# Evaluation of Three Sources of Nitrogen for Corn[1]

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Leaching of nitrogen from sandy northern Indiana soils is a problem when moisture is optimum for corn. Even though rainfall is seldom sufficient for corn, water for irrigation is generally available. Where irrigation water can be used, a material or method to supply nitrogen efficiently for corn throughout the growing season is important.

Armiger *et al.* (1) and Musser (2) found that the overall efficiency of properly formulated urea-form materials equals or exceeds that of conventional nitrogen fertilizers in respect to long season crops. Musser (2) also found that split applications of soluble nitrogen made at monthly intervals throughout the growing season gave growth responses similar to single applications of urea-form fertilizers on turf. Studies on the effect of urea-formaldehyde materials on cotton and corn were conducted by Scarsbrook (4) in Alabama. He compared these materials with a standard soluble source of ammonium nitrate. Yields of both cotton and corn increased with increasing rates of nitrogen from both sources. However, yields from the urea-formaldehyde fertilizer were equivalent to those produced on lots receiving only half as much nitrogen from ammonium nitrate. Both the nitrogen content in the sixth corn leaf at tasseling and the protein content of the grain at harvest were lower where urea-formaldehyde was the source of nitrogen.

The main purpose of these experiments was to evaluate the relative effect of a urea-formaldehyde source and two other common sources of nitrogen for corn under supplementary irrigation on Coloma sand.

## METHODS AND PROCEDURES

### Experiment I

This experiment was conducted on Coloma sand on the Sand Experiment Field near Culver, Indiana, in 1959. The soil is extremely drouthy when rainfall is either scarce or poorly distributed (Table 1). Irrigation was used after 30% to 60% of the available soil water was depleted. Gravimetric soil moisture determinations and a soil moisture depletion curve were used to determine when to irrigate. Light weight aluminum

Table 1. Determination of Water Held by Coloma Sand at Field Capacity and at Permanent Wilting, Sand Experiment Field, Experiment I.

| Depth in Inches | Inches of Water | | |
|---|---|---|---|
| | Field Capacity | Permanent Wilting Point | Available Water |
| 0–6 | 0.70 | 0.22 | 0.48 |
| 6–12 | 0.69 | 0.21 | 0.48 |

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portable pipes and overhead, circulatory sprinklers were used to apply the irrigation water. The amount of water applied per irrigation was determined as a function of time, spacing of sprinklers, and pressure. The total precipitation during June, July, and August was 6.62 inches, and the total amount of irrigation water applied was 14.50 inches (Table 2).

Table 2. Distribution and Amount of Precipitation and Irrigation in Inches During June, July, and August, 1959, Sand Experiment Field, Experiment I.

| Date | Rainfall | Irrigation | Rainfall Plus Irrigation |
|---|---|---|---|
| June 8 | .... | 2.00 | |
| " 11 | 0.39 | .... | |
| " 12 | 0.10 | .... | |
| " 15 | 0.02 | .... | |
| " 16 | 0.01 | .... | |
| " 22 | 0.13 | .... | |
| " 23 | .... | 2.00 | |
| " 26 | 0.93 | .... | |
| " 30 | 0.02 | .... | |
| June total | 1.60 | 4.00 | 5.60 |
| July 1 | 0.34 | 1.50 | |
| " 8 | .... | 2.00 | |
| " 17 | 0.52 | 1.00 | |
| " 18 | 0.65 | .... | |
| " 19 | 0.66 | .... | |
| " 20 | 0.95 | .... | |
| " 23 | 0.33 | .... | |
| " 24 | 0.35 | .... | |
| " 28 | 0.02 | .... | |
| " 30 | 0.55 | .... | |
| July total | 4.37 | 4.50 | 8.87 |
| August 4 | 0.38 | .... | |
| " 6 | .... | 2.00 | |
| " 8 | 0.04 | .... | |
| " 16 | 0.03 | .... | |
| " 17 | 0.18 | 2.00 | |
| " 22 | .... | 2.00 | |
| " 25 | 0.02 | .... | |
| August total | 0.65 | 6.00 | 6.65 |
| Three month total | 6.62 | 14.50 | 21.12 |

