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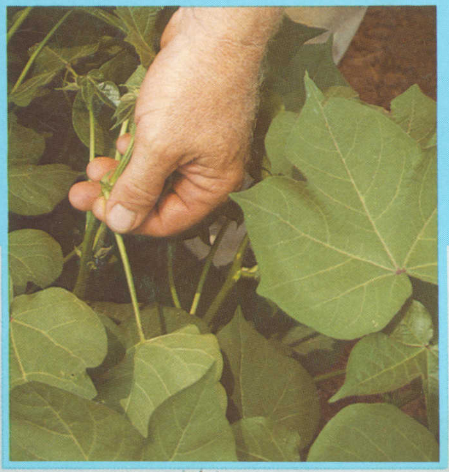
Nitrogen Fertilizer Rates and Cotton Petiole Analysis in Alabama Field Experiments



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NITROGEN FERTILIZER RATES AND COTTON PETIOLE ANALYSIS IN ALABAMA FIELD EXPERIMENTS

J. T. Touchton, Fred Adams, and C. H. Burmester [1]

INTRODUCTION

THE AMOUNT of fertilizer nitrogen (N) needed to produce economical, as well as maximum, yields of cotton has been researched continuously by the Alabama Agricultural Experiment Station for more than 50 years. A major objective of this research has always been to supply an adequate, but not excessive, amount of N to the crop. An inadequate N supply, particularly during fruiting, results in a low yield. An excessive N supply may also result in a low yield, because it can cause excessive vegetative growth and delayed maturity, which increases problems from insects, boll rot, and lodging.

In determining the optimum rate of fertilizer N for cotton production, the contribution of soil N to the crop must be considered. Soil N consists of that from residual fertilizer and that contained in the organic matter. Most soil N is contained in the organic matter, from which only a fraction is converted into a plant-available form during the growing season. Predicting that amount which becomes available, however, is not simple, because it is influenced by such factors as soil characteristics, rainfall, temperature, and previous cropping system. There is also the problem of N losses from the soil. This occurs through the actions of leaching, denitrification, and volatilization. Unfortunately, these losses cannot be predicted, and they differ considerably from year to year because of their dependence on soil characteristics and climatic factors.

Because of the influence that climate has on the release of N from organic matter and on N losses from the soil, a N rate that is optimum one year may be deficient or excessive in another year. The purpose of adding fertilizer N, of course, is to compensate for the lack of available soil N needed for optimum

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yield. Since available soil N is not predictable because it is an integrated result of several climatic variables, the most reliable means of determining the amount of fertilizer N needed is by field experiments in which several rates of N are used over many years. In this way, the effect of climate is averaged, and practical recommendations of N rate can be made. In Alabama, recommended N rates for cotton are based on yield responses to N from scores of experiments throughout the State. Results have shown that the optimum rate of N for most Alabama soils is 60 to 90 pounds per acre.

Because the need for fertilizer N varies from year to year and field to field, a form of tissue testing, known as petiole analysis, has been proposed as a method of identifying N deficiencies and excesses early enough during the flowering period that corrections can be made. Any successful tissue-testing program for N is based on the following tenets: (1) it must identify a N deficiency due to a lack of N and not due to some environmental factor, (2) the tissue sample truly represents the field from which it was taken, and (3) application of fertilizer N will correct the deficiency and increase yield.

LITERATURE REVIEW

Tissue testing as a guide for nutrient requirements is not new. It has been used off and on for about 150 years. A key to successful tissue testing is to choose the plant part that will best indicate the plant's nutrient status. The use of cotton petioles for assessing N needs was first suggested by Joham *(7)* at the Texas Agricultural Experiment Station. His suggestion was based on laboratory and greenhouse studies. Since Joham's suggestion of 30 years ago, several researchers have attempted to use cotton-petiole analysis as a guide for determining the N status of field-grown cotton. Unfortunately, not much in the way of successful application has been reported in scientific journals.

