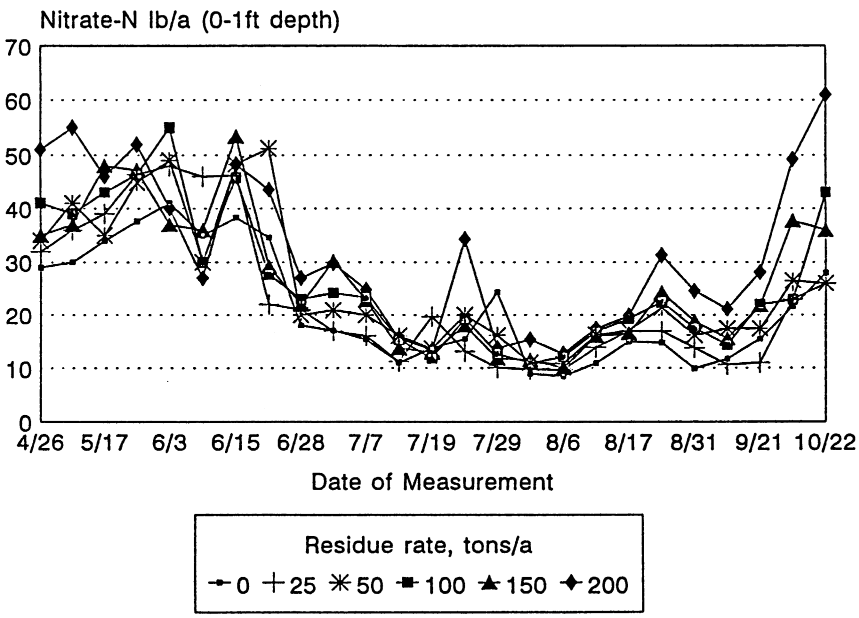


Figure 6. Effect of residue treatments on soil nitrate-N concentrations, 1993.

Table 7. Effect of residue rate on soil nitrate-N concentrations during the 1992 growing season.

Residue	23 April				27 May				30 June				29 July				26 October			
	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total
Rate	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3
	NO_3-N, lb/acre																			
0	40	30	34	104	74	34	31	139	102	42	39	183	39	18	27	84	54	16	12	82
25	50	35	34	119	105	38	32	175	121	44	37	202	73	34	34	141	77	26	21	124
50	77	55	41	173	132	85	56	273	144	61	46	251	79	54	48	181	98	57	42	197
75	59	44	40	143	129	44	41	214	142	56	48	246	124	42	32	198	139	65	31	235
100	69	44	47	160	135	40	51	226	138	56	53	247	107	36	39	182	142	72	53	267

Table 8. Effect of residue rate and N rate on soil nitrate-N concentrations during the 1992 growing season.

Residue Rate (tons/acre)	N Rate (lb/acre)	27 May Soil Depth (feet) 0-1	27 May 1-2	27 May 2-3	27 May Total 0-3	30 June Soil Depth (feet) 0-1	30 June 1-2	30 June 2-3	30 June Total 0-3	29 July Soil Depth (feet) 0-1	29 July 1-2	29 July 2-3	29 July Total 0-3	26 October Soil Depth (feet) 0-1	26 October 1-2	26 October 2-3	26 October Total 0-3
		NO_3-N, lb/acre															
0	0	74	34	31	139	102	42	39	183	39	18	27	84	54	16	12	82
50	75	195	55	47	297	226	73	52	351	146	45	39	230	148	74	41	263
100	75	224	62	54	340	232	95	73	400	182	67	55	304	183	109	60	352
0	150	226	39	38	303	184	81	66	331	147	52	44	243	85	70	39	194
50	150	251	66	43	360	275	102	80	457	303	65	45	413	200	125	59	384
100	150	256	57	47	360	242	95	77	414	270	67	44	381	188	135	66	389

Table 9. Effect of residue rate on soil nitrate-N concentrations during the 1993 growing season.

