UREA NITROGEN FOR POTATOES[1]

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The choice of a nitrogen source for potato production in the light-textured, heavily irrigated soils of California has proven to be of equal importance to the selection of proper rate of application. Many field tests have been conducted by Lorenz, et al. at the U.S.D.A. Cotton Experiment Station near Shafter, California (1) in which sources of nitrogen have been compared. Urea was tested against ammonium sulfate in 11 of these tests. In every comparison, yields from ammonium sulfate were higher than yields from the urea with differences as great as 100 sacks or more per acre. In two tests where half of the nitrogen supplied came from urea and the other half from amonium sulfate, yields were equal to those obtained with amonium sulfate alone and appreciably better than those where all of the nitrogen was obtained from urea.

The experiments reported here were conducted in 1959 and 1960 to determine whether or not these observations applied to other areas and soils, and to study the reasons for the inferior behavior of urea as a nitrogen source in comparison with ammonium sulfate.

Materials and Methods

Nine experimental sites were selected in grower fields of two major potato producing areas of southern California. Four of these tests were located in western Riverside County and five in the Chino area of San Bernardino County. In the selection of sites, an effort was made to provide a good representation of the potato soils of each area.

Field plots consisted of four beds, each 60 feet long. Fertilizer treatments were repeated four times in every test and all experiments were laid out in randomized block design.

Sources of nitrogen were amonium sulfate (21% N) and urea (45% N) applied at rates of 120 and 240 pounds per acre. In every test phosphorus was applied at planting at the rate of 120 pounds P_2O_5 per acre. In the Riverside County tests, all of the nitrogen was applied at planting while in the coarser textured potato soils of San Bernardino County half of the nitrogen was applied at planting and the remainder sidedressed about four weeks after emergence. Placement at planting was effected by banding 2 inches below and 2 to 4 inches to each side of the seed row. Post-emergence fertilizer was placed 2 inches below and 4 to 5 inches to each side of the seed row.

Soil samples were taken prior to planting and analyzed for exchangeable sodium, calcium, potassium and magnesium by using a neutral normal ammonium acetate extract. The first three elements were analyzed with a flame photometer. Magnesium wes determined by the thiazole yellow method (4). Sodium bicarbonate-soluble phosphorus in the soil was determined on a 1:20 extract according to the method outlined by Olsen, et al.

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(2). Soil pH was measured with a glass electrode on a 1:1 soil-water suspension.

The potatoes were planted in beds 32 inches between centers and with 8 to 10 inches between seed pieces. Individual growers prepared the seed bed, cultivated and irrigated the potato crop in their respective fields according to their own schedules. Yield and grade of potato tubers were determined at the time of harvest.

Petioles of the fourth fully expanded leaf from the growing tip of the plants, were selected for analysis. During the growing season, petiole samples of recently matured leaves were collected at 2-week intervals and analyzed for potassium, calcium, and magnesium in the ashed samples. Potassium and calcium were analyzed with a flame photometer. Magnesium was determined by the thiazole yellow method (4). Nitrate-nitrogen and phosphate-phosphorus soluble in 2% acetic acid solution were also determined by colorimetric methods on the dried, ground samples.

In addition to the nine tests, two experiments were conducted in Kern County using nitrogen treatments with and without phosphorus. Rates of nitrogen from urea or from ammonium sulfate were 75, 150, 225, and 300 pounds per acre. In these experiments two urea materials containing a high and low biuret percentage were also tested.

Results

Soils

Analytical data from the soils of the nine experimental fields are presented in Table 1. Soil pH values ranged from slightly acid to medium alkaline (pH 6.0-8.1). Bicarbonate soluble phosphate-phosphorus (PO_4-P) analyzed as low as 5 ppm and as high as 29 ppm. Large differences in the levels of exchangeable potassium, calcium, and magnesium were also obtained. Organic matter content of most of the soils was very low, less than 1%. Soils of Fields 5 and 9 were considerably higher in organic matter due to the grower's practice of chopping and discing under large quantities of grain straw before cropping to potatoes. Electrical conductivity measurements, also taken on these soils, indicated that salinity was not a problem.