MacKenzie et al. *(8)* in California were probably the first to report on the relationship between fertilizer N and petiole-nitrate levels of field-grown cotton. They conducted several experiments between 1953 and 1960 with irrigated cotton in the San Joaquin Valley of California. Ammonium nitrate was applied at rates ranging from 0 to 300 pounds per acre of N; one-third was applied at planting and two-thirds as a sidedressing. They found that both yield and petiole-nitrate content increased with increasing N rates. They also reported that 10,000, 8,000, and 2,000 ppm nitrate-N in the petiole were critical levels for adequate N in the early-, mid-, and late-bloom stages, respectively, i. e., lower nitrate levels generally resulted in lower yields. They did not, however, apply N when nitrate levels dropped below the critical points to determine if the deficiencies could be corrected by a soil or foliar application of fertilizer.

Similar studies have since been conducted in Arizona by Gardner and Tucker *(5)*, in Egypt by Amer and Abuamin *(1)*, in Oklahoma by Baker et al. *(3)*, in California by Grimes et al. *(6)*, in Arkansas by Maples et al. *(9)*, and in Texas by Sunderman et al. *(13)*. The most important characteristics of all these studies were: (1) each was conducted with irrigated cotton, (2) each suggested that petiole-nitrate levels were related to the N status of a cotton plant, and (3) no fertilizer N was applied to verify a suspected N deficiency in the petiole tissue.

There have also been several experiments conducted in recent years in the Delta and Southeast, the results of which are not published, in which efforts were made to relate the crop's N status to petiole-nitrate content. Most of these were on fields where natural rainfall was the only water source. Field trials at the Louisiana Agricultural Experiment Station, Mississippi Agricultural Experiment Station, and the South Carolina Agricultural Experiment Station have failed to demonstrate a consistent relationship between petiole-nitrate content and the N status of a cotton crop.

Research with foliar-applied N on cotton has also been conducted in recent years in Mississippi, Louisiana, Missouri, Arkansas, and South Carolina, most of which remains unpublished. In general, the data show that foliar-applied N is an effective fertilizer source if applied early enough. Although the root system is the natural plant organ for nutrient absorption, it has been known for many years that leaves are also efficient nutrient absorbers. This was demonstrated in field experiments with N for cotton by Anderson *(2)* in Mississippi. He showed cotton leaves to be very effective absorbers of foliar-applied N fertilizer. He did not, however, monitor petiole nitrate during those experiments.

In a field experiment with low rates of foliar-applied N, Roth et al. *(11)* in Missouri used both nitrate and phosphate levels of cotton petioles as predictors of the need for N fertilizer. Petioles sampled on July 19 and July 27, 1977, showed that N was deficient (according to the standard used in Arkansas). Subsequent foliar applications of N at the rate of 4.5 pounds per acre on August 4 and again on August 11 failed to increase either yield or nitrate level in the petiole. In two subsequent experiments, Roth and Barton *(11)* found, once again, that foliar-applied urea had no effect on cotton yield. Unpublished 1979 and 1980 data of Lawrence Harvey of Clemson University in South Carolina (personal communication) also showed that foliar-applied urea, when used in response to a low petiole-nitrate level, failed to affect yield or subsequent levels of petiole nitrate.

Baker et al. *(3)* in Oklahoma and Sunderman et al. *(13)* in Texas both concluded from their experiments that by the time that N deficiency had been clearly identified through petiole analysis, it would be too late to correct the deficiency for that crop. Thus, petiole analysis was useful only for the succeeding crop.

The recent widespread interest among growers in petiole analysis as a practical tool for predicting fertilizer-N needs of cotton has been due largely to the efforts of Arkansas agronomists *(4, 9)*. They currently have a very active cotton-petiole-analysis program, which is recommended by the Arkansas Cooperative Extension Service. Their objective appears to be to help farmers avoid the use of excessive N fertilizer and its concomitant lower yields because of excessive vegetative growth.

The Arkansas program for N fertilization of cotton is based on a combination of soil N levels prior to planting and on petiole analyses during the growing season *(9)*. Residual soil N levels are determined on soil samples taken prior to planting, and these are then used to determine the preplant N fertilizer rate. If petiole analysis subsequently indicates a N deficiency prior to the third week of blooming, an additional soil N application is recommended. If N deficiency is indicated after the third week of blooming, a foliar application of urea is recommended.

Because dry weather causes low petiole-nitrate levels regardless of N status, Maples et al. (9) suggest that both nitrate and phosphate levels of the petioles be used for determining whether N is needed. This concept is based on the theory that when both nitrate and phosphate levels are low, insufficient moisture, and not N deficiency, is the reason for low petiole nitrate. If, however, nitrate is low while phosphate is high, N is deficient and should be applied. Additional field validation is needed for this concept.