Residue	26 April				26 May				2 July				29 July				22 October			
	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total
Rate	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3
	NO_3-N, lb/acre																			
0	29	17	28	74	38	21	26	85	17	17	21	55	7	3	9	19	28	7	6	41
25	32	20	29	81	46	23	24	93	17	20	15	52	10	3	10	23	26	7	7	40
50	34	21	22	77	45	25	32	102	21	20	17	58	16	6	15	37	26	7	7	40
100	41	22	27	90	46	27	27	100	24	24	20	68	13	6	14	33	43	10	8	61
150	35	19	23	77	47	26	23	96	30	23	21	74	12	3	11	26	36	9	9	54
200	51	24	23	98	52	28	29	109	30	38	26	94	14	7	16	37	61	10	10	81

Table 10. Effect of residue rate and N rate on soil nitrate-N concentrations during the 1993 growing season.

Residue	N	26 May				2 July				29 July				22 October			
Rate	Rate	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total	Soil Depth (feet)			Total
(tons/acre)	(lb/acre)	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3	0-1	1-2	2-3	0-3
		NO_3-N, lb/acre															
0	0	38	21	26	85	17	17	21	55	7	3	9	19	28	7	6	41
0	60	103	37	35	175	63	30	20	113	13	7	20	40	29	8	10	47
0	90	154	32	34	220	77	45	25	147	15	11	24	50	34	12	19	65
0	120	259	39	35	333	176	70	40	286	35	41	33	109	67	61	35	163
0	150	216	46	42	304	198	58	48	304	66	48	37	151	47	43	41	131
50	60	120	42	28	190	75	37	39	151	17	18	25	60	40	12	15	67
100	60	145	38	32	215	59	46	26	131	24	17	20	61	56	23	21	100
150	60	131	34	29	194	79	45	25	149	26	25	28	79	91	37	33	161
200	60	104	39	33	176	78	36	27	141	20	26	26	72	94	28	33	155

SOIL INORGANIC NITROGEN CONTENT (RESIDUAL STUDY)

Soil inorganic N was measured during the 1993 growing season in residue and N rate treatments applied in 1992. All treatments represent second year residual effects, except the 150 lb N/acre without residue treatment. These measurements were made to determine the residual effects of residue on N mineralization. The residual effects of residue and fertilizer N treatments on profile nitrate-N contents at three dates during the 1993 growing season are shown in Table 11. These measurements show that the sweet corn residue is still mineralizing N until the last measurement in October, where it appears that N mineralization from the residue may be complete. Nitrate-N distributions with depth show substantial amounts of nitrate in the 1 to 2 and 2 to 3 foot depths in April and June which is probably a result of N mineralization and leaching during the previous fall and winter.

At the October sampling most of the nitrate-N is found in the top foot of soil and all residual treatments, including the control, have similar nitrate-N contents. This suggests that N mineralization from sweet corn residue is probably complete 2 years after application. The amount of N produced the second year is not sufficient to satisfy all of the corn N needs, but must be considered to avoid excess N applications where sweet corn residues were applied for the previous crop.

SOIL WATER NITROGEN CONTENT

Figures 7 and 8 show soil water nitrate-N concentrations for three treatments from May to November 1992 and five treatments from May to November 1993. Figure 7 shows nitrate-N concentrations were similar for all treatments until mid-July when the control treatment decreased. The decrease in soil water nitrate-N concentrations in the control treatment is likely due to N uptake by the corn. In the 100 ton/acre residue treatment with and without added N, soil water nitrate-N concentrations remained constant throughout the growing season. Both of these treatments showed an increase in soil water nitrate-N concentrations in November, suggesting leaching of previously mineralized N. Figure 8 shows that the 150 lbs N + 0 tons residue treatment produced the highest nitrate-N concentrations. The treatment that contained 100 tons residue + 0 lbs N produced the lowest nitrate-N concentrations. Nitrate-N concentrations for individual treatments remained relatively constant (except the control) until late August when nitrate-N concentrations decreased. The control treatment (0 tons residue + 0 lbs N) nitrate-N concentrations decreased in late June, suggesting a net N loss due to corn N uptake. Most of the treatments increased in nitrate-N concentration in late October, suggesting an end to corn N uptake and a net N mineralization from treatments. These results suggest that application of 100 tons/acre of residue have less impact on soil water nitrate concentrations than 150 lb/acre of fertilizer N.