Even though drouthy, this Coloma sand was relatively high in soil pH and available phosphate and potash. Tests by the Purdue Soil Testing Laboratory showed the following:

| | |
|---|---|
| Soil pH | 6.5 |
| Available $P_2O_5$, 0–6 inches | Very High |
| Available $P_2O_5$, 6–12 inches | Very High |
| Available $K_2O$, 0–6 inches | Very High |
| Available $K_2O$, 6–12 inches | High |
| Organic Matter, 0–6 inches | 1% |

This soil had been used for growing sorghum under high fertility in 1957 and in 1958. A few days before planting, the experimental area was uniformly fertilized with 30 pounds per acre of available $P_2O_5$ from 48% superphosphate, 150 pounds of water soluble $K_2O$ from 60% muriate of potash, and a mixture of minor elements. This mixture included 2 pounds per acre of zinc from zinc sulfate, 4 pounds per acre of manganese from manganese sulfate, 5 pounds per acre of copper from copper chloride, 10 pounds per acre of magnesium from magnesium sulfate, and 2 pounds per acre of boron from borax. After the experimental area was plowed, the fertilizer was drilled and then disked into the soil.

Two main variables were used in the experimental design. One was rate of nitrogen application, and the other was method or time of application. Three rates of nitrogen and five methods of application were used in fifteen different treatments. These treatments were arranged in a randomized split plot design with four replications. Rates of nitrogen composed the main plots, and methods of application were the sub-plots. Methods of application included three sources of nitrogen—urea, ammonium nitrate, and urea-formaldehyde—and two times of application—all at planting or five split applications. Sub-plots or methods of application were 35 feet long and four corn rows wide.

The urea with 45% nitrogen and the ammonium nitrate with 33% nitrogen are easily available from commercial sources. However, the urea-formaldehyde source used is not so readily available. The product used was called Nitroform, and it was supplied by Nitroform Agricultural Chemicals.[2] The available chemical data for nitroform were as follows:

| | |
|---|---|
| Total nitrogen | 38.1% |
| Cold water soluble nitrogen | 11.9% |
| Cold water insoluble nitrogen | 26.2% |
| Availability Index (AI) | 35.0% |

The first application of nitrogen in split application treatments was broadcast by hand on May 15. Four other applications of ammonium nitrate and urea used in split application treatments were applied: (1) at the first cultivation on June 8, (2) at the second cultivation on June 26, (3) on July 8, and (4) at the start of tasseling on July 18. These last four applications of ammonium nitrate and urea after planting were side-dressed. While the second and third applications were immediately followed by cultivations, the fourth and fifth applications were followed by irrigations.

The single application treatments of ammonium nitrate, urea, and urea-formaldehyde were also broadcast by hand on May 15. Then all

2. Courtesy of Professor W. H. Daniel, Turf Specialist, Agronomy Department, Purdue University.

plots were disked to mix the fertilizer within the top 3 to 4 inches of soil. A single cross hybred corn WF9 x OhO7 was planted in 38 inch rows on May 16. The rate of seeding was one kernel every 4 inches. On May 28 a 10% failure in emergence of the seedlings was noted. The blank spaces were immediately replanted by hand. After thinning on June 8, the final stand was one plant every 8 inches.

Leaf samples for nitrogen determinations were taken at tasseling. The sixth leaf above the ground was taken from 8 to 10 plants in the two center rows of each plot. These leaves were dried for 48 hours at 70° C. ground, and total nitrogen determined by the Kjeldahl method (3).

Yields were determined by harvesting and weighing the ears in the two center rows of each plot. Moisture content of the grain was determined by drying at a temperature of 105° C. for 24 hours. Yields were calculated on the basis of 56 pounds of shelled corn per bushel at 15.5% moisture, or number 2 corn. Tables were used to determine the pounds of ears required to shell a bushel at a particular moisture content.

Protein content of the corn grain was determined from composite samples of the four replications of each treatment. These grain samples were dried for 72 hours at 70° C., ground, and total nitrogen determined on the dry weight bases. Protein content was determined by multiplying the total nitrogen content by 6.25 (3).

