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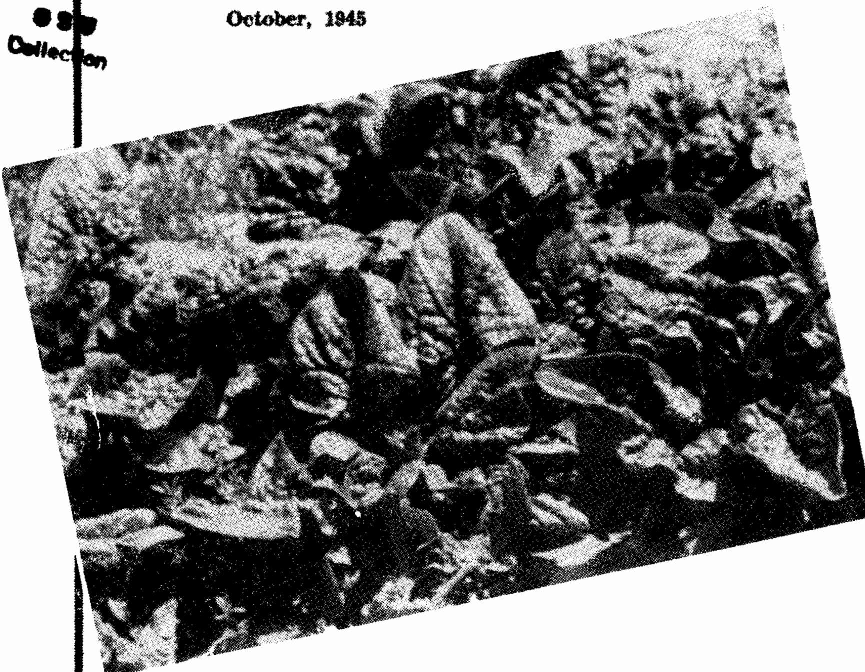

Effect of Ammonium Nitrate As a Fertilizer for Spinach

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Experiment Station Tests Show—

Nitrogen fertilizers will increase the production of spinach on soils low in available nitrate, unless leaching is severe or weed competition serious. Where weed competition may develop if soluble nitrogen is applied when the seed is planted, fertilizer applications should be delayed until the spinach has developed the fifth or sixth permanent leaf. *An application of ammonium nitrate may be very harmful to spinach plants which have from one to three permanent leaves.* The appearance of the leaves can be helpful in determining need for nitrogen fertilizer during the growing season. A severe nitrogen deficiency causes the edges of the leaves to turn yellow. On non-acid, high phosphate soils, a light green color and slow growth is a good indication that nitrogen is needed. Chemical tests of plant tissue can be used to detect a nitrate deficiency before plant symptoms appear.

Effect of Ammonium Nitrate as a Fertilizer for Spinach

By HORACE J. HARPER and FRANK B. CROSS*

This bulletin reports a series of tests to study the effect of ammonium nitrate as a fertilizer for spinach

The importance of providing adequate nitrogen for spinach gained attention in the Arkansas River Valley in Oklahoma after the 1943 floods deposited large quantities of sand and silt on much of the land where this crop had been grown. These deposits were very low in organic matter,† and much of the spinach planted on deeply silted areas in the fall of 1943 failed due to lack of available nitrogen. Spinach growers have also had difficulty in producing good crops on land where a large amount of low nitrogen material such as crop residues or grass was plowed under shortly before planting time. So much available soil nitrogen is required to decompose this vegetation that there is a temporary shortage of available nitrogen for plant growth. A combination of abundant rainfall and cool, wet weather will also reduce the availability of soil nitrogen.

Spinach production will be increased by nitrogen fertilization on many soils where similar treatment on summer-growing crops will show no effect. This is because the soil organic matter does not decay as rapidly in cool weather, and the quantity of available nitrogen released is much less than during periods when the temperature is more favorable for biological activity in the soil.

Large quantities of ammonium nitrate should be available during the postwar period. Many synthetic ammonia plants were constructed to produce nitric acid for the manufacture of explosives and will continue to make ammonia or other nitrogen products for industrial and agricultural use.

Very little information has been published on the comparative value of ammonium nitrate and other nitrogen fertilizers for the production of spinach. Tests in Virginia** have shown that a mixture of ammonia and nitrate nitrogen is favorable for spinach on nonacid soils (pH 6.5 or higher).