Figure 9 shows second year residual effects of residue treatments on soil water nitrate-N concentrations. Treatments monitored were the ones established in 1992. As shown, for all three treatments nitrate-N concentrations increased from late May to early June then decreased until the last measurement in late October. This data suggests that N mineralization from sweet corn residue is complete after the second year of application.

Table 11. Effect of 1992 residue and N rates on soil nitrate-N concentrations during the 1993 growing season.

Residue Rate (tons/acre)	N Rate (lb/acre)	26 May Soil Depth (feet) 0-1	26 May 1-2	26 May 2-3	26 May Total 0-3	2 July Soil Depth (feet) 0-1	2 July 1-2	2 July 2-3	2 July Total 0-3	22 October Soil Depth (feet) 0-1	22 October 1-2	22 October 2-3	22 October Total 2-3
		NO_3-N, lb/acre											
0	0	27	12	14	53	37	24	18	79	25	8	6	39
0	150†	27	16	31	74	234	97	39	370	48	17	27	92
50	0	64	24	22	110	49	35	26	110	34	10	7	51
50	75	29	13	22	64	75	45	27	22	30	9	7	46
100	0	31	19	28	78	46	32	24	102	25	6	6	37
100	150	25	19	44	88	45	30	26	101	28	9	6	43

†150 lb N/acre applied in 1992 and 1993.

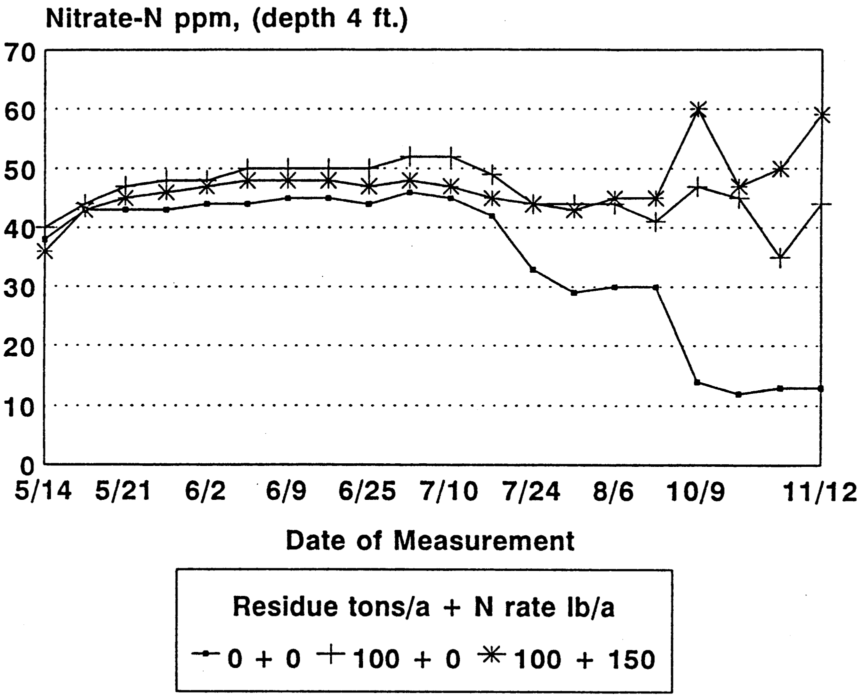


Figure 7. Effect of residue and N rate on soil water nitrate-N concentrations, 1992.