**Experiment II**

This experiment was also conducted on Coloma sand on the Sand Experiment Field in 1959 very close to the area used for Experiment I. Irrigation was used to supplement rainfall during July and August as shown in Table 3. Tensiometer readings related to gravimetric soil moisture determinations were used to determine when to irrigate. More moisture stress was allowed in both June and July than was allowed in Experiment I before irrigation was initiated. The same irrigation equipment and method of determining amounts of water applied were used in this experiment as were used in Experiment I.

The area used for Experiment II had been in corn in 1957 and 1958. A uniform application of 180 pounds per acre of 60% water soluble $K_2O$ was plowed down in spring. One hundred pounds per acre of Sul-Po-Mag containing 21% or more of water soluble $K_2O$ was applied beside the row at planting. One hundred pounds per acre of 11-48-0 was also applied beside the row at planting.

The hybrid corn variety A.E.S. 601 was planted in 38 inch rows on June 1. Fifty pounds per acre of nitrogen from ammonium nitrate with 33% nitrogen was sidedressed on all plots on June 8.

Three different fertilizer sidedressing treatments were applied on June 26. One hundred pounds per acre of actual nitrogen was applied from each of three sources. Urea with 48% nitrogen, ammonium nitrate with 33% nitrogen, and 16-8-8 were sidedressed. Urea-formaldehyde was used to supply nitrogen in 16-8-8. Fifty percent of the nitrogen in the 16-8-8 was water soluble and 50% was not water soluble. Equivalent amounts of available phosphate and water soluble potash were sidedressed with the urea and ammonium nitrate so that all three treatments received equal amounts of plant food.

Table 3. Distribution and Amount of Precipitation and Irrigation in Inches During June, July, and August, 1959, Sand Experiment Field, Experiment II.

| Period | Rainfall | Irrigation | Rainfall Plus Irrigation |
|---|---|---|---|
| 1st week in June...... | 0.00 | | |
| 2nd week in June...... | 0.49 | | |
| 3rd week in June...... | 0.03 | | |
| 4th week in June...... | 1.30 | | |
| June total ............ | 1.82 | 0.00 | 1.82 |
| 1st week in July...... | 0.36 | 1.50 | |
| 2nd week in July...... | 0.00 | | |
| 3rd week in July...... | 1.83 | 2.00 | |
| 4th week in July...... | 1.63 | | |
| 5th week in July...... | 0.57 | | |
| July total ............ | 4.39 | 3.50 | 7.89 |
| 1st week in August.... | 0.42 | 2.00 | |
| 2nd week in August.... | 0.03 | | |
| 3rd week in August.... | 0.18 | 2.00 | |
| 4th week in August.... | 0.02 | 2.00 | |
| August total ......... | 0.65 | 6.00 | 6.65 |
| Three Month Total.... | 6.86 | 9.50 | 16.36 |

The three different fertilizer sidedressing treatments were arranged in three randomized replications. The plots used in these replications were 4 corn rows wide and 150 feet long.

Sampling of the corn leaves and nitrogen analyses were accomplished the same as in Experiment I. Yields of shelled corn were weighed from the two center rows of each plot, moisture determined as in Experiment I, and yields calculated on the basis of 56 pounds of grain per bushel with 15.5% moisture.

## RESULTS AND DISCUSSION

### Experiment I

Foliar symptoms of nitrogen deficiency were evident during the latter part of the growing season. They were most evident on the 80 pounds per acre rate of nitrogen, particularly on the urea-formaldehyde treatments. The leaves of corn in the 160 and 240 pound per acre rates of nitrogen from urea-formaldehyde were lighter green than those from urea and ammonium nitrate with comparable rates.

Corn height on June 23 (Table 4) and on July 28 (Table 5) was less at the 80 pound per acre rate of nitrogen than at the higher rates. There was a definite trend for the 80 pound rate of nitrogen treatments and for the urea-formaldehyde treatments to have fewer ears per 100 corn plants (Table 6) and lower ear weights (Table 7). The ear weights averaging

Table 4. Corn Height in Inches on June 23, Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs./A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 20 | 16 | 20 | 18 | 17 | 18 |
| 160 | 21 | 20 | 21 | 22 | 18 | 20 |
| 240 | 22 | 23 | 21 | 23 | 21 | 22 |
| Average | 21 | 20 | 21 | 21 | 19 | |

