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Greenhouse And Field Measurements Of Nitrogen Loss From A Sharkey Clay Soil As Influenced By Water-Logged Soil, Nitrogen Sources And Placement

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SUMMARY

In a greenhouse test a water-logged Sharkey clay soil lost all (150 ppm) of the applied nitrate nitrogen within a 16-day period.

A field experiment was conducted over a 4-year period to measure the influence of water-logged soil treatments, nitrogen sources and placement of these sources upon the amount of nitrogen loss from a Sharkey clay soil. The results of this experiment are listed below:

1. Nitrogen loss each year, from the non-water-logged soil was proportional to the amount of rainfall and mean temperature for the duration (20 days) of the experiment. The amount of nitrogen lost was greatest for the periods with the most rainfall and highest mean temperature.

2. Nitrogen loss, each year, from the continuously water-logged soil was proportional to the mean temperature for the duration (20 days) of the experiment. The amount of nitrogen lost was greatest for those periods with the highest mean temperature.

3. The 4-year average (nitrogen sources and placement averaged) nitrogen loss over a 20 day period from the non-water-logged soil was 45 pounds per acre compared to 92 pounds from the water-logged soil.

4. More nitrogen was lost from ammonium sulfate than from sodium nitrate in the non-water-logged soil. More nitrogen was lost from sodium nitrate when the soil was maintained under a water-logged condition.

5. Nitrogen loss was less when the nitrogen was placed 4 inches under the soil as compared to a surface application regardless of the water-logged soil condition and/or nitrogen sources. The greatest amount of nitrogen lost (118 pounds per acre) was from the water-logged soil where sodium nitrate was surface applied.

Greenhouse and Field Measurements of Nitrogen Loss From a Sharkey Clay Soil as Influenced by Water-Logged Soil, Nitrogen Sources and Placement of Nitrogen

By W. I. SPURGEON and P. H. GRISSOM[1]

The Mississippi Delta region of the state of Mississippi has about 70 percent of the total land in crop production. The soil types on which these crops are grown vary. However, about 45 to 50 percent of the total cropped area is Sharkey clay or very closely related soil types. Most of these soils have a very high clay content ranging from 30 to 60 percent. The predominate clay material is Montmorillinite. Practically all of these soils have poor internal drainage and usually have poor surface drainage.

The normal annual rainfall for the Mississippi Delta is 51.2 inches, with about 21 percent of this amount occurring from mid-March until mid-June. Frequent and extensive rainy periods may occur at any time during this period. The poorly drained clay soils may be subjected to water-logged conditions for periods of 5-20 days or more. A water-logged soil is saturated with water to the extent that practically all of the soil air is removed. These conditions may and usually do occur after nitrogen has been applied in Spring.

For several years nitrogen deficiency symptoms have been observed in cotton and corn growing on Sharkey clay and related soil types although the applied nitrogen was far greater than the crop could have used. Without exception the more severe nitrogen deficiency symptoms were observed following extensive rainy periods. It seemed apparent that nitrogen was being lost and that the loss was associated with rainfall.

Numerous laboratory studies have shown that nitrogen is lost from water-logged soils through the process of denitrification. In the absence of soil oxygen specific soil bacteria remove the oxygen from nitrate nitrogen. When oxygen is removed from the nitrates, a nitrogen gas is formed which is lost from the soil into the atmosphere. Nitrogen loss by this method is designated as denitrification.

The objectives of this study were to determine, by greenhouse and field experiments, the approximate nitrogen loss from a Sharkey clay soil as influenced by water-logged treatments, nitrogen sources and placement of nitrogen.

Greenhouse Experiment Procedure

In the greenhouse experiments the treatments were: (1) soil with no nitrogen and non-water-logged, (2) soil with 150 PPM (parts per million) of nitrogen and non-water-logged, and (3) soil with 150 PPM of nitrogen and water-logged. One part per million of nitrogen is equal to 2 pounds per acre. Four replications were used in all experiments. Air dried Sharkey clay soil (500 grams) was placed in quart milk containers. The soil moisture was adjusted to 45 percent with distilled water. Nitrogen as KNO_3 was applied in aqueous solution to individual soil containers. Appropriate treatments were water-logged with distilled water and maintained in this condition for a period of 20 days. The soil of the non-water-logged treatments was kept at a moisture level of 45 percent for the same period.

