EFFECT OF SOURCES OF NITROGEN ON YIELD AND NITROGEN ABSORPTION OF POTATOES[1]

O. A. LORENZ, B. L. WEIR AND J. C. BISHOP[2]

ABSTRACT

In tests with sources of N, $(NH_4)_2SO_4$, when banded in the soil, usually resulted in highest tuber yield. Yields with Nitroform and sulfur-coated urea were similar to each other, and somewhat less than those from urea. Application of Aqua Humus, a humic acid derivative, in addition to several sources of N, had no significant effect on yields.

Nitrogen absorption was highest from $(NH_4)_2SO_4$, as measured by NO_3 content of the petioles or total N absorption by the entire plant. There was little difference in N absorption from Nitroform and sulfur-coated urea. These materials did not result in increased N absorption by plants during late growth.

In Kern County experiments, about 80% of the N from $(NH_4)_2SO_4$ and urea had nitrified and leached from the fertilizer band by 40 days after application. At 80 days after application, half of the N from Nitroform was still in place. In an experiment at Davis on a heavier soil, Nitroform had a slower rate of N release than sulfur-coated urea, followed in order by $(NH_4)_2SO_4$ and urea.

INTRODUCTION

The superiority of ammoniacal sources of N for fertilizing potatoes in California was demonstrated in previous experiments (9, 11). Highest yields were usually obtained with $(NH_4)_2SO_4$ or $NH_4H_2PO_4$, when all or part of the N was applied at planting. Some of the benefit from $(NH_4)_2SO_4$ was related to the effect of soil acidification on the release of native soil P (10). Both aqua and anhydrous ammonia resulted in toxicity and reduced yields when placed too close to the plant. Nitrate sources gave poor yields, and were often little better than no N due to the rapid leaching on the coarse-textured, heavily irrigated soils. Applications of urea in soils of neutral or alkaline reaction usually resulted in lower yields than obtained with $(NH_4)_2SO_4$ (19). The injury from urea has been related to the NH_3 produced by the hydrolysis of urea in the soil (4), and to the production of nitrites (5).

There is a scarcity of information on the effectiveness of "controlled" or "slow-release" N for potatoes, although information is available for greenhouse (3, 6), turf (16), and forage crops (2, 15). In these instances the fertilizers were applied broadcast, and often to slow-maturing crops. When applied in bands to potatoes, which grow more rapidly, these materials might elicit responses different from those with the previously mentioned crops.

Studies on the rate of nitrification of urea-formaldehyde were summarized by Hays (7). Byrne and Lunt (3) reported that about 25% of the N from this material was soluble in cold water, and the rate of mineralization of the remainder approached 7% per month.

[1]Received for publication July 5, 1973.

[2]Professor, Staff Research Associate, and Specialist, Department of Vegetable Crops, University of California, Davis, California 95616 .

Allen et al. (1) and Mays et al. (14) reported that N was released slowly from sulfur-coated urea, and that the rate of release was affected by temperature, degree of coating with S, incorporation of a microbiocide, and method of application. Rindt et al. (17) found a dissolution rate in water of about 0.2% per day, compared to 100% for uncoated urea. Future, Scaroni, and Breece (6) concluded that dissolution rates of 1% per day were better for extended gorwth of greenhouse crops than were rates 5 to 6 times higher.

Martin et al. (12) reported benefits from the use of humic and fulvic acids on certain horticultural crops, and Martin, Ervin, and Shepherd (13) obtained better growth of orange seedlings by the addition of ammonium humate.

This paper reports the results of field experiments with potatoes in which several N sources, applied in bands at the time of planting, were compared. Data were obtained on yields, grade, N uptake, and N transformations in the soil. In some experiments, the effect of applying humic acid derivatives was also studied.

Materials and Methods

Five experiments were conducted on Hesperia fine sandy loam soils in Kern County, California, two on Moreno fine sandy loams near Hemet in Riverside County, and one on a Yolo fine sandy loam at Davis, Yolo County. The soils were light to medium textured, alkaline calcareous, with pH values about 7.6. Plantings were made in February, and the crops were harvested in June or July. Fertilizers were applied in bands 3 inches to each side and 2 inches below the seed piece at time of planting. When used, the humic acid materials were mixed and applied with the fertilizer. In addition to the N under test, all plots received 50 lb P and 100 lb K per acre. There were four plots of each treatment. Each plot consisted of two rows, 32 inches apart and 65 feet long. All crops were furrow irrigated, with water supplied in amounts consistent with commercial practice. The cultivar White Rose was used in all tests except one in Riverside County in which Kennebecs were grown.