Yield

Total yield data for the nine field experiments in Riverside and San Bernardino counties are presented in Table 2. Yield increases resulting from nitrogen fertilization occurred in every test, although the magnitude of these responses varied greatly from one test to the other. In six of the experiments, applications of nitrogen at the rate of 120 pounds per acre more than doubled the total yield as compared with the unfertilized plants.

In every comparison of sources at the 120 pound rate of nitrogen, potatoes fertilized with ammonium sulfate outyielded those which received urea. Yield differences ranged from 7 to 61 cwt per acre with an average difference of 25 cwt per acre. Comparable differences were also evident at the 240 pound rate. In all but two fields (numbers 4 and 6) yield differences were in favor of ammonium sulfate; an average of all fields showed that ammonium sulfate produced 34 cwt per acre

TABLE 1.—*Analyses of soil samples from nine experimental fields in Riverside and San Bernardino Counties, California.*

Field No.	Soil type	Parts per million				
		pH	P	K	Ca	Mg
1	Hanford sandy loam	7.4	19	94	1205	132
2	Hanford fine sand	7.1	14	63	854	127
3	Tujunga fine sand	7.6	15	94	455	57
4	Ramona sandy loam	6.6	20	105	598	92
5	Hanford sandy loam	6.9	23	377	1169	175
6	Ramona sandy loam	6.0	26	217	474	62
7	Hanford fine sand	7.2	29	172	182	81
8	Hanford fine sand	8.1	18	80	656	98
9	Hanford sandy loam	6.3	5	267	1575	163

TABLE 2.—*Nitrogen treatments and total yields of potatoes from nine experiments conducted in Riverside and San Bernardino Counties, California.*

Nitrogen source	Pounds N per acre	Field experiments									Average 9 fields
		1	2	3	4	5	6	7	8	9	
		Hundredweight per acre									
None	0	120	174	116	309	176	144	145	224	265	186
Am. Sulfate	120	284	356	284	411	407	327	401	379	322	352
Urea	120	277	340	249	396	373	313	340	352	303	327
Am. Sulfate	240	307	374	353	396	445	347	440	422	310	377
Urea	240	247	349	261	423	388	373	408	384	255	343

All nitrogen applications resulted in yields higher than from no nitrogen plots (odds > 1000:1).

Yields from use of ammonium sulfate were higher than from urea at both rates of application (odds > 19:1).

Yield differences between 120 and 240 pound rates of application were not significant.

Rate by source interaction was not significant.

more than urea. The two tests in which ammonium sulfate was not superior to urea were conducted on Ramona sandy loam soils with an acid reaction (Table 1).

Grade

Data showing per cent of U. S. No. 1, Size A potatoes for the nine experiments are given in Table 3. The application of either 120 or 240 pounds of nitrogen per acre greatly increased the percentage U. S. No. 1, Size A potatoes in 7 tests. The percentage of U.S. No. 1, Size A potatoes was approximately the same from both nitrogen sources.

Nutrient composition

Soluble nitrate-nitrogen concentrations in petiole tissue at midseason are shown in Table 4. At both the 120 and 240 pound rates of nitrogen the urea fertilized plants were generally higher in petiole nitrogen than

TABLE 3.—*Per cent U. S. No. 1, Size A potatoes from nine field experiments in Riverside and San Bernardino Counties, California.*

Nitrogen source	Pounds N per acre	Per cent U. S. No. 1, size A potatoes Field experiments								
		1	2	3	4	5	6	7	8	9
None	0	28	49	15	60	85	49	21	50	76
Am. Sulfate	120	71	73	38	68	81	67	84	74	79
Urea	120	68	75	49	71	84	70	80	64	79
Am. Sulfate	240	70	68	46	64	71	66	88	75	75
Urea	240	60	72	52	61	86	67	85	65	67

TABLE 4.—*Soluble nitrate-nitrogen (NO_3-N) content of potato leaf petioles from nine field experiments in Riverside and San Bernardino Counties, California.*