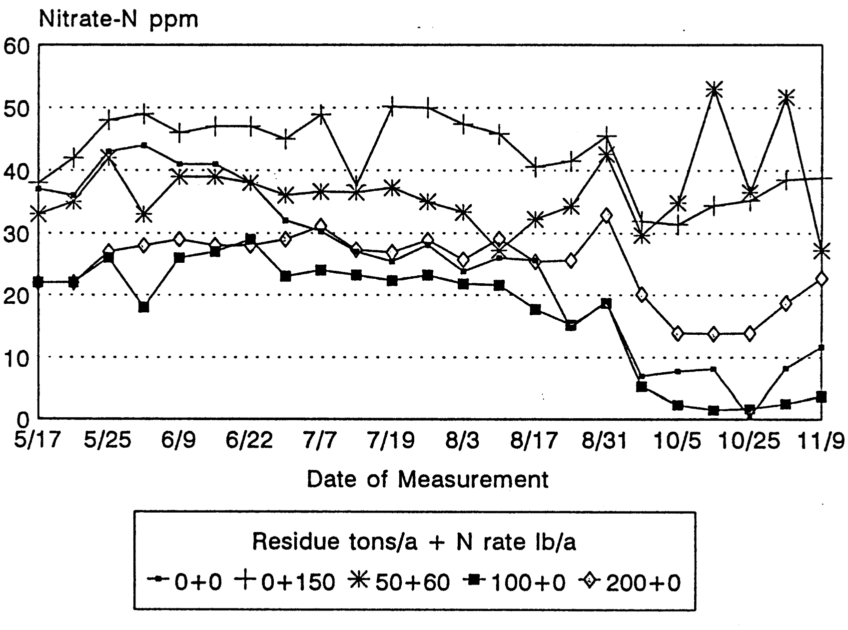


Figure 8. Effect of residue and N rate on soil water nitrate-N concentrations, 1993.

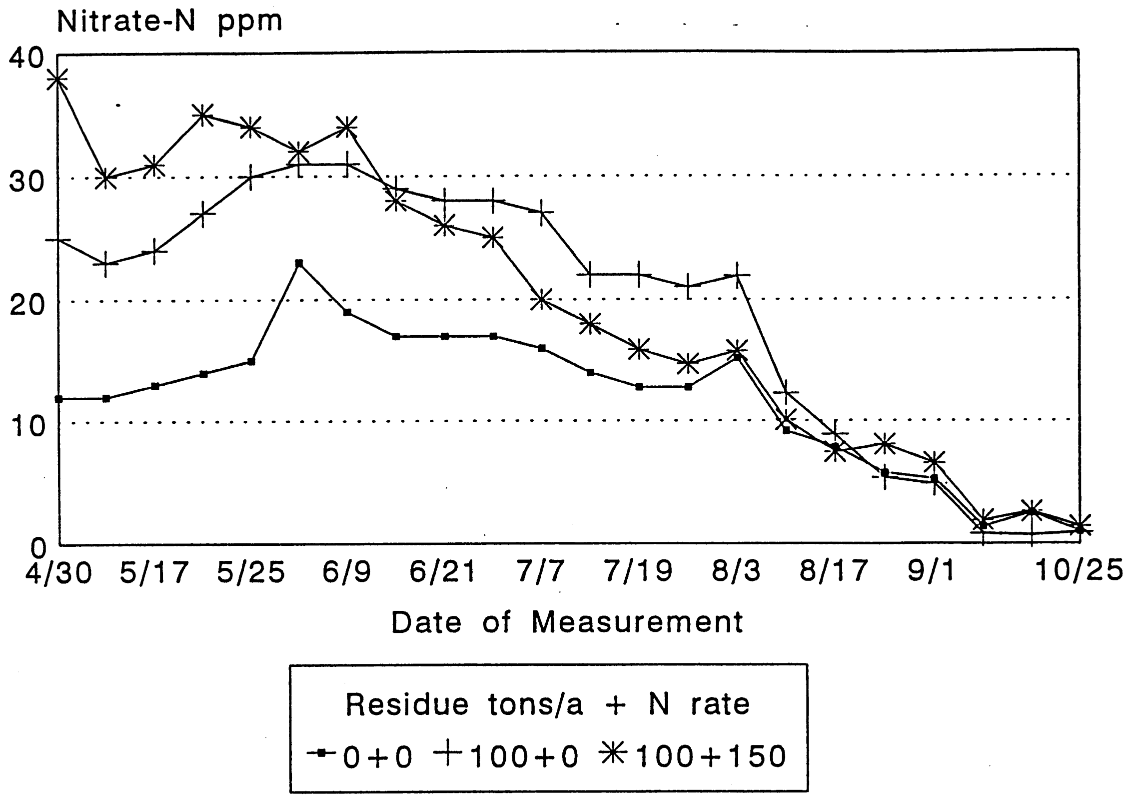


Figure 9. Residual effect of residue and N-rate on soil water nitrate-N concentrations, 1993.