Soil samples from all treatments were analyzed for nitrate nitrogen after the nitrogen was added and before the water-logged treatments were initiated. Thereafter, soil samples were removed from each container of all treatments at 2-day intervals and analyzed for nitrate nitrogen.

Field Experiment Procedure

The field tests on Sharkey clay soil

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were conducted in August and September over a four-year period from 1957 through 1960. The experimental design was a split-split plot with 6 replications. The main plot treatments were (1) soil artificially water-logged for 10 and 20 days and (2) soil non-water-logged (with the exception of that which occurred through rainfall) for 10 and 20 days. The first sub-plots were nitrogen sources, sodium nitrate and ammonium sulfate. The second sub-plots were placement of nitrogen on the soil surface and drilled approximately 4 inches deep. The nitrogen was applied at the rate of 120 pounds of N per acre. The main plots were separated by double levees to control water on the water-logged plots and to prevent seepage of water into the non-water-logged plots.

After 10 days, plots water-logged for this period and the non-water-logged plots were sampled to a soil depth of 12 inches. A composite soil sample was obtained from 10 positions within each nitrogen placement plot by taking an equivalent number of samples from the band of nitrogen placement and midway between the bands of placement. After 20 days, the non-water-logged and 20-day water-logged plots were sampled by the same procedure. The soil samples were oven-dried at 55° C, ground to pass a 10-mesh screen and analyzed for ammonium and nitrate nitrogen. The amount of ammonium and nitrate nitrogen in the soil, plus the amount applied, minus that remaining after the 10- and 20-day periods was used to evaluate the nitrogen loss.

In 1957 soil samples from the 12- to 18-inch soil depth were analyzed for nitrate nitrogen to determine if any loss occurred by leaching. The small quantity (10-15 lbs./A) of nitrate nitrogen found below the 12-inch soil depth indicated that very little leaching had occurred. Denitrification is assumed to be the primary cause for nitrogen loss which occurred in the experiment.

Greenhouse Results

Figure (1) shows that the nitrogen loss was more rapid during the first 2 days after the soil was water-logged. The water-logged soil lost about 50 percent of the applied nitrogen during the first 2 days. The rate of nitrogen loss was rather consistent from the 2-12 day period and then decreased during the 12-16 day period. After 16 days all of the applied nitrogen had been lost, presumably by denitrification.

The nitrate nitrogen content of the non-water-logged soil with and without 150 PPM of nitrogen remained nearly constant throughout the 16-day period.

Field Experimental Results and Discussion

The field experiments were conducted each year from August 1 until September 31. The mean precipitation, at Stoneville Mississippi, (30 years), for this 60-day period from August 1 through September 31, is 2.77 inches. The mean temperature for the same period is 78.4 degrees Fahrenheit. This period of low normal rainfall was selected to partially eliminate the variation in nitrogen loss, from soil of the non-water-logged plots as influenced by soil water-logged from rain. The rainfall for the 20-day periods (duration of the experiment each year) was 7.20, 6.68, 3.55, and 2.37 inches in 1957, 1958, 1959, and 1960, respectively. Figure 2A shows the influence of rainfall on the nitrogen loss from soil of the non-water-logged plots. The nitrogen loss over a 20-day period from the non-water-logged soil was almost directly proportioned to the amount of rainfall. One exception occurred in 1957 when the lower mean temperature influenced the amount of nitrogen loss was less in 1957 than in 1958 because of the lower mean temperature.

Figure 2B illustrates influence of the mean temperature for the 20-day period on the nitrogen loss from soil of the water-logged plots. The mean temperatures for the 20-day periods were 75.8,