Nitrogen source	Pounds N per acre	Field experiments and days after planting								
		1 (77)	2 (71)	3 (74)	4 (71)	5 (78)	6 (73)	7 (67)	8 (66)	9 (69)
		PPM Nitrate-nitrogen (NO_3-N) in petioles								
None	0	480	8450	762	820	786	410	750	2100	6650
Am. Sulfate	120	9925	11700	6162	5225	7775	625	5412	7500	10556
Urea	120	12450	14045	4450	7325	10075	2124	6670	10162	11762
Am. Sulfate	240	13518	15372	9494	7425	6112	4012	11231	11876	10894
Urea	240	13962	14050	8556	12362	9100	8837	11678	12878	12131

those fertilized with ammonium sulfate. Only three exceptions to this were found in 18 comparisons. Based on a midseason deficiency level of 6000 ppm, established by Tyler, et al. (3), plants in 7 of the 9 fields, where no nitrogen was applied, would be considered deficient; 3 were deficient at the 120 pound rate of nitrogen from ammonium sulfate, 2 were deficient at the same rate of nitrogen from urea and 1 deficient at the 240 pound rate of nitrogen from ammonium sulfate.

Fig. 1 presents analytical data from samplings of Field 1, Chino area, 1960, showing nitrate-nitrogen concentrations during the season in potato plants fertilized with urea and ammonium sulfate at two rates. Trends observed in this experiment were fairly typical of the entire series of nine fields.

Differences in petiole nitrate-nitrogen concentrations between the two sources at either the 120 or 240 pound rates were small during early season. At the 240 pound rate these differences did not increase greatly with time. At the 120 pound rate, however, differences in nitrate-nitrogen were considerable at the third and fourth sampling dates and favored urea as a source. All of the concentrations shown in Fig. 1 (Field 1) would be considered sufficiently high for maximum production according to levels already determined (3).

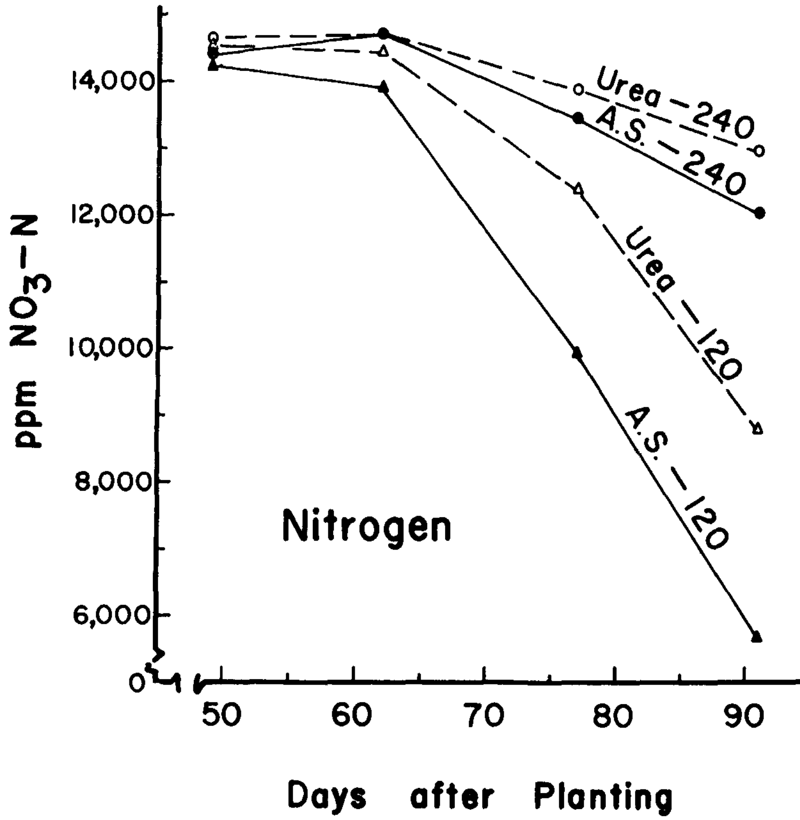

FIG. 1.—Seasonal nitrate-nitrogen concentrations in petioles of potatoes fertilized with 120 and 240 pounds of nitrogen per acre from ammonium sulfate and urea. Field 1, 1960.