CORN GROWTH EFFECTS

Corn emergence was usually enhanced slightly by the addition of sweet corn residue (Figures 10 and 11). The improved emergence may be due to higher soil moisture contents in the residue treatments during the early growing season (Figures 2b and 4b). Plant height measurements taken early in the growing season (Tables 12 and 13) show that increased residue rates apparently stimulated corn growth rates. Plants were 3 to 3.5 inches taller in the 100 tons/acre and 200 tons/acre residue treatments than the control in 1992 and 1993.

YIELDS AND NITROGEN UPTAKE

Treatment effects on silage and grain yields and N uptake are shown separately for residue plus fertilizer N treatments and residue only treatments in Tables 12 through 15, respectively. Silage yield (total dry matter yield) at physiological maturity increased with increasing rates of residue application, except for the 150 tons/acre residue rate in 1993. In 1992 (Table 12) yields at the 100 tons/acre residue rate were significantly higher then those obtained with 150 lb/acre fertilizer N while similar yields were obtained in the control treatment and the 150 lb/acre fertilizer N treatment. This suggests that the yield increase was not due to N provided by the residue. Residue rate did not affect silage N concentration or N uptake in 1992 (Table 14), but it had a significant effect on silage N concentration and N uptake in 1993 (Table 15).

Treatments did not significantly affect corn grain yields when an analysis was performed over all treatments (Tables 12 and 13), but a trend toward higher yields with increasing residue rates is apparent. This effect is significant in 1992 (Table 14) when only residue rates are considered in the analysis. Corn grain yields were 24 bushels/acre higher at the 100 tons/acre residue rate than in the control. Although this effect was not significant in 1993 (Table 15) grain yields were 25 bushels/acre higher in the 200 tons/acre residue rate than the control. These responses were observed even though yields in the control were at high levels. High amounts of available N provided by the soil at the experimental sites probably prevented corn yield response to N in both years. It does not seem likely that the response is due to other nutrients in the residue because soil test levels at the experimental site are well above optimum for the major nutrients.

YIELDS AND NITROGEN UPTAKE (RESIDUAL STUDY)

Residual effects of 1992 residue and fertilizer N treatments on silage and grain yields, silage N concentration, and N uptake are shown in Tables 16 and 17. Silage yield, N concentration, and N uptake at physiological maturity usually increased with increasing rates of residue application. The treatment that received 150 lbs N/acre in 1992 and 1993 had the highest silage yield, silage N concentration, and N uptake, indicating that the residual effects of the residue treatments did not supply adequate amounts of N to the corn crop. A similar response pattern is apparent in the grain yield data (Tables 16 and 17). Residual effects of residue treatments (Table 17) significantly affected yields. The 100 tons/acre residue treatment yielded 33 bushels/acre more than the control. Highest grain yields were obtained with 150 lbs N/acre applied in 1993 (21 bushels/acre higher than the 100 tons/acre residue treatment). This data shows that N mineralization from residue treatments