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* Professor of Soils, and Head of Horticulture Department, respectively.

† Harper, Horace J.: Improvement of Flood-Damaged Land in Eastern Oklahoma. Oklahoma Agri. Exp. Sta. Bul. B-282 (1944).

** Zimmerly, H. H.: *Spinach Fertilization with Synthetic Nitrogen Salts.* Va. Truck Exp. Sta. Bul. 63 (1928).

Fig. 1.—Both plots of spinach were fertilized with ammonium nitrate at the rate of 100 pounds per acre at planting time. The plot at the right also received a top-dressing of 100 pounds 67 days after planting. Respective yields (estimated) were three-fourths and two tons per acre. Light colored plot in background was unfertilized and produced no spinach suitable for harvesting. These plots are on soil covered with silt 8 to 12 inches by flood water in May, 1943. J. L. Short farm southeast of Webbers Falls.

FIELD EXPERIMENTS

Four field experiments were conducted in the winter seasons of 1943-44 and 1944-45 on commercial spinach planted on flood-silted areas in Muskogee County.

J. L. Short Farm

A deeply silted soil on the J. L. Short farm southeast of Webbers Falls produced no spinach suitable for harvesting on unfertilized soil. One hundred pounds of ammonium nitrate per acre, applied February 25 before the spinach was planted, produced three-fourths of a ton per acre.* An additional top-dressing of 100 pounds of ammonium nitrate applied May 2, 67 days after planting, produced two tons per acre. Some of these plots are shown in Figure 1.

* The yields for the J. L. Short farm are estimates agreed upon by three spinach growers. Because of the slow rate of growth on the unfertilized land, the crop was not harvested until seed stalks began to form on the fertilized plots.

D. K. Scott Farm

The second experiment was located on a deeply silted area on the D. K. Scott farm in the McLain bottom southeast of Muskogee. Ammonium nitrate was broadcast at the rate of 100 pounds per acre when the young spinach plants were about one inch high and were forming their first, second or third permanent leaf. The leaf surfaces were highly crinkled and were in a horizontal position near the surface of the soil. The fertilizer was uniformly distributed over the area and some of the material was retained on the leaves and in the axils of the plants. Rain fell on the second and third days following the application; nevertheless, a high percentage of the young plants were killed.*

Twelve days later several rows not previously fertilized were side-dressed at the rate of 50, 100, and 150 pounds of ammonium nitrate per acre. Although some of the fertilizer lodged in the axils and on the curled surfaces of the leaves, no noticeable damage to subsequent growth occurred. Ammonium sulfate and sodium nitrate containing equivalent quantities of nitrogen were also applied on adjacent rows without injury to the plants.

W. P. Fite Farm

Spinach planted in December, 1943, on a lightly silted soil on the W. P. Fite farm in the Fort Gibson bottom east of Muskogee was fertilized on March 8, 1944, by broadcasting ammonium nitrate, ammonium sulfate, and sodium nitrate. The plants were unharmed. The beneficial effect of ammonium nitrate on the growth of spinach in this study is illustrated in Figure 2.

Yields given in Table I indicate that the nitrate nitrogen was more readily available to this crop of spinach than the ammonia nitrogen. This effect may have been due to the short period of time between application and harvest, only 26 days.

The low yield obtained from the plot fertilized with ammonium sulfate may have been partly due to a change in soil reaction. This soil is slightly acid (pH 6.1) and the heavy fertilizer treatment may have made it temporarily too acid for the best growth of spinach.†

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* There was also a noticeable deflocculation of the surface soil, which had a pH of 8.1, as a result of the fertilizer treatment.

† Zimmerly, *op. cit., and* Zimmerly, H. H., Soil Acidity in Relation to Spinach Production. Va. Truck Exp. Sta. Bul. 57.

Fig. 2.—Spinach in the foreground was unfertilized; it yielded 1.5 tons per acre. The plot in the background was top-dressed with 300 pounds of ammonium nitrate per acre and yielded 4.12 tons. The soil was temporarily low in available nitrogen because a heavy growth of grass had been plowed under just before the spinach was planted.