In several fields, plants fertilized with urea, especially at the 240 pound rate, exhibited symptoms during early season similar to those of known phosphorus deficiency. These symptoms gradually disappeared during late season growth. Soluble phosphate-phosphorus content of potato petioles was influenced more consistently by source of nitrogen than any of the other elements analyzed in these experiments. The data of Table 5 represent phosphate-phosphorus analyses of petiole samples collected in early season. With both materials, phosphate-phosphorus was of lower concentration in petiole tissue at the 240 pound rate of nitrogen than at the 120 pound rate. Ammonium sulfate application always resulted in higher phosphate-phosphorus concentrations during early season than urea applications. During late season these differences generally became small as illustrated by data in Fig. 2 (Field 1) which shows these phosphate-phosphorus concentrations in petioles of plants fertilized at the 240 pound rate. Potatoes grown in this field without benefit of phosphorus fertilization were deficient in this nutrient. At the time of the first sampling phosphate-phosphorus in plants fertilized with ammonium sulfate

TABLE 5.—*Soluble phosphate-phosphorus (PO_4-P) content of potato leaf petioles from nine field experiments in Riverside and San Bernardino Counties, California.*

Nitrogen source	Pounds N per acre	Field experiments and days after planting								
		1 (49)	2 (41)	3 (46)	4 (57)	5 (50)	6 (45)	7 (39)	8 (52)	9 (56)
		PPM Phosphate-phosphorus (PO_4-P) in petioles								
None	0	4672	5134	5098	4260	3759	4472	3028	4891	1421
Am. Sulfate	120	4230	5065	4975	4940	5044	4910	4809	5500	1715
Urea	120	2288	3670	3801	3918	4530	3676	3964	4282	1585
Am. Sulfate	240	3666	4329	4299	4172	4522	4535	4684	4455	1952
Urea	240	1856	2825	2866	1978	3224	3176	3800	3765	980

was 1800 ppm higher than in those fertilized with urea. This difference decreased at the second sampling and became insignificant at the two later samplings. Urea-fertilized plants which received 120 pounds P_2O_6 per acre were very similar in phosphate-phosphorus content during the season to plants receiving 240 pounds of N from ammonium sulfate but no phosphorus. Tuber yields resulting from these treatments are shown in the inset of Fig. 2. Yield without phosphorus application was 259 cwt. per acre. Phosphorus with urea yielded 247 cwt. per acre and phosphorus with ammonium sulfate yielded 307 cwt. of tubers per acre.

At the 120 pound rate of nitrogen increased calcium content was clearly evident in plants fertilized with urea in three of the nine experiments (Table 6). At the 240 pound rate urea resulted in an increased calcium content in eight of the nine fields. The differences in calcium content due to source of nitrogen became larger as the season progressed and the plants matured.

Table 7 shows magnesium concentrations in the petioles at late season. At the higher rate of nitrogen, urea usually resulted in slightly higher magnesium content than ammonium sulfate. In Field 1 (Fig. 3) early season, magnesium content was low and was the same for plants receiving both materials. Differences, which favored urea, became larger as the plants matured and tubers enlarged.

TABLE 6.—*Calcium content of potato leaf petioles from nine field experiments in Riverside and San Bernardino Counties, California.*

Nitrogen source	Pounds N per acre	Field experiments and days after planting								
		1 (91)	2 (85)	3 (74)	4 (85)	5 (94)	6 (89)	7 (84)	8 (83)	9 (85)
		Per cent calcium (Ca) in petioles								
None	0	3.0	2.6	2.4	2.8	2.2	2.9	2.8	2.2	3.1
Am. Sulfate	120	2.0	1.8	2.4	1.6	1.8	1.7	2.2	1.4	1.9
Urea	120	2.5	1.8	2.4	1.5	2.0	2.2	2.7	1.6	1.8
Am Sulfate	240	1.9	1.5	2.1	1.4	1.4	1.4	2.1	1.2	1.6
Urea	240	2.8	1.8	2.5	2.0	1.9	1.7	2.7	1.6	1.5