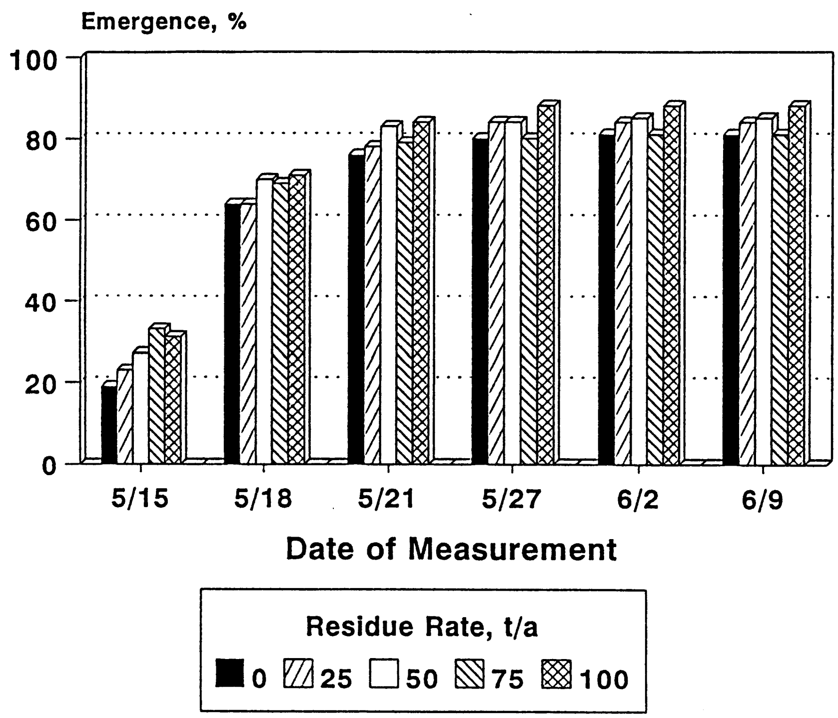


Figure 10. Effect of residue treatments on corn emergence, 1992.

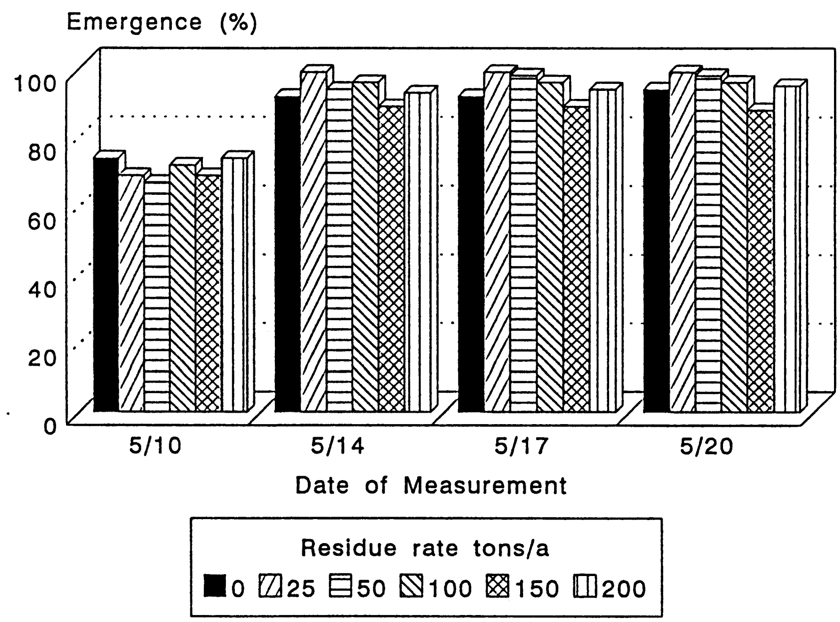


Figure 11. Effect of residue treatments on corn emergence, 1993.

Table 12. Effect of residue and N rate on plant height, grain and silage yields, silage N concentration, and silage N uptake, 1992.

Treatment						
Residue Rate (tons/acre)	Fertilizer N Rate (lb/acre)	Plant Height† (cm)	Grain Yield (bushel/acre)	Silage Yield (tons/acre)	Silage N (%)	Silage Uptake (lbs N)
0	0	63.0c*	188NS	8.2cd	1.37bc	225NS‡
25	0	62.8c	198	8.2cd	1.45ab	238
50	0	68.6ab	205	8.6bcd	1.31c	226
75	0	68.8ab	200	8.7abcd	1.35bc	237
100	0	71.0a	212	9.7a	1.34bc	261
50	75	69.1ab	204	9.0abc	1.38bc	249
100	75	70.7ab	202	8.9abcd	1.34bc	240
0	150	65.9bc	189	7.9d	1.50a	237
50	150	66.4abc	200	8.5bcd	1.44ab	244
100	150	68.1ab	205	9.3ab	1.40abc	261
PR>F		0.02	0.13	0.04	0.06	0.41

* Values followed by the same letter are not significantly different using Fisher's least significant difference (0.05) test.

