Effect of Nitrapyrin on Uptake of Nitrogen by Sugarbeet from Labeled Ammonium Sulfate*

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INTRODUCTION

Nitrification inhibitors offer the possibility of conserving fertilizer nitrogen through preventing losses from denitrification and leaching. The literature concerning nitrification inhibitors is extensive. Maynard and Lorenz (3) have prepared an indexed reference to studies dealing with horticultural and many agronomic crops. Studies involving the effect of nitrapyrin (2-chlro-6-(trichloromethyl)pyridine) on sugarbeet production were done by Swezey and Turner (4) and Hagemann and Meyer (1) on sandy loam and clay loam soils in the Imperial Valley of California. In these tests sugarbeet yields were increased by about 10 percent when nitrapyrin, at 0.5 percent of the N applied, was mixed with ammonium sulfate or applied with anhydrous ammonia and sidedressed on both sides of plant rows.

The experiment reported here utilized labeled ammonium sulfate which allows the determination of nitrogen in the crop derived from the fertilizer and thus a precise estimation of the effect of nitrapyrin on the fate of fertilizer nitrogen.

MATERIALS AND METHODS

Sugarbeet (*Beta vulgaris* L.), cultivar "US H10", was planted 24 May 1978 on a Zamora loam soil (mixed, nonacid, thermic Mollic Haploxeralfs). On 7 June, after emergence was complete and seedlings were in the cotyledon to two-leaf stage, ^{15}N depleted ammonium sulfate was applied in solution at 100 lb N/acre through a tube welded behind

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a thin fertilizer knife 3 to 4 inches deep and 9 inches on each side of rows spaced 30 inches apart. Nitrapyrin was also applied in solution through a second tube welded just behind the first at 0.5 lb/acre. Both solutions were applied under pressure from separate N_2 cylinders. Treatments were: fertilizer N alone, fertilizer N plus nitrapyrin, and a zero N control in which the sidedressing knives were kept in the soil. Plots were four rows wide and 52 feet long. The treatments were arranged in a double latin square design.

Plants were irrigated in furrows between the rows at two-week intervals. The last irrigation before harvest was on 18 September. Petiole samples were collected from the center two rows of each plot at two-week intervals, one week after each irrigation. Nitrate plus ammonium was determined by semi micro-Kjeldahl after extraction of plant material with calcium sulfate solution and reduction of NO_3 to NH_3 by MgO and Devardas' alloy. Fifty feet of the center two rows of each plot were harvested by hand on 12 October, 20 weeks after planting.

Two samples of tops and two samples of roots, about 10 each, were taken from each plot to determine dry matter, N uptake, root tare, and root sucrose concentration. Total N was determined by the Kjeldahl procedure modified to include nitrate. Percent nitrogen-15 was determined by mass spectrometry after conversion of ammonium to nitrogen gas with lithium hypobromite. Percent N in plant samples derived from fertilizer was calculated as $\{(P_u-P_f)/(P_u-F)\}100$, where P_u and P_f are the atom percent ^{15}N of unfertilized and fertilized plants, respectively and F is the atom percent ^{15}N of the ^{15}N depleted fertilizer. Postharvest soil samples were taken by compositing two one-inch diameter cores per plot in one foot increments to a depth of six feet.

RESULTS AND DISCUSSION

The first irrigation following fertilizer application was on 12 June. On 16 June, nine days after fertilization, 20 seedling tops were taken from each plot. At this time there were no significant differences in fresh or dry seedling weight due to fertilizer N. There was an indication, though not statistically significant, that nitrapyrin was already inhibiting the uptake of fertilizer N as plants with nitrapyrin averaged 8.1 percent N from the fertilizer but without nitrapyrin averaged 11.5 percent N from fertilizer.

To assess the extent to which plants take up ammonium ion and the possible effect of nitrapyrin on this uptake, NH_4-N was determined with an ammonium electrode in petiole samples. On 3 July, four weeks after fertilization, the concentrations of NH_4-N in dry petioles of plants not fertilized, fertilized with N alone, and fertilized with N plus nitrapyrin were 145, 285, and 245 ppm, respectively (LSD,5% = 43, CV = 14.8%) and on 17 July, two weeks later were 60, 78, and 65 ppm, respectively (LSD,5% = 11, CV = 12.9%). Thus fertilized plants took up more ammonium but nitrapyrin appears to have reduced this uptake. Reasons for inhibition of NH_4 uptake by nitrapyrin are not readily apparent but could be due to toxicity to roots in the areas where fertilizer and nitrapyrin were banded, either by nitrapyrin itself or by higher levels of NH_4. Ulrich and Mostofa (5) have shown toxicity of high concentrations of ammonium ion to young sugarbeets. After 17 July the concentrations of petiole NH_4 were too low to evaluate.