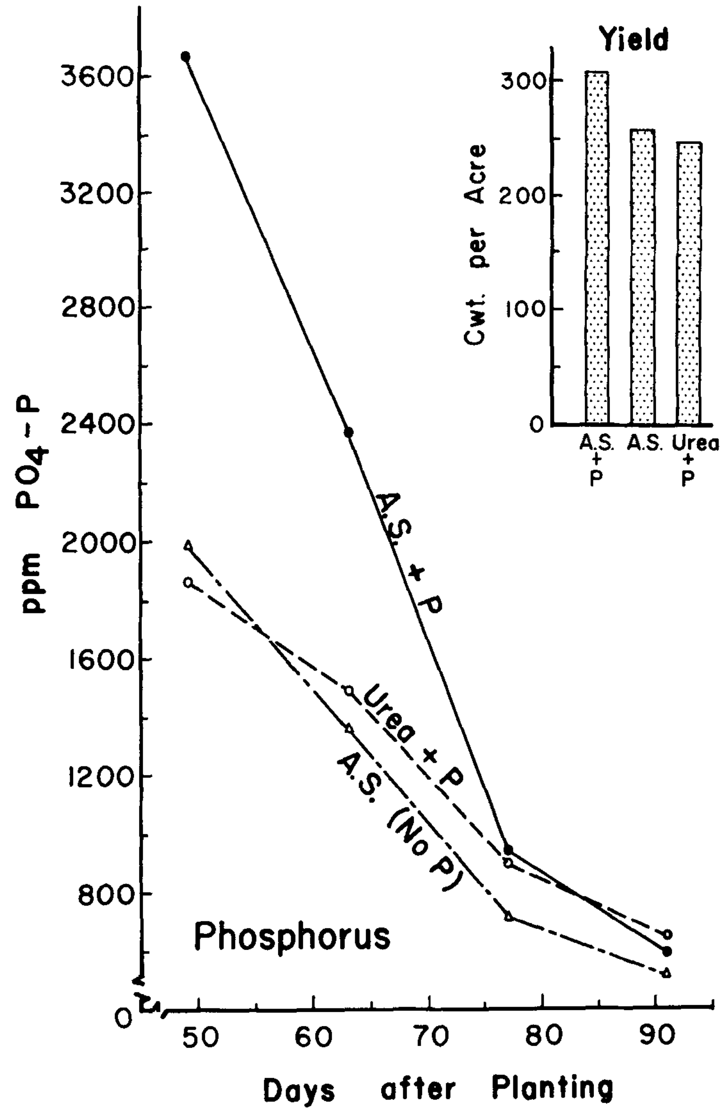

FIG. 2.—Seasonal phosphate-phosphorus concentrations in petioles of potatoes fertilized with 240 pounds of nitrogen per acre from ammonium sulfate and urea. Field 1, 1960.

TABLE 7.—*Magnesium content of potato leaf petioles from nine field experiments in Riverside and San Bernardino Counties, California.*

Nitrogen source	Pounds N per acre	Field experiments and days after planting								
		1 (91)	2 (85)	3 (74)	4 (85)	5 (94)	6 (89)	7 (84)	8 (83)	9 (85)
		Per cent magnesium (Mg) in petioles								
None	0	0.8	2.3	1.3	1.2	0.9	0.7	0.6	1.2	1.0
Am. Sulfate	120	1.4	2.3	1.6	1.0	0.6	0.4	1.1	1.3	0.7
Urea	120	1.6	2.2	1.6	1.0	0.6	0.6	1.2	1.4	0.7
Am. Sulfate	240	1.3	2.1	1.6	1.0	0.5	0.4	1.1	1.3	0.6
Urea	240	1.7	2.2	1.6	1.2	0.8	0.5	1.6	1.4	0.6

TABLE 8.—*Potato tuber yields from two source-of-nitrogen experiments conducted near Shafter, California in 1959 and 1960.*

Nitrogen source	Rate of nitrogen	Total yield—cwt. per acre	
		1959 Expt.	1960 Expt.
	Lbs./Acre		
Am. Sulfate	75	488	383
Urea	75	448	387
Am. Sulfate	150	524	437
Urea	150	487	425
Am. Sulfate	225	576	478
Urea	225	505	470
Am. Sulfate	300	..	478
Urea	300	..	479
Am. Sulfate*	150	571	419
Urea*	150	474	411

*No phosphorus applied.