‡ Plant heights were measured 25 June 1992.

NS = not significant.

Table 13. Effect of residue and N rate on plant height, grain and silage yields, silage N concentration, and silage N uptake, 1993.

Treatment: Residue Rate (tons/acre)	Treatment: Fertilizer N Rate (lb/acre)	Plant Height (cm)	Grain Yield (bushel/acre)	Silage Yield (tons/acre)	Silage N (%)	Silage Uptake (lbs N)
0	0	113bc*	159NS	7.4cd	1.07e	161fg
25	0	116bc	162	7.5cd	1.16de	176efg
50	0	115bc	175	7.9cd	1.19cde	188defg
100	0	118bc	170	7.9cd	1.23bcd	196cdefg
150	0	119bc	163	6.7d	1.07e	144g
200	0	122ab	184	8.3bc	1.29abcd	215bcdef
50	60	121b	174	8.8abc	1.31abcd	231abcde
100	60	120bc	178	8.5abc	1.30abcd	222abcde
150	60	130a	176	9.9a	1.39a	276a
200	60	121b	184	8.2bcd	1.31abc	214bcdef
0	60	120b	177	9.4ab	1.33abc	250abc
0	90	119bc	177	8.8abc	1.30abcd	228abcde
0	120	111c	176	8.7abc	1.39a	243abcd
0	150	122ab	173	9.2ab	1.35ab	251ab
PR>F		0.04	0.17	0.008	0.0003	0.0008

* Values followed by the same letter are not significantly different using Fisher's least significant difference (0.05) test.
‡ Plant heights were measured 7 July 1993.
NS = not significant.

Table 14. Effect of residue on grain and silage yields, silage N concentrations and silage N uptake, 1992.

Treatment					
Residue Rate (tons/acre)	Fertilizer N Rate (lb/acre)	Grain Yield (bushel/acre)	Silage Yield (tons/acre)	Silage N (%)	Silage Uptake (lbs N)
0	0	188c*	8.2b	1.37NS	225NS
25	0	198bc	8.2b	1.45	238
50	0	205ab	8.6b	1.31	226
75	0	200abc	8.7ab	1.35	237
100	0	212a	9.7a	1.34	261
PR>F		0.03	0.06	0.20	0.33

* Values followed by the same letter are not significantly different using Fisher's least significant difference (0.05) test.
NS = not significant.

Table 15. Effect of residue on grain and silage yields, silage N concentrations and silage N uptake, 1993.

Treatment					
Residue Rate (tons/acre)	Fertilizer N Rate (lb/acre)	Grain Yield (bushel/acre)	Silage Yield (tons/acre)	Silage N (%)	Silage Uptake (lbs N)
0	0	159NS	7.4NS	1.07bc*	161bc
25	0	162	7.5	1.16abc	176abc
50	0	175	7.9	1.19abc	188abc
100	0	170	7.9	1.23ab	195ab
150	0	163	6.7	1.07c	144c
200	0	184	8.3	1.29a	215a
PR>F		0.15	0.26	0.06	0.09

* Values followed by the same letter are not significantly different using Fisher's least significant difference (0.05) test.
NS = not significant.

Table 16. Residual effects of residue and N rates on grain and silage yields, silage N concentrations and silage N uptake, 1993.