All comparisons were made without N, and with $(NH_4)_2SO_4$ as the standard source of N. The other nitrogen sources varied with the experiments. The urea-formaldehyde (Nitroform) supplied by the Hercules Powder Company contained 38% total N and 24% to 28% insoluble N, and had an activity index of 40 to 50 (7). The sulfur-coated ureas (SCU) were obtained from the Tennessee Valley Authority. In the 1970 trials, this material contained 35.6% N, conditioned with 1.5% diatomaceous earth, a wax coating of 3%, and a microbiocide coating of 0.25%. It had dissolution rates in water of 16.8% in 5 days and 22.9% in 16 days. The SCU in 1966 contained 26.8% N. The humic acid derivative (HAD) was supplied by the American Humates Inc., Dallas, Texas, under the trade name "Aqua Humus" (8). It consists of an NH_4OH extract of leonardite, a type of brown coal or peat high in humic and fulvic acids.

Petiole samples were taken three or more times during the growing season, and analyses were made as described by Tyler et al. (18). Soil samples for N transformation studies were taken at approximately 3-week intervals. The fertilizer bands were marked at time of application by adding colored pebbles along with the fertilizer. At sampling, four cores of soil each 8 inches long and 3 inches in diameter, and including the fertilizer band were taken from each of four plots. Because the N in the Nitroform and SCU was largely water insoluble, total N was obtained by the Kjeldahl method, and the rate of nitrification was determined by comparison with soil not receiving the N fertilizers. The amount of N remaining in the area of placement, and not leached as NO_3 or other soluble form, was used as the measure of nitrification that had occurred.

Results and Discussion

Yields:

In all Kern County experiments $(NH_4)_2SO_4$ resulted in higher yields than did SCU or Nitroform (Table 1). Yields from $(NH_4)_2SO_4$ were significantly higher than from urea only at the 240 lb rate of N in 1967 and the 60 lb rate in 1970, but were numerically higher in all comparisons. Yields from SCU and Nitroform were significantly less than from urea at the 60 and 240 lb N rates with White Rose (Table 2). The higher than from SCU; but in 1970, yields from Nitroform were significantly lower, at the 120 lb N rate.

Various ratios of $(NH_4)_2SO_4$ and Nitroform were included in the 1967 tests (data not presented), but there was no advantage from using a mixture of the materials. For example, at the 120 lb N rate, the yield from $(NH_4)_2SO_4$ was 354 cwt/acre, as compared to 205 with Nitroform and 279 with a 50:50 mixture of the two sources. At the 240 lb N rate, the yields from $(NH_4)_2SO_4$ and the 50:50 mixture of $(NH_4)_2SO_4$ and Nitroform were equal.

In the Riverside County tests, $(NH_4)_2SO_4$ significantly outyielded urea at the 60 and 240 lb N rates with 'White Rose' (Table 2). The yields from NH_4Cl were lower than from $(NH_4)_2SO_4$ at the 120 and 240 lb rates of N. There were no significant differences in yields between SCU and urea, indicating that the sulfur coating on this material was ineffective. With the Kennebec cultivar there were no significant differences in yield associated with sources of N.

Results from the Davis experiment were similar to those obtained in Kern County (Table 3). All sources of N gave large increases in yield, with the highest yields resulting from $(NH_4)_2SO_4$ applied at the higher rates. The yield from urea was significantly lower than that from $(NH_4)_2SO_4$ only at the 120 lb N rate. Urea gave slightly higher yields than did SCU; and, in all instances, higher yields were obtained with SCU than with Nitroform.

The addition of Aqua Humus (HAD) to N-containing fertilizers was evaluated in five experiments (Table 4). Comparisons were made with both $(NH_4)_2SO_4$ and urea at rates of 120 and 240 lb N/acre. In no test did the addition of Aqua Humus have any significant effect on yield, either positive or negative.