H. C. Harkey Farm

In the fall of 1944, spinach on a deeply silted soil on the H. C. Harkey farm southeast of Webber Falls was fertilized with ammonium nitrate at the rate of 100 pounds per acre. Some of the plants were large and others were small when the fertilizer was applied, due to uneven germination caused by dry weather. The small plants were killed as a result of the fertilizer treatment. The larger plants were not injured and their growth was materially increased.

GREENHOUSE EXPERIMENTS

The damage to young plants in the test on the D. K. Scott farm led to further experiments in the greenhouse at Stillwater. The first greenhouse tests were set up to determine whether plant damage might be caused by salt injury to seedling development. Soil was brought from the experimental area on the Scott farm for these tests. A clay loam soil from Cow Creek bottom on the Experiment Station farm at Stillwater was also used.

Fertilizer Applied at Planting Time

These soils were placed in eight-inch pots, and fertilizer was applied and mixed with the surface soil immediately after the spinach seed was planted. Ammonium nitrate, ammonium sulfate, sodium nitrate, and ammonium hydroxide were applied at different rates per acre. The test included ammonium nitrate from three different sources: Pittsburg, Kansas, Ft. Smith, Arkansas, and Muscle Shoals, Alabama.

All fertilizers were applied at rates 12 times those normally used in the field.

Ammonium Nitrate.—In the soil from the Scott farm, spinach seedlings survived an application of 600 pounds of ammonium nitrate per acre, although the young plants grew very slowly. At 1,200 pounds per acre the stand was poor and 2,400 pounds killed all the seedlings.

In the soil from the Experiment Station farm, germination was uninjured by applications of ammonium nitrate as high as 2,400 pounds per acre.

Crystalline and pellet forms of ammonium nitrate produced similar effects on the early growth of spinach on both soils.

Sodium Nitrate.—Spinach made a fair growth on the soil from the Scott land where sodium nitrate was applied at 1,200 pounds per acre. At 2,400 pounds, the number of plants was less than in the ammonium nitrate pots treated at the rate of 1,200 pounds per acre. No plants survived an application of 4,800 pounds per acre.

In the clay loam soil from the Experiment Station farm, both germination and early growth were uninjured by 1,200 pounds of sodium nitrate per acre, but were reduced by the 2,400- and 4,800-pound applications. The greater tolerance of the clay loam as compared with the very fine sandy loam is

TABLE I.—Effect of Nitrogen Fertilizers Applied as a Top-Dressing on the Yield of Spinach.

Kind of Fertilizer	Rate of Application (Lbs. per Acre)	Yield (Tons per Acre)
None	None	1.50
Ammonium sulfate	480	2.27
Ammonium nitrate	100	2.92
Ammonium nitrate	300	4.12
Sodium nitrate	600	4.72

Location of Test: W. P. Fite farm, Ft. Gibson bottom, Muskogee County.

due to the higher optimum moisture content of the finer-textured soil, which would decrease the salt concentration in the soil water.

Ammonium Hydroxide.—Ammonium hydroxide applied at the rate of 384 pounds of nitrogen per acre prevented growth due to high alkalinity. This rate of application was equivalent to the 1,200-pound ammonium nitrate treatment.

Ammonium Sulfate.—Ammonium sulfate applied at the rate of 1,920 pounds per acre was very harmful to the spinach seedlings. This rate is equivalent in nitrogen content to 1,200 pounds of ammonium nitrate.

Fertilizer Applied to Young Spinach

In another test for possible salt injury to roots, fertilizers were applied in solution to soil in which young seedlings were growing to avoid any possibility of getting fertilizer particles on the leaves. All solutions were added after the second or third permanent leaf had appeared. No injury was caused by 50, 100, or 150 pounds of ammonium nitrate per acre, which would be similar to rates used under field conditions, nor by equivalent amounts of nitrogen added in solution as sodium nitrate or ammonium sulfate.

Effect of Size of Fertilizer Particles

Another greenhouse test was set up in December, 1944, to compare the effects of large and small particles of fertilizer applied broadcast at different stages of seedling development. Soil from the H. C. Harkey farm was placed in flats and spinach plants were spaced three inches apart. The weather was cloudy and the young leaves were crinkled and developed horizontally near the surface of the soil. Fertilizer particles which did not pass through a 20-mesh sieve and particles ground to pass through a 100-mesh sieve were used in this experiment. The fertilizers were applied broadcast to the soil when the second or third permanent leaf had appeared. Figure 3 shows the effect of the 100-mesh material on reduced growth. A comparison of yields from untreated flats and from others which had been fertilized at time of planting is shown in Table II.