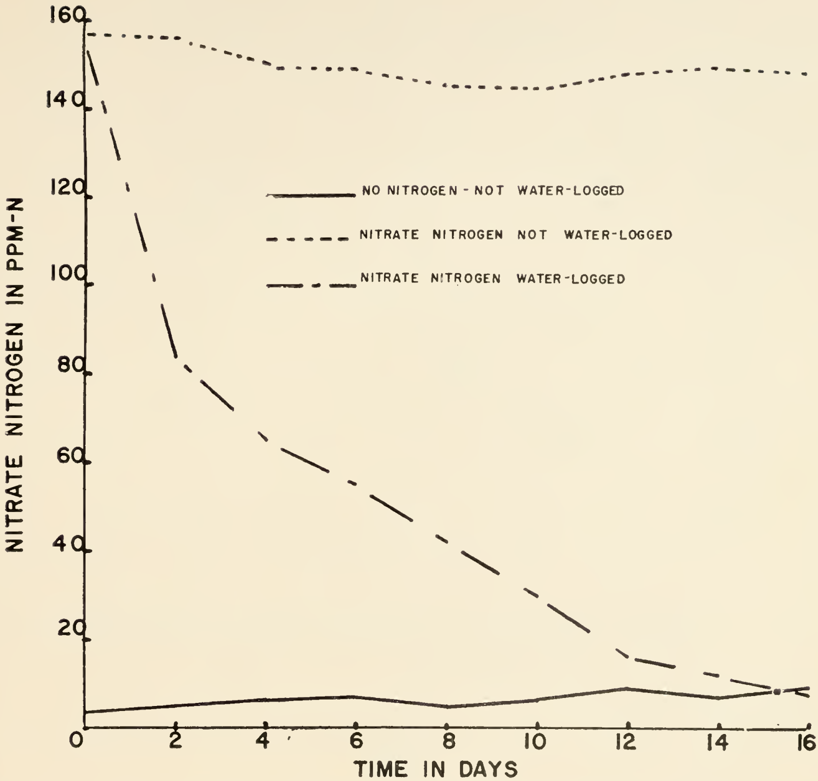


Figure 1. The influence of water-logged soil on the nitrogen loss from a Sharkey clay soil (average of 3 greenhouse experiments).

82.6, 80.1, and 71.3 for the years 1957, 1958, 1959, and 1960, respectively. Nitrogen loss from soil of the water-logged plots increased as the mean temperature increased (Figure 2B).

Nitrogen loss from a Sharkey clay soil as influenced by water-logged soil treatments is shown in Table 1. Nitrogen loss from soil of the non-water-logged plots was proportional to the amount of rainfall and mean temperature during the 10-day and 20-day periods. In 1957 most of the 7.20 inches of rain came during the second 10-day period. The nitrogen loss for the first 10 days was only 10 pounds per acre as compared to 41 pounds during the second 10 days. The rainfall pattern was reversed in 1958 with most of the 6.68 inches occurring during the first 10 days. The nitrogen loss was 55 pounds per acre the first 10 days and only 6 pounds the second 10 days.

As previously mentioned the nitrogen loss from soil of the water-logged plots was proportional to the mean temperature. The experiment was conducted during August in 1958 and 1959 and in September for the years of 1957 and 1960. The mean temperature was higher during the first 10 days when the experiment was conducted in August with greater nitrogen loss occurring during this 10-day period. The loss for the 20-day period was higher during 1958 and 1959 because of the higher mean temperature.

The 4-year average shows that the ni-

FIGURE 2A - EFFECT OF RAINFALL ON THE NITROGEN LOSS FROM A SHARKEY CLAY SOIL (NON-WATER-LOGGED PLOTS).