Petiole analyses —

The effect of source and rate of N on NO_3 content of the petioles was determined in all experiments. In the first sampling of the 1966 Kern County test, $(NH_4)_2SO_4$ resulted in the highest levels of NO_3 in the petioles, whereas SCU resulted in the lowest (Table 5). In the two later samplings, the highest NO_3 levels were obtained with SCU, whereas

TABLE 1.—*Effect of sources and rates of N on potato yields in Kern County over a period of 4 years.*

		Total yield/acre (cwt)[1]			
		Source of N			
Year of test	lb N/acre	$(NH_4)_2SO_4$	Nitro-form	Sulfur-coated urea	Urea
1966	0	108 a	......	108 a	108 a
	120	400 cd	......	300 b	382 c
	240	442 d	......	360 c	431 d
1967	0	119 a	119 a	119 a	119 a
	60	284 e	185 b	......	269 e
	120	354 f	205 c	189 b	322 f
	240	389 g	244 d	189 b	337 f
1968	0	204 a	204 a	......	......
	60	346 de	243 b	......	......
	120	444 f	278 c	......	......
	240	510 g	332 d	......	......
1970	0	118 a	118 a	118 a	118 a
	60	414 fg	252 b	290 bc	350 d
	120	465 g	301 bc	355 de	420 fg
	240	567 h	402 ef	414 fg	529 h

[1]For each experiment, treatments with the same letter designation are not statistically different at the 5% level.

TABLE 2.—*Effect of sources and rates of N on potato yields, Riverside County, 1962.*

		Total yield/acre (cwt)[1]			
		Source of N			
Cultivar	lb N/acre	$(NH_4)_2SO_4$	NH_4Cl	Sulfur-coated urea	Urea
White Rose	0	172 a	172 a	172 a	172 a
	60	257 cd	......	235 bc	219 b
	120	272 d	243 bc	269 d	255 cd
	240	310 e	236 bc	240 bc	237 bc
Kennebec	0	246 a	......	246 a	246 a
	120	343 b	......	325 b	339 b
	240	366 b	......	......	313 b

[1]For each experiment, treatments with the same letter designation are not statistically different at the 5% level.

levels with $(NH_4)_2SO_4$ and urea were about equal. Thus SCU released N slowly during early season, but at an accelerated rate some 70-80 days after application.

At the first two samplings in the 1970 Kern County test, there was increased NO_3 absorption with increased rates of N from all sources (Table 6). At low rates of application, much higher NO_3 accumulation occurred with $(NH_4)_2SO_4$ and urea than with Nitroform or SCU. Also in early growth, NO_3 accumulation was higher with SCU than with

TABLE 3.—*Effect of sources and rates of N on potato yields, Davis, 1970.*

	Total yield/acre (cwt)[1]			
	Source of N			
lb N/acre	$(NH_4)_2SO_4$	Urea	Nitroform	Sulfur coated urea
0	182 a	182 a	182 a	182 a
60	339 d	303 de	251 b	284 cd
120	399 h	349 fg	274 bc	327 ef
240	416 h	392 h	329 f	365 g

[1]For each experiment, treatments with the same letter designation are not statistically different at the 5% level.

TABLE 4.—*Effect of humic acid derivative (Aqua Humus) on potato yields.*

		Total yield/acre (cwt)[1]			
		lb N/acre			
		120		240	
Test designation	Source of N	—HAD	+HAD	—HAD	+HAD
Hemet - 1962	$(NH_4)_2SO_4$	272 a	247 a		
Davis - 1965	16-20-0	408 a	431 a		
Shafter - 1965	Urea	261 a	265 a		
Shafter - 1966	$(NH_4)_2SO_4$	251 abc	267 bc	305 c	298 c
	Urea	224 abc	212 a	227 ab	233 ab
Shafter - 1967	$(NH_4)_2SO_4$	354 abc	359 abc	385 bc	412 c
	Urea	322 ab	299 a	337 abc	365 abc

[1]For each experiment, treatments with the same letter designation are not statistically different at the 5% level.