Treatment					
Residue Rate (tons/acre)	Fertilizer N Rate (lb/acre)	Grain Yield (bushel/acre)	Silage Yield (tons/acre)	Silage N (%)	Silage Uptake (lbs N)
0	0	118c*	6.1b	1.04b	128b
25	0	122c	6.6b	1.04b	138b
50	0	140b	7.2ab	1.16ab	168b
75	0	146b	7.6ab	1.13b	174ab
100	0	151b	7.2ab	1.13b	164b
50	75	149b	--	--	--
50	150	143b	--	--	--
100	75	144b	--	--	--
100	150	152b	--	--	--
0	150†	172a	8.5a	1.32a	227a
PR>F		0.0001	0.08	0.02	0.03

* Values followed by the same letter are not significantly different using Fisher's least significant difference (0.05) test.

† 150 lb N/acre applied in 1992 and 1993.

Table 17. Residual effects of 1992 residue rate on grain and silage yields, silage N concentrations and silage N uptake, 1993.

Treatment					
Residue Rate (tons/acre)	Fertilizer N Rate (lb/acre)	Grain Yield (bushel/acre)	Silage Yield (tons/acre)	Silage N (%)	Silage Uptake (lbs N)
0	0	118c*	6.1NS	1.04NS	128NS
25	0	122bc	6.6	1.04	138
50	0	141ab	7.2	1.16	168
75	0	146a	7.6	1.13	174
100	0	151a	7.2	1.13	164
PR>F		0.01	0.43	0.44	0.42

* Values followed by the same letter are not significantly different using Fisher's least significant difference (0.05) test.
NS = not significant.

continues after the first year of application, but will not supply all of the corn N needs in the second year after application.

SUMMARY AND CONCLUSIONS

Results from the first 2 years of this study to determine appropriate application rates for sweet corn processing wastes indicate land application for management of waste materials is a feasible approach. Agronomic responses of field corn to residue applications up to 100 tons/acre in 1992 and 200 tons/acre in 1993 were largely positive. Plant emergence, plant height, dry matter yields, and grain yields increased with increasing rates of residue application.

Yields were highest when 100 tons/acre (1992) and 200 tons/acre of sweet corn residue was applied with or without added fertilizer N (1993). These treatments yielded 24 and 25 bushels/acre more than the control. These responses were observed even though no response to fertilizer N was obtained. This suggests that sweet corn residues have beneficial effects other than supplying N to subsequent crops.

Soil inorganic N measurements throughout the growing season show that sweet corn residues decompose to release available N rapidly. At the 100 tons/acre residue rate in 1992, about 70 lb/acre of available N was released by mid-June. Comparison of soil profile nitrate-N contents in 1992 indicates that a 50 tons/acre residue application rate probably provides about 75 lb/acre of available N during the corn growing season. In 1993 soil inorganic N did not reach excessive levels throughout the growing season even at high rates. This observation may be due to the large amounts of precipitation received in 1993, which promoted nitrate-N leaching. End-of-season soil nitrate levels may be substantial at high residue rates (200 tons/acre) in years with normal precipitation. This indicates that the 200 tons/acre rate is probably excessive for meeting the N needs of a subsequent corn crop.

Soil water data shows that there is little effect on soil water nitrate-N concentrations from residue treatments until corn N uptake is complete in the fall. Fall soil water nitrate-N concentrations are usually higher in the residue treatments than the control. Residual effects of residue treatments on soil water nitrate-N concentrations shows that these values are higher than the control until mid-August. From mid-August to the last measurement in late October, soil nitrate-N concentrations in the residue treatments are equal to the control. This suggests that N mineralization from residue treatments is complete 2 years after application.

Data from the residual study shows that N mineralization is not complete after the first year of application, but the amount of N supplied to the second year will not provide all of the corn N needs. The 100 tons/acre residue treatment yielded 33 bushels/acre higher than the control. Highest grain yields were obtained with 150 lbs N/acre applied in 1993 (21 bushels/acre higher than the 100 tons/acre residue treatment). The second year residual effects of residue treatments must be considered to avoid excess N applications in the second year after residues are land-applied.

Results indicate that residue rates up to 100 tons/acre will not increase the risk of nitrate loss to groundwater relative to customary N fertilizer rates applied for corn. Beneficial effects on corn yield are likely and the residual effects of the residue applications will provide part of the N requirement of corn in the second year after application.

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