Table 5. Corn Height in Inches on July 28, Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs./A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 97 | 98 | 97 | 99 | 88 | 96 |
| 160 | 103 | 106 | 105 | 105 | 100 | 104 |
| 240 | 105 | 106 | 106 | 107 | 105 | 106 |
| Average | 102 | 103 | 103 | 104 | 98 | |

Table 6. Numbers of Ears per 100 Corn Plants as Affected by Treatment, Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs./A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 76.6 | 91.1 | 79.1 | 93.4 | 72.2 | 82.5 |
| 160 | 89.6 | 102.0 | 89.7 | 100.0 | 81.3 | 92.5 |
| 240 | 100.0 | 100.0 | 93.5 | 100.0 | 81.3 | 95.0 |
| Average | 88.7 | 97.7 | 87.4 | 97.8 | 78.3 | |

Table 7. Average Ear Weights in Pounds at 15.5% Moisture as Affected by Treatment, Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs./A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 0.29 | 0.25 | 0.28 | 0.27 | 0.14 | 0.25 |
| 160 | 0.35 | 0.32 | 0.34 | 0.34 | 0.24 | 0.33 |
| 240 | 0.35 | 0.34 | 0.35 | 0.36 | 0.30 | 0.34 |
| Average | 0.33 | 0.30 | 0.32 | 0.32 | 0.23 | |

from .14 to .36 pound were all too low, since .50 pound per ear is considered the ideal. Evidently, the population of stalks per acre was too high. However, it was approximately the same for all treatments (Table 8).

Table 8. Observed Population at Harvest in Thousands of Plants Per Acre, Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs./A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 20.1 | 20.7 | 18.8 | 19.9 | 18.8 | 19.7 |
| 160 | 20.1 | 20.4 | 20.4 | 20.7 | 19.6 | 20.2 |
| 240 | 18.3 | 20.1 | 20.4 | 20.4 | 19.6 | 19.8 |
| Average | 19.5 | 20.4 | 19.9 | 20.3 | 19.3 | |

The average nitrogen percentage of the sixth leaf of the urea-formaldehyde treatments was significantly lower than those of all other sources (Table 9). This trend was quite evident at all three nitrogen

Table 9. Nitrogen Content of Sixth Leaf of Corn at Tasseling Stage in Percent, Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs./A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 1.96 | 2.12 | 1.69 | 2.32 | 1.41 | 1.90 |
| 160 | 2.46 | 2.76 | 2.65 | 2.64 | 1.88 | 2.48 |
| 240 | 2.70 | 2.76 | 2.77 | 2.63 | 2.09 | 2.59 |
| Average | 2.37 | 2.55 | 2.37 | 2.53 | 1.79 | |

Significant difference at the 5% level

Between two levels of nitrogen....................... 0.28
Between two methods ............................ 0.12
Between two methods, at the same level of nitrogen.... 0.29
Between two levels of nitrogen, at the same method.... 0.35

levels. Also, the average nitrogen percentages were significantly higher with five applications than with one equivalent application at planting. This was true for both the ammonium nitrate and the urea sources.

The average yield of corn with five applications of urea was significantly higher than that with one application (Table 10). A trend in favor of the five applications over one application also was evident at all levels with ammonium nitrate. Yields of all treatments with urea-formaldehyde were significantly lower than those of both urea and ammonium nitrate for both one and five applications. Yields increased significantly from the 80 pound to the 160 pound per acre level of nitrogen in all five methods. Even though the increases from 160 pounds to 240 pounds per acre were

Table 10. Corn Yields in Bushels of Grain Per Acre (15.5% Moisture), Sand Experiment Field, 1959, Experiment I.

| Level of Nitrogen Lbs/A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 73.9 | 76.0 | 70.4 | 86.7 | 32.0 | 67.8 |
| 160 | 104.0 | 111.9 | 105.5 | 113.4 | 62.0 | 99.4 |
| 240 | 104.8 | 111.1 | 111.3 | 116.2 | 80.6 | 104.8 |
| Average | 94.2 | 99.7 | 95.7 | 105.4 | 58.2 | |

Significant difference at the 5% level
- Between two levels of nitrogen...................... 13.6
- Between two methods .......................... 6.5
- Between two methods, at the same level of nitrogen.... 11.3
- Between two levels of nitrogen, at the same method.... 18.3

not significant in four of the five methods of application, there was a trend in this direction.