TABLE 5.—*Effect of sources and rates of N on NO_3-N in petioles. Kern County, 1966. Planted February 15 and harvested June 17.*

	ppm NO_3-N in petiole (dry wt basis)		
	lb N/acre		
Sampling date and source of N	0	120	240
4/19/66			
$(NH_4)_2SO_4$	trace	15515	16340
Sulfur-coated urea	trace	1625	6245
Urea	trace	6015	11745
5/12/66			
$(NH_4)_2SO_4$	trace	130	3130
Sulfur-coated urea	trace	875	5745
Urea	trace	455	2345
6/4/66			
$(NH_4)_2SO_4$	trace	130	1665
Sulfur-coated urea	trace	1415	6220
Urea	trace	180	895

TABLE 6.—*Effect of sources and rates of N on NO_3-N in petioles. Kern County, 1970. Planted February 10 and harvested June 16*

	ppm NO_3-N in petiole (dry wt basis)			
	lb N/acre			
Source of N	0	60	120	240
4/6/70				
$(NH_4)_2SO_4$	1325	18835	23530	26245
Urea	1325	19795	23000	26745
Sulfur-coated urea	1325	8030	9785	19315
Nitroform	1325	2385	5915	12045
4/21/70				
$(NH_4)_2SO_4$	tr	5125	14020	21420
Urea	tr	3750	9470	19025
Sulfur-coated urea	tr	2900	3500	5200
Nitroform	tr	80	150	1065
5/5/70				
$(NH_4)_2SO_4$	tr	170	1995	13795
Urea	tr	tr	1490	11125
Sulfur-coated urea	tr	tr	tr	170
Nitroform	tr	tr	tr	tr
5/22/70				
$(NH_4)_2SO_4$	tr	tr	450	9205
Urea	tr	80	tr	3895
Sulfur-coated urea	tr	95	115	150
Nitroform	tr	75	95	415

Nitroform. As the plants approached maturity, only the highest applications of $(NH_4)_2SO_4$ and urea resulted in appreciable quantities of NO_3 in the plants.

During early growth, plants in the Riverside County experiment accumulated much less NO_3 from NH_4Cl than from the other sources (Table 7). At the first sampling, plants not receiving N contained as much NO_3 as those fertilized with 240 lb N/acre from NH_4Cl. There was little difference in NO_3 content of plants receiving $(NH_4)_2SO_4$, urea, or SCU at any rate on any sampling date.

The results of the Davis experiment were very similar to those in Kern County and showed much higher accumulation of NO_3 from $(NH_4)_2SO_4$ and urea than from SCU or Nitroform (Table 8). In late season, the only plants containing appreciable quantities of NO_3 were those fertilized with 240 lb N/acre from $(NH_4)_2SO_4$ and urea. At the first two samplings, plants receiving SCU contained more NO_3 than those receiving Nitroform.

Total N absorption:

In the 1967 Kern County experiment, both plant tops and tubers were harvested to evaluate the total amount of N absorbed from the various sources and rates of N (Table 9). The highest N absorption of 187 lb/acre was obtained with an application of 240 lb N/acre of $(NH_4)_2SO_4$. Only 30 lb N/acre were removed by plants not receiving N fertilization. At both the 120 and 240 lb N/acre rates, plants receiving

TABLE 7.—*Effect of sources and rates of N on NO_3-N in petioles. Riverside County, 1962. Planted April 9 and harvested August 10.*

Sampling Date and Source of N	ppm NO_3-N in petiole (dry wt basis) lb N/acre 0	60	120	240
5/15/62				
$(NH_4)_2SO_4$	8097	12125	13000	12717
Urea	8097	13252	14293	14012
Sulfur-coated urea	8097	15665	13695	13428
NH_4Cl	8097	9067	7858	7750
5/28/62				
$(NH_4)_2SO_4$	3700	5500	10800	12450
Urea	3700	11150	13075	13252
Sulfur-coated urea	3700	11925	12550	13340
NH_4Cl	3700	6025	8725	8837
6/12/62				
$(NH_4)_2SO_4$	836	3125	4275	9025
Urea	836	4500	9475	10625
Sulfur-coated urea	836	5150	7425	9888
NH_4Cl	836	1458	3655	5475
6/25/62				
$(NH_4)_2SO_4$	1114	1254	2725	7500
Urea	1114	2314	5459	9088
Sulfur-coated urea	1114	2610	4702	9362
NH_4Cl	1114	668	4230	5750

$(NH_4)_2SO_4$ removed more than twice as much N as those given Nitroform, and about 25% more than those fertilized with urea. Plants fertilized with $(NH_4)_2SO_4$ recovered N equivalent to 80% of that applied at the 120 lb rate, and 65% of that applied at the 240 lb rate. Comparable recoveries from Nitroform were 20% and 18%, respectively.