*TABLE II.—Effects of Fine and Coarse Particles of Nitrogen Fertilizers on Yield of Spinach; Greenhouse Experiments.**

Kind of Fertilizer	Rate of Applcation (Lbs. per Acre)	Yield From Area 10x14 In. (Grams)
None	----	47
Fine ammonium nitrate	100	28
Fine ammonium nitrate	200	10
Coarse ammonium nitrate	100	29
Coarse ammonium nitrate	200	31
Fine sodium nitrate	100	25
Fine sodium nitrate	200	20
Coarse sodium nitrate	100	37
Coarse sodium nitrate	200	36
Ammonium nitrate**	150	62
Sodium nitrate**	150	70

* Soil used was a fine sandy loam deposited by flood water on the H. C. Harkey farm near Webbers Falls in May, 1943.

** Fertilizer applied when the seed was planted. Other applications were made when plants were developing first and second pairs of leaves.

Fig. 3.—These greenhouse tests show the effect of top-dressing spinach with ammonium nitrate at the wrong time. The flat at the right was fertilized when the first and second permanent leaves appeared; the one at the left was not fertilized. Fertilizer should be applied at the time of planting, or after the fifth or sixth permanent leaves have appeared.

*TABLE III.—Effect of Time of Application and Particle Size of Sodium and Ammonium Nitrate on the Yield of Spinach; Greenhouse Experiment.**

Kind of Fertilizer	Fineness	Rate of Application (Lbs. per Acre-	Time of Application	Yield from Area 14x20 In. (Grams)
None	------		------	385
Ammonium nitrate	100 mesh	100	1st & 2nd leaf	196
Ammonium nitrate	100 mesh	200	1st & 2nd leaf	110
Ammonium nitrate	20 mesh	100	1st & 2nd leaf	469
Ammonium nitrate	20 mesh	200	1st & 2nd leaf	540
Ammonium nitrate	100 mesh	100	5th & 6th leaf	688
Ammonium nitrate	100 mesh	200	5th & 6th leaf	502
Ammonium nitrate	20 mesh	100	5th & 6th leaf	526
Ammonium nitrate	20 mesn	200	5th & 6th leaf	528
Sodium nitrate	100 mesh	100	1st & 2nd leaf	469
Sodium nitrate	100 mesh	200	1st & 2nd leaf	540
Sodium nitrate	20 mesh	100	1st & 2nd leaf	586
Sodium nitrate	20 mesh	200	1st & 2nd leaf	508
Sodium nitrate	100 mesh	100	5th & 6th leaf	561
Sodium nitrate	100 mesh	200	5th & 6th leaf	526
Sodium nitrate	20 mesh	100	5th & 6th leaf	570
Sodium nitrate	20 mesh	200	5th & 6th leaf	550

The same soil* was used for a second test comparing coarse and fine particles of ammonium nitrate fertilizer under different weather conditions. In this test, which was started in February, 1945, the leaves were more upright, due to more favorable light in the greenhouse; therefore, a smaller quantity of the fertilizer adhered to the plants as it was broadcast over the soil. The 100-mesh particles of ammonium nitrate were scattered more evenly than those of the sodium nitrate. The atmosphere was rather moist when the fertilizers were applied, and the sodium nitrate was more adhesive, therefore more difficult to distribute evenly. The 20-mesh materials did not adhere to the leaves except as a crystal might be held in the axil between the leaves. Yields from this experiment are shown in Table III. The 20-mesh ammonium nitrate caused less damage than in the previous study. The 100-mesh material was more harmful to early seedling development than the 20-mesh material, as shown in Figure 4. Twenty-mesh material applied after the fifth or sixth permanent leaf appeared, increased crop production.

* Flats used for the preceding experiment were emptied, the soil thoroughly mixed, and the flats refilled.