Other experiments

Two field experiments were conducted in Kern County, one in 1959 on the U.S.D.A. Cotton Experiment Station and the other in 1960 in a nearby field. The yield data from these experiments are summarized in Table 8. At all rates of application urea proved inferior to ammonium sulfate in its effect on yields in the 1959 experiments. Yields from 1960 experiments in an adjacent field were the same for both sources. Soils of these two fields were of the same series, Hesperia sandy loam; however, the soil of the 1960 experiment was more acid in reaction with a pH of 6.3 whereas in the 1959 experiment the soil pH was 6.9.

In both of these experiments an attempt was made to determine whether biuret contained in urea might exert a toxic effect on plant growth and decrease yields. Three materials were used containing 1.3, less than 0.5 and less than 0.2% biuret. Yield results presented in Table 9 indicate that these levels of biuret were not affecting tuber yields; nor were there,

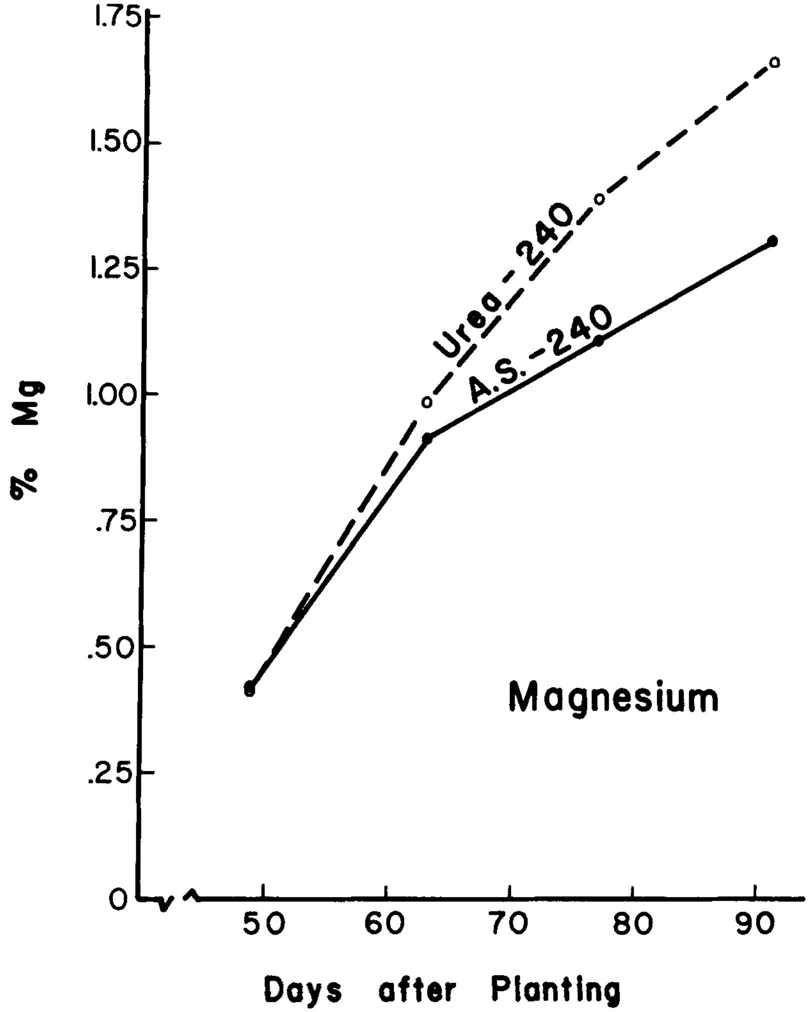

FIG. 3.—Seasonal magnesium concentrations in petioles of potatoes fertilized with 240 pounds of nitrogen per acre from ammonium sulfate and urea. Field 1, 1960.

during the growing season or at harvest, any noticeable differences in plant or tuber growth and appearance due to biuret content of the urea fertilizer.