Soil nitrification.

The rates of nitrification of Nitroform were compared to those of $(NH_4)_2SO_4$ and urea (Fig. 1). Early in the season, in the Kern County experiments, the availability of N from Nitroform was much less than from urea or $(NH_4)_2SO_4$. When 120 lb N/acre were applied, less than 20% of the N from $(NH_4)_2SO_4$ and urea remained in the area of the fertilizer band 40 days after application, compared to over 60% with Nitroform. At 80 days after application, about half the N from Nitroform was still in place, and at the end of the growing season, 120 days after application, about 40% of the N from Nitroform had not nitrified and leached from the area of placement.

Results from the 1970 experiment at Davis are given in Fig. 2. This soil is of finer texture and was irrigated less frequently than the soils in Kern County. Nitrification was slower than in Kern County, but the relative rates from the N sources were similar. Nitroform had a slower rate of N release than SCU followed in order by $(NH_4)_2SO_4$ and urea. All the

TABLE 8.—*Effect of sources and rates of N on NO_3-N in petioles. Davis, 1970. Planted March 21 and harvested July 13.*

	ppm NO_3-N in petiole (dry wt basis)			
	lb N/acre			
Sampling date and source of N	0	60	120	240
5/12/70				
$NH_4)_2SO_4$	1330	13105	15425	17285
Urea	1330	15410	18095	18575
Sulfur-coated urea	1330	6345	14450	16685
Nitroform	1330	3910	8805	11680
Nitroform	1330	3910	8805	11680
5/26/70				
$(NH_4)_2SO_4$	tr	1655	5460	10415
Urea	tr	1195	5115	11035
Sulfur-coated urea	tr	tr	2170	3085
Nitroform	tr	tr	135	380
6/8/70				
$(NH_4)_2SO_4$	tr	tr	425	1330
Urea	tr	tr	481	1250
Sulfur-coated urea	tr	tr	tr	tr
Nitroform	tr	tr	tr	tr
6/23/70				
$(NH_4)_2SO_4$	tr	tr	tr	2250
Urea	tr	tr	tr	1010
Sulfur-coated urea	tr	tr	tr	tr
Nitroform	tr	tr	tr	tr

TABLE 9.—*Effect of sources and rates of N on N recovery by potatoes, Kern County, 1967.*

	Total N absorption (lb/A - tops and tubers)			
	lb N/A applied			
Source of N	0	60	120	240
$(NH_4)_2SO_4$	29.6	85.1	125.3	186.6
Urea	29.6	76.3	101.3	131.8
Nitroform	29.6	51.3	53.6	75.6

urea had nitrified 70 days after application, $(NH_4)_2SO_4$ after 100 days and SCU after 130 days. Over 40% of the N from Nitroform remained in the area of the fertilizer band 130 days after application.

These results confirm those of previous studies (9, 11) which showed the superiority of ammoniacal sources of N. The yields from urea were often less than from $(NH_4)_2SO_4$. At both low and high rates of application, the yields from Nitroform and SCU were inferior to $(NH_4)_2SO_4$. Nitrogen absorption by the plants as measured by NO_3 content of the petiolar tissue or total N absorption by the tops and tubers was closely