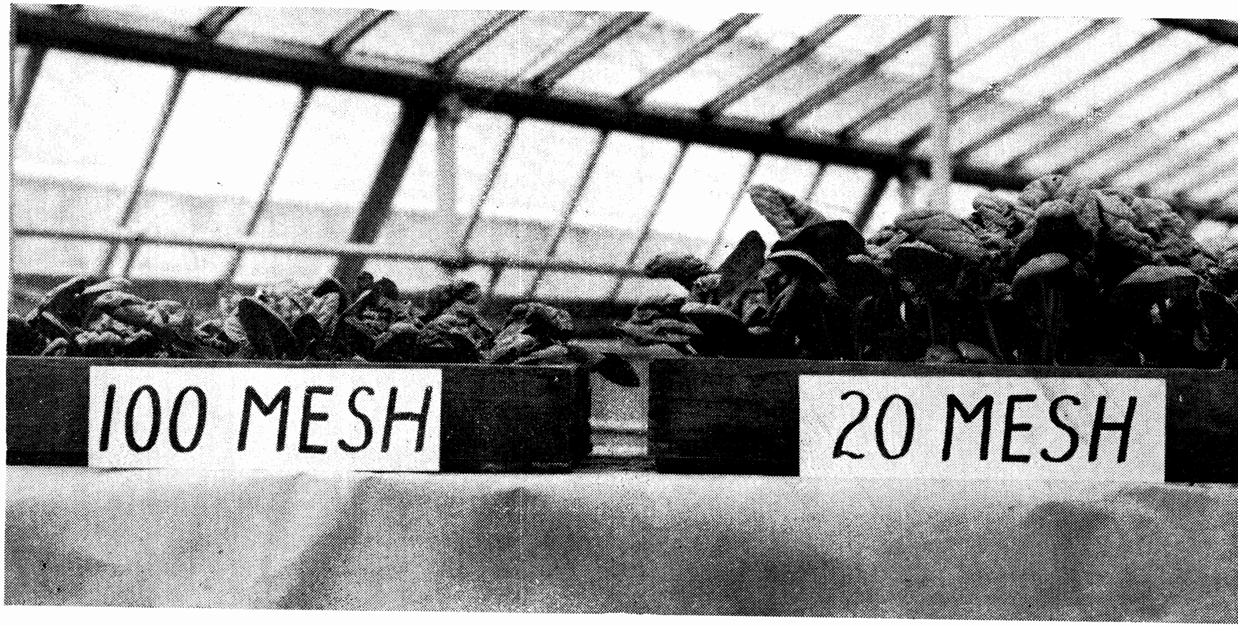

Fig. 4.—Spinach showing retarded development of plants fertilized with 100-mesh ammonium nitrate as compared with 20-mesh material. Both flats received the same amount of fertilizer.

Variation in Particle Size

Ammonium nitrate from three sources was compared to obtain information on the variation in particle size. Five one gram samples of each material were weighed and the number of particles held on a 40-mesh sieve was counted. The percentage of each sample passing through the 40-mesh sieve was determined on a 150 gram sample. The results of this comparison are given in Table IV.

When the rate of application is 100 pounds per acre the average number of particles larger than 40-mesh which would fall on each square inch, if uniformly distributed, would be 4.1, 6.2 and 16.8 for the Canadian, Pittsburg and Muscle Shoals materials, respectively. Because of the larger percentage of fine material in the ammonium nitrate from Muscle Shoals it is quite probable that more particles would adhere to spinach leaves and a greater harmful effect would be obtained from this material than from the use of a coarser product.

CONCLUSIONS

Spinach seedlings were severely damaged by ammonium nitrate applied as a top-dressing when the first, second or third permanent leaves were developing in both field and greenhouse tests. After the fifth and sixth permanent leaf had developed, ammonium nitrate applied at the rate of 200 pounds per acre caused no serious damage and yields were greatly increased on nitrogen-deficient soils.

Ammonium nitrate broadcast at the rate of 100 pounds per acre on a field plot where spinach plants varied in size because of uneven germination killed the small plants and did not

TABLE IV.—Percentage of Fine Material and Relative Number of Particles in Three Amomnium Nitrate Fertilizers.

Source of Material	Percent Through 40-mesh Sieve	Av. No. of Particles Larger than 40-mesh in One Gram
Canada	.55	564
T. V. A. Muscle Shoals, Ala.	13.65	2310
Military Ordnance Works, Pittsburg, Kansas	1.90	851

injure the larger ones. This fertilizer was more toxic than sodium nitrate in these experiments. It is quite probable that coarse particles of crystalline ammonium nitrate would be less harmful than material containing a higher percentage of finely-divided particles. Severe injury occurred where ammonium nitrate crystals or finely-divided particles lodged on the leaves of young plants.

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