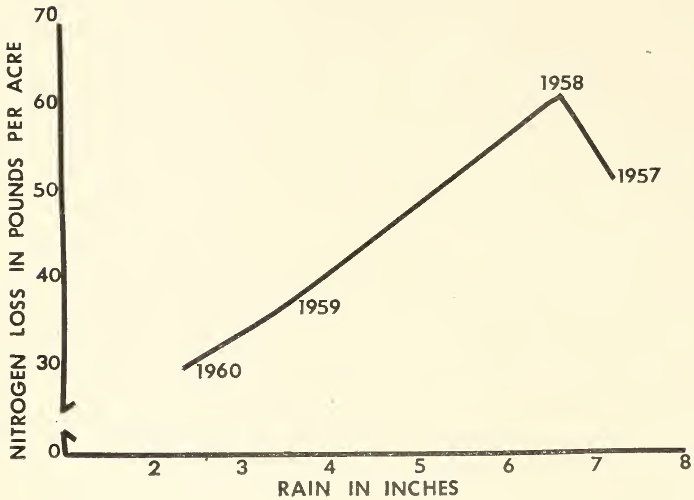
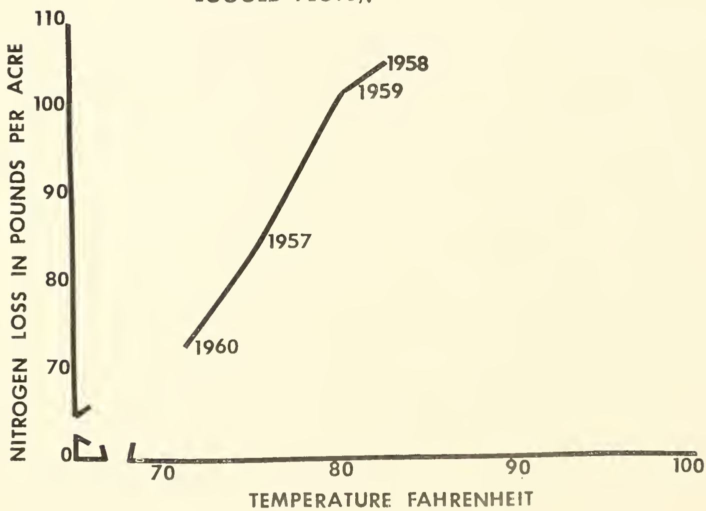


FIGURE 2B - EFFECT OF TEMPERATURE ON THE NITROGEN LOSS FROM A SHARKEY CLAY SOIL (WATER-LOGGED PLOTS).



trogen loss from soil of the water-logged plots was twice that of the loss from soil of the non-water-logged plots.

Nitrogen loss as influenced by two sources of nitrogen is shown in Table 2. The four-year averages for both 10- and 20-day periods, show very little difference between ammonium sulfate and sodium nitrate with respect to the amount of nitrogen lost from the non-water-logged soil. There was more variation in the degree of nitrogen loss between years with

Table 1.—Nitrogen loss from a Sharkey clay soil as influenced by water-logged soil treatments (Nitrogen sources and placement averaged).

Year	10-Day period		20-Day period	
	Not water-logged[1]	water-logged	Not water-logged	water-logged
	Lbs./A of ammonium plus nitrate nitrogen lost			
1957	10	32	51	85
1958	55	68	61	105
1959	28	97	37	102
1960	14	52	30	73
4-year average	27	63	45	92

[1]Not water-logged with the exception of that occurring through rainfall.

Table 2.—Nitrogen loss from a Sharkey clay soil affected by 2 nitrogen sources (nitrogen placement treatments averaged).

Year	10-Day period				20-Day period			
	Not water-logged		water-logged		Not water-logged		Water-logged	
	Ammonium sulfate	Sodium nitrate	Ammonium sulfate	Sodium nitrate	Ammonium sulfate	Sodium nitrate	Ammonium sulfate	Sodium nitrate
	Lbs./A of ammonium plus nitrate nitrogen lost							
1957	22	0	29	36	53	50	81	89
1958	34	76	45	81	39	82	87	122
1959	47	10	105	89	63	11	98	106
1960	25	4	38	67	36	24	58	87
4-yar avg.	32	22	55	71	48	42	81	101

Table 3.—Nitrogen loss from a Sharkey clay soil as influenced by nitrogen placement on the soil surface vs drilled about 4 inches deep. (Nitrogen sources averaged).

Year	10-Day period				20-Day period			
	Not water-logged		Water-logged		Not water-logged		Water logged	
	Surface	Drilled	Surface	Drilled	Surface	Drilled	Surface	Drilled
	Lbs./A of ammonium plus nitrate nitrogen lost							
1957	17	4	39	26	69	33	99	71
1958	79	31	96	40	80	41	109	100
1959	29	28	96	97	38	36	111	92
1960	41	0	97	7	61	0	117	29
4-year avg.	42	16	82	43	62	28	109	73

sodium nitrate as compared to ammonium sulfate. This variation in loss, between years from sodium nitrate was influenced by rainfall. The greatest loss occurred during the years with the highest rainfall.