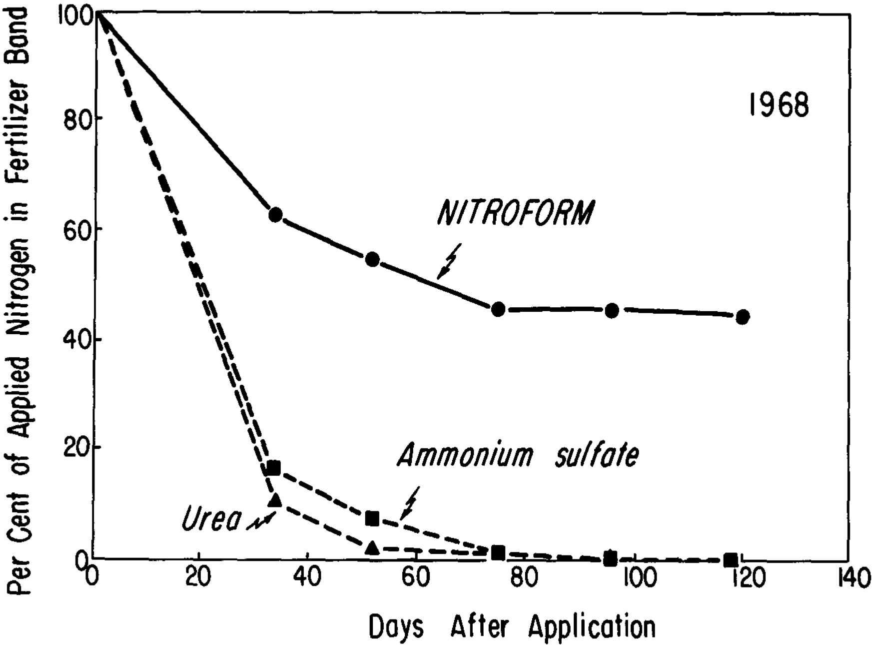

FIG. 1.—Effect of sources of N on the rate of leaching of N from the fertilizer band. Hesperia fine sandy loam soil, Kern County, 1968.

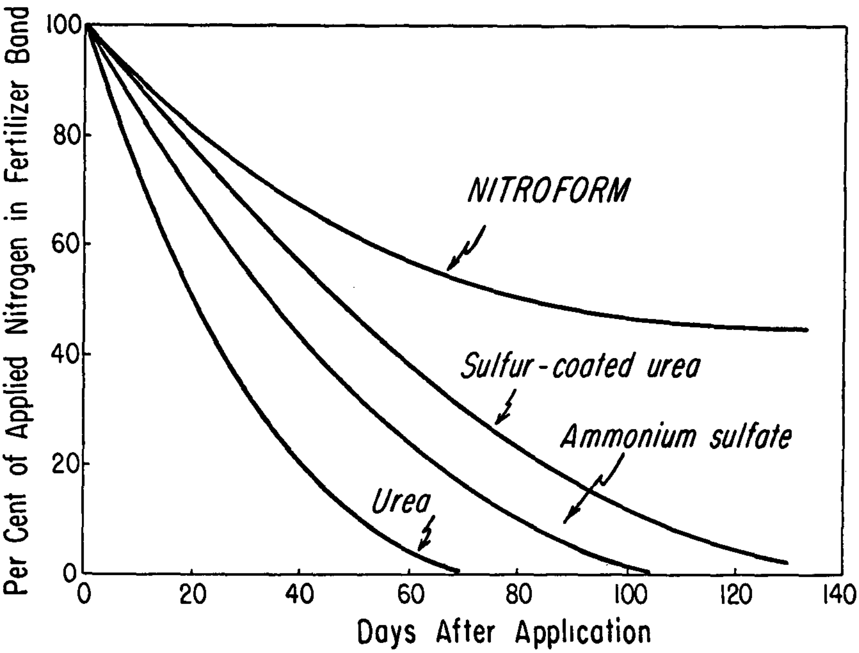

FIG. 2.—Effect of sources of N on the rate of leaching of N from the fertilizer band. Yolo fine sandy loam soil, Davis, 1970.

related to the yields. Nitroform and SCU both exhibited slow-release characteristics which were often too slow for potato crops maturing in about 100 days. Different formulations will be required if these materials are to be used effectively. At 60 days after application, practically all of the N from $(NH_4)_2SO_4$ and urea had leached from the fertilizer band while nearly 60% of the N from Nitroform and 40% from SCU was still in place.

The addition of Aqua Humus (a humic acid derivative) did not increase yields above those obtained with N alone. There was no indication that this material made the N fertilizers more efficient.

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