By 17 July, plants of the zero N plots began to show N deficiency symptoms and continued to appear smaller in top growth throughout the rest of the growing period. At no time, however, was there a visible difference in the growth or color of fertilized plants without and with nitrapyrin. Table 1 compares the treatments during the season as to concentrations of NO_3+NH_4 in recently matured petioles and gives the percentages of the concentrations derived from the fertilizer. Figure 1 shows concentrations of NO_3+NH_4 in petioles from fertilizer and soil, respectively. Nitrapyrin reduced the uptake of fertilizer N and to some extent soil N for at least eight weeks after fertilization. From 10 weeks on there were no significant differences in concentrations of NO_3+NH_4, but from 12 weeks on concentrations were slightly higher for plants with nitrapyrin.

Figure 1 also shows that fertilized plants took up

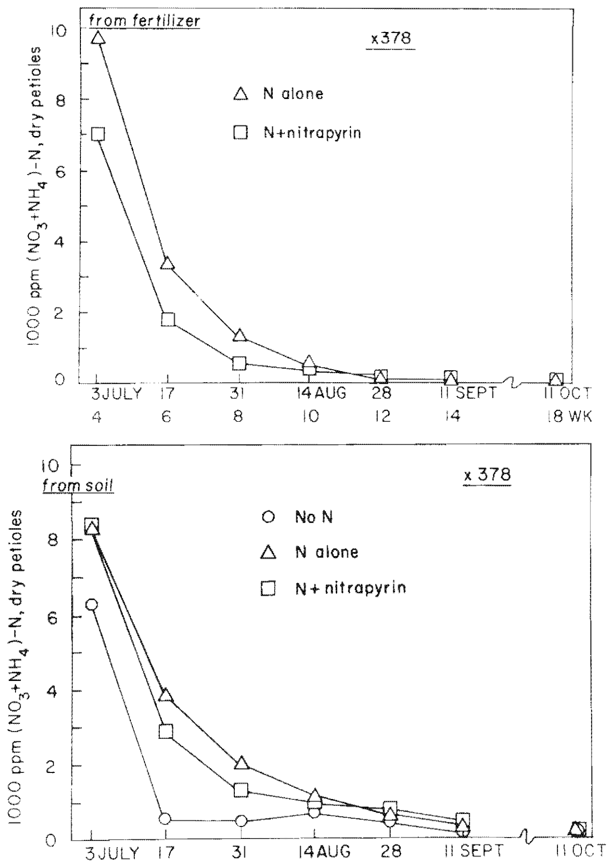

Figure 1. – Effects of fertilization with ^{15}N depleted ammonium sulfate (100 lb N/acre applied 7 June 1978) on concentration of NO_3 + NH_4 derived from fertilizer (upper) and soil (lower) in petioles of recently matured sugarbeet leaves.

more soil N than unfertilized plants for eight weeks following fertilization. The increase could be due to more rapid extension of the fibrous roots of the fertilized plants and/or to increased mineralization of organic matter stimulated by the presence of fertilizer N. The fact that nitrapyrin caused some reduction in the uptake of soil N lends suport to the hypothesis that fertilization stimulates the mineralization of soil N as in the presence of nitrapyrin there probably was some reduction in the nitrification of the increased supply of soil NH_4.

Table 1. Effect of ^{15}N depleted ammonium sulfate and nitrapyrin, applied 7 June 1978, on the concentration of (NO_3+NH_4)-N in dry recently matured sugarbeet petioles at several sampling dates.

Fertilizer N	Nitrapyrin	Date: / Weeks:[1]	3 July / 4	17 July / 6	31 July / 8	14 Aug. / 10	28 Aug. / 12	11 Sept. / 14	11 Oct. / 18
--------lb/acre--------			ppm (NO_3+NH_4)-N						
0	0		6316	532	471	698	400	152	146
100	0		18210	7133	3276	1596	649	373	253
100	0.5		15522	4715	1859	1297	884	432	274
LSD, 5%			1700	1424	1335	910	ns	ns	ns
CV[2], %			9.9	26.8	47.2	46.1	79.4	70.9	53.8
			% (NO_3+NH_4)-N from fertilizer						
100	0		54.2	46.6	38.4	28.7	16.0	18.0	23.7
100	0.5		45.5	38.8	28.0	25.5	14.6	19.2	23.3
LSD, 5%			3.5	5.5	5.5	ns	ns	ns	ns
CV, %			4.7	8.7	11.1	8.2	16.2	19.6	37.3

[1] Weeks after fertilization.