When the soil was kept water-logged for 10 to 20 days, considerably more nitrogen was lost from sodium nitrate than from ammonium sulfate. When the soil was water-logged for 10 days the nitrogen loss from ammonium sulfate was 55 pounds of N per acre compared to 71 pounds from sodium nitrate. After 20 days the nitrogen loss from ammonium sulfate and sodium nitrate was 81 and 101 pounds per acre, respectively.

Nitrogen loss as influenced by placement of nitrogen on the soil surface vs an application drilled about 4 inches deep is shown in Table 3.

Nitrogen loss each year was greater from the surface than from the drilled application regardless of the water-logged condition of the soil.

The 4-year average nitrogen loss from the non-water-logged soil was 42 pounds of N per acre when the nitrogen was surface applied and 16 pounds when drilled. After 20 days the nitrogen loss for the surface and drilled application was 62 and 28 pound of N per acre, respectively.

When the soil was maintained under a water-logged condition for 10 days the 4-year average nitrogen loss was 82 pounds of N per acre from the surface applied nitrogen and 43 pounds from the drilled application.

Where the soil was water-logged for 20 days the average nitrogen loss from the surface applied nitrogen was 109 pounds of N per acre compared to 73 pounds from the drilled application.

The amount of nitrogen lost was greater from the surface than from the 4-inch depth of application regardless of water-logged treatments and nitrogen sources as shown in Table 4.

Where the soil was not water-logged, except by rain, more nitrogen was lost from surface applied ammonium sulfate than from sodium nitrate applied in the same manner. The reason for the greater nitrogen loss from surface applied ammonium sulfate than from similarly applied sodium nitrate can not be explained. However, some ammonium fixation by this soil could have occurred when the soil surface dried after each rainfall. Some loss as ammonia may have occurred through volitilization of surface applied ammonium sulfate. After a 10-day period the nitrogen loss was about equal for ammonium sulfate and sodium nitrate applied 4 inches under the soil surface. At the end of 20 days the nitrogen loss from sodium nitrate was about twice that from ammonium sulfate when both nitrogen sources were applied 4 inches under the soil surface.

When the soil was maintained in a water-logged condition for periods of either 10 and/or 20 days the nitrogen loss from sodium nitrate was greater than from ammonium sulfate regardless of the method of placement.

Under field conditions most of the nitrogen loss in the clay soils will occur from the time of nitrogen applications or from about April 1 until July 1. Anytime during this 3-month period, the quantity and distribution of rain may be sufficient to keep clay soils water-logged for extensive periods. If rainfall does water-log these clay soils, the amount of applied nitrogen that is lost through denitrification will be proportional to the length of time that the soil is water-logged and the temperature. As the mean temperature increases, nitrogen loss from the water-logged soil also increases. Most of the nitrogen losses may occur rapidly during 1 or 2 extensive wet periods and/or gradually during several shorter wet periods. Generally, the nitrogen losses increase with an increase in total rainfall and an increase in mean temperature.

At present there are no direct measures to avoid loss of nitrogen through denitrification in water-logged clay soils. The loss can be reduced by proper nitrogen placement. The nitrogen should be applied under the soil surface about 4-8 inches deep. As a preventive measure, it is suggested that farmers apply nitrogen to these clay soils in a split application. Approximately 50-60 pounds of nitrogen could be applied at planting and 50-60 pounds as an early side-dressing after the cotton has been thinned. There is no assurance that the nitrogen applied as a split-application will not be lost but the interval during which losses may occur is reduced by this method of application. Nitrogen deficiency symptoms of plants growing in these soils, between the time of the side-dress application and early plant maturity indicate that the nitrogen has been lost. Additional nitrogen may be applied to cotton to correct this deficiency but should not be applied later than mid-July.

Table 4.—Nitrogen loss from a Sharkey clay soil as influenced by water-logged treatments, 2 nitrogen sources, and 2 methods of nitrogen placement. (4-year average).

Nitrogen source and placement	10-Day period: Not-water-logged	10-Day period: Water-logged	20-Day period: Not-water logged	20-Day period: Water-logged
Ammonium sulfate-surface	52	78	77	100
Ammonium sulfate-drilled 4"	12	31	19	64
Sodium nitrate-surface	31	86	48	118
Sodium nitrate-drilled 4"	14	55	36	83