There is also a recommendation that boron be foliar applied if petiole nitrate becomes "too high". This is based on the theory that extra B would create a greater demand in the leaves for the petiole nitrate by translocating sugar out of the leaves. However, there is still no conclusive evidence that boron is directly implicated in sugar translocation in plants (10). If a soil is boron deficient, of course, this element should be applied, just as any other deficient nutrient should be.

In an effort to assess the feasibility of a cotton-petiole-analysis service to Alabama growers, the Agricultural Experiment Station initiated field experiments on the subject in 1978. The major objective was to determine if petiole analysis during the growing season could be used to measure the actual N status of the cotton crop.

MATERIALS AND METHODS

During 1978-1980, 18 nitrate-petiole experiments were conducted at the following sites in Alabama: Prattville Experiment Field, Tennessee Valley Substation, Sand Mountain Substation, and on several farmers' fields in the Tennessee Valley. The best known production practices for nonirrigated cotton were used at each location. Soil pH was above 6.0 and soil P and K levels were in the "high" range. To ensure a range in available N levels, N rates of 0, 30, 60, 90, and 120 pounds per acre were applied prior to planting. Treatments were replicated four times.

Petiole sampling was initiated when the tenth-leaf development predominated throughout all treatments. To maintain consistency, all samples were collected between 10 a. m. and

2 p. m. After sampling, the petioles were dried at 70°C and ground to pass an 80-mesh sieve. A 0.2-gram subsample from each sample was shaken with 20 milliliters of distilled water for 30 minutes and filtered. Nitrates in the filtrate were determined by reduction and steam distillation.

RESULTS AND DISCUSSION

Results of 18 field experiments conducted during the 3-year period, 1978-1980, are shown in figures 1-18. Data include petiole-nitrate levels by dates, "critical" petiole-nitrate levels by dates shown with shaded area (according to the Arkansas standard), seed-cotton yields, and rainfall data where available. Seed-cotton yields ranged from a low of 600 to more than 3,000 pounds per acre, primarily because of rainfall differences.

Tennessee Valley Substation, Belle Mina, figures 1, 2, 3. An experiment with five rates of preplant N fertilizer was conducted on a Decatur silt loam. Maximum yield was achieved with a 30-pound N rate each year. In 1978, figure 1, petiole-nitrate levels remained below the critical value throughout the test period for all except the highest N rate of 120 pounds per acre at two sampling dates, July 17 and August 7. The crop suffered from drought through most of the season. In 1979, figure 2, a 5-inch rain on July 22 greatly increased petiole-nitrate levels. Prior to the rain, petiole nitrates for the three lowest N rates were below the critical level. The 30-pound N rate exceeded the critical petiole-nitrate level at only two sampling dates, July 30 and August 6. In 1980, figure 3, the pattern of petiole-nitrate contents was intermediate between 1978 and 1979 values. There was a petiole-nitrate response to a July 24 rain, but the 30-pound N rate maintained petiole nitrate considerably below the critical value throughout the season. This 3-year experiment showed that the petiole content of the 30-pound N rate, optimum rate, was less in 1978 than the no-N rate (deficient rate) in 1979 at similar sampling dates. Such conflict in data precludes the establishment of a valid critical value for petiole-nitrate levels.

Prattville Experiment Field, Prattville, figures 4, 5, 6. An experiment with five N rates, all applied preplant, was conducted on a Lucedale sandy loam. The crop suffered from drought stress each year, and maximum yield was achieved from the 30-pound N rate. In 1978, figure 4, petiole nitrate never reached the lower critical level until late August at any N rate. Furthermore, petiole-nitrate levels of the no-N rate (N deficient) were as high as the 30-pound rate, N sufficient. In 1979, figure 5, petiole nitrate responded positively to rainfall during July, but the 30-pound N rate (optimum rate) never reached the critical level. In 1980, figure 6, the drought was more severe and yields were lower, but petiole-nitrate levels were generally higher than in 1978. Data from the 3 years are too variable to be used to define a critical petiole-nitrate level for maximum yields.

Sand Mountain Substation, Crossville, figures 7, 8. An experiment with five N rates, all applied preplant, was conducted on a Hartsells fine sandy loam. Maximum yield was achieved