The relationship between yields and percent nitrogen in the sixth leaf at tasseling stage was measured by the calculation of a regression coefficient. The calculated regression coefficient value was 5.3 or an average increase of 5.3 bushels of corn per 0.1% increase in nitrogen content of the sixth leaf. The correlation coefficient was .499, significant at the 6% level with 13 degrees of freedom.

Percentages of protein in the grain tended to increase with increasing rates of nitrogen with one exception (Table 11). The protein content of

Table 11. Percentage of Protein in Corn Grain as Affected by Nitrogen Treatments, Sand Experiment Field, 1959, Experiment I

| Level of Nitrogen Lbs/A | Source of Nitrogen and Number of Applications (Method) | | | | | |
|---|---|---|---|---|---|---|
| | Ammonium Nitrate | | Urea | | Urea-Formaldehyde | |
| | One Applic. | Five Applic. | One Applic. | Five Applic. | One Application | Average |
| 80 | 5.98 | 6.29 | 5.82 | 6.04 | 6.43 | 6.11 |
| 160 | 7.62 | 8.41 | 7.17 | 8.76 | 6.29 | 7.65 |
| 240 | 8.06 | 8.83 | 8.08 | 8.74 | 6.33 | 8.01 |
| Average | 7.22 | 7.84 | 7.02 | 7.85 | 6.35 | |

the grain from the three urea-formaldehyde treatments appeared to be about the same. An explanation for this lack of increase in protein has been given by Zuber, Smith, and Gehrke (5). They said that probably there would be substantial increases in percentage nitrogen in corn grain only where nitrogen is present in amounts above optimum.

### Experiment II

Neither nitrogen percentage in the sixth leaf at tasseling nor yields showed any significant differences related to treatment (Table 12). The

Table 12. Nitrogen Content of Corn Leaves at Tasseling and Yield of Corn, Sand Experiment Field, 1959, Experiment II.

| Sources of Nitrogen Sidedressed on June 26 at the Rate of 100 lbs N/A | Nitrogen Content of Leaves at Tasseling Time (July 14) % | Yield of Corn at 15.5% Moisture bu./A. |
|---|---|---|
| 48–0–0 * | 2.71 | 87.5 |
| 33–0–0 * | 2.65 | 89.4 |
| 16–8–8 | 2.78 | 85.9 |
| Least Significant Difference | Not Significant | Not Significant |

* Equivalent amounts of $P_2O_5$ and $K_2O$ were sidedressed on the first two treatments when 16-8-8 was sidedressed on the third treatment.

nitrogen content of the sixth leaf was high enough to indicate that there was enough nitrogen for higher yields had other conditions been better. However the lower leaves of the treatments with 16-8-8 containing urea-formaldehyde showed a deficiency of nitrogen while the other sources did not. The population of 19,000 stalks per acre at harvest was high enough to allow a much higher yield. The late planting date of June 1 no doubt prevented higher yields. There is some likelihood that lack of irrigation in June slowed down early growth of the corn.

## Summary

Urea-formaldehyde was compared with urea and with ammonium nitrate as a source of nitrogen fertilizer for irrigated corn. Two different experiments comparing these fertilizers were conducted on Coloma sand in northern Indiana in 1959. In one experiment no meaningful differences among treatments were obtained, probably because of the relatively low yields of less than 90 bushels per acre. In the other experiment average yields of the better treatments ranged from 104 to 116 bushels per acre.

In the latter experiment urea-formaldehyde was not as good as urea or ammonium nitrate as a nitrogen fertilizer. Both the average percentage of nitrogen in the sixth corn leaf at tasseling and the average yield of grain were significantly lower with urea-formaldehyde than with the other two nitrogen fertilizers. There was a definite trend for split applications of urea and ammonium nitrate to be better than a single application of the same total amount of nitrogen at planting. Percentage of nitrogen in the sixth corn leaf and yields of grain tended to increase from 80 to 240 pounds per acre of applied nitrogen fertilizer. However, only the increase in yield from 80 to 160 pounds per acre of nitrogen was large and significant.

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