[2] Coefficient of variation.

Table 2 shows the effects of the treatments at harvest on fresh and dry wt yield, N uptake, and percent N from fertilizer. On average, root yield increased 20 percent with fertilizer N but there was no significant increase with nitrapyrin over fertilizer N alone. Fresh top yield, however, was significantly increased 0.9 tons/acre in response to nitrapyrin. Concomitantly, root sucrose concentration declined 0.3 percentage points and gross sugar yield was the same without and with the nitrification inhibitor. There were no significant differences in the percentage of fertilizer N in roots and tops due to nitrapyrin but percentages with nitrapyrin were slightly higher. From Table 2 it is calculated that crop uptake of nitrogen was nine pounds/acre greater with than without nitrapyrin and that about four pounds of this difference came from the fertilizer and about five pounds from the soil.

Postharvest soil samples showed 10 and 12 lb fertilizer N/acre as NO_3+NH_4 to a depth of six feet without and with nitrapyrin, respectively. Total fertilizer N in crops and N in soil as NO_3 and NH_4 accounted for 48 and 54 percent of the fertilizer N applied without and with nitrapyrin leaving 52 and 46 percent not accounted for. Data are not available to assess the fate of this N but subsequent research by Abshahi (unpublished) indicates that most of it may have been incorporated into soil organic matter.

From these results it does not appear that nitrapyrin at 0.5 percent of the applied N will result in saving much fertilizer or soil N for sugarbeets when soil conditions favor nitrification.

In an earlier experiment (2) we determined that sugarbeets fertilized for maximum sugar yield contained 24 to 76 percent N from fertilizer and soil, respectively. In the present experiment it is estimated that sugarbeets without nitrapyrin derived 23 and 77 percent of their N from the fertilizer and soil respectively, in close agreement with the previous experiment.

Table 2. Response of sugarbeet to fertilization and nitrapyrin. Nitrogen-15 depleted ammonium sulfate applied 7 June 1978. Harvest on 12 October 1978.

Fertilizer N	Nitrapyrin	Fresh weight: Yields, Roots	Fresh weight: Yields, Tops	Fresh weight: Sucrose Con. roots	Dry weight yield: Roots	Dry weight yield: Tops	Dry weight yield: Sucrose	Total N uptake: Roots	Total N uptake: Tops	Crop N from fertilizer: Concentration, Roots	Crop N from fertilizer: Concentration, Tops	Crop N from fertilizer: Total amount[1]
---------lb/acre-------		-tons/acre-		%	-----100 lb/acre--------			--lb/acre--		------%-------		lb/acre
0	0	24.2	9.1	15.8	100.3	29.3	76.5	56.5	59.5	--	--	
100	0	28.8	11.7	15.7	123.4	39.1	90.3	84.2	79.8	23.1	23.6	38.3
100	0.5	29.3	12.6	15.4	122.1	39.4	90.2	87.3	85.7	25.0	24.0	42.4
LSD, 5%		0.9	0.8	0.3	5.2	2.2	3.3	5.4	2.0	ns	ns	
CV, %		2.4	5.2	1.3	3.2	4.4	2.7	5.1	1.9	8.3	6.8	

[1]Computed eg 38.3 = 0.236(79.8)+0.231(84.2).

SUMMARY

A field experiment at Davis, California compared concentrations of fertilizer N in petioles throughout the season and fertilizer N uptake after 20 weeks from labeled ammonium sulfate at 100 pounds N/acre without and with nitrapyrin at 0.5 lb/acre. For at least six weeks fertilization resulted in more NH_4 in petioles but this was reduced slightly by nitrapyrin. Fertilization markedly increased concentrations of NO_3+NH_4 in petioles from fertilizer and soil for about eight weeks. During this period nitrapyrin reduced the uptake of fertilizer and, to some extent, soil N. Sugarbeets responded markedly to nitrogen fertilization but plants without and with nitrapyrin showed no visible difference throughout the season. Sugarbeets with the inhibitor yielded 0.9 and 0.5 tons/acre more fresh tops and roots, respectivelly, root sucrose concentration was decreased 0.3 percentage points but dry matter and sucrose yields were little changed. Fertilizer recovery was 38 percent without nitrapyrin and 42 percent when the inhibitor was used. There were nine more pounds N/acre in plants with nitrapyrin compared to those without, four from the fertilizer and five from soil, indicating that fertilizer N might be reduced about 10 percent by using the inhibitor under the conditions of this experiment. Sugarbeets without nitrapyrin obtained 23 and 77 percent of their N from fertilizer and soil respectively compared to 24 and 76 percent for sugarbeets with nitrapyrin.

ACKNOWLEDGMENT

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