Discussion

Results of these studies substantiate the findings of Lorenz, et al. (1) with respect to the inferior effect of urea nitrogen in comparison with ammonium sulfate in Hesperia sandy loam soils. Furthermore, these results show that similar differences occur in plant growth and nutrient absorption in other soils and in other potato producing districts of California. In all

TABLE 9.—*Total yield of potatoes fertilized with urea containing different percentages of biuret.*

Nitrogen source*	Biuret per cent	Yield cwt./acre	
		1959	1960
Urea	1.3	493	414
Urea	0.5	496	..
Urea	0.2	487	425

*Nitrogen rate: 150 pounds per acre.

soils of alkaline or neutral reaction, ammonium sulfate was more efficient in producing maximum tuber yields than was urea. Ammonium sulfate proved better even in some of the slightly acid soils, but in soils of more distinct acid reaction, urea performed equal to ammonium sulfate with respect to total yields.

In all comarisons, urea fertilization resulted in lower concentrations of phosphate-phosphorus in the leaf petioles during early season. Visual symptoms observable in urea fertilized plants were similar to those generally attributable to phosphorus deficiency and were indistinguishable from symptoms observed in known phosphorus deficient plants. These symptoms occurred even though phosphorus was banded with the nitrogen materials at a rate normally found sufficient to correct the deficiency. Thus it seems evident that urea interfered in some manner with phosphorus absorption or utilization by the potato plant during early season growth. In late season, after the urea had presumably been hydrolyzed and subsequently nitrified, this inhibition decreased, the foliar symptoms of phosphorus deficiency vanished and the petiole concentrations of phosphorus increased to compare favorably with those plants fertilized with ammonium sulfate.

The differences in phosphorus concentrations are difficult to explain solely on the basis that one material, ammonium sulfate, was residually more acid than the other and produced a more favorable condition in the soil root zone for phosphorus uptake by the plant. If these differences were strictly from ammonium sulfate's greater residual acidity, then doubling the application rate of ammonium sulfate should logically increase the soil acidity and hence the phosphorus uptake. Such was not the case. Instead of increasing petiole phosphorus concentrations, doubling the application rate actually resulted in decreased phosphate-phosphorus concentrations.

Biuret toxicity, suspected as a possible cause of reduced yields when urea was used in early tests, did not appear to be the principal cause for the inferior performance of urea in these tests since identical results were obtained with ureas of both high and low biuret content.

In soils which had an acid reaction or were acid as a result of sulfur or fertilizer application, urea appeared to be as efficient as ammonium sulfate, as far as yields were concerned. But even in these acid soils, phosphate-phosphorus in the petioles was much higher with ammonium sulfate application than with urea.

Summary and Conclusions

1. The source of nitrogen influenced the total yield of potato tubers, the nutrient concentrations in the potato petiole and the appearance of growing plants, especially in fields of low available phosphorus.
2. Urea resulted in higher nitrate-nitrogen, calcium, and magnesium concentrations in the plant petiole, but in lower phosphate-phosphorus concentrations as compared with ammonium sulfate.
3. Urea application in soils of neutral and alkaline reaction resulted in lower total yields than did ammonium sulfate at equal rates of nitrogen. In acid soils, urea appeared equal to ammonium sulfate.
4. Potatoes from urea-fertilized plants grown on soils of low available phosphurus exhibited symptoms of phosphorus deficiency during early season but outgrew these symptoms as the plants approached maturity.
5. Increasing the biuret content in the urea material from 0.2 to 1.3 per cent had no effect on yield or plant appearance.
6. In neutral and alkaline soils, ammonium sulfate was more efficient than urea as a nitrogen source for potatoes. In acid soils, indications were that urea equaled ammonium sulfate in efficiency for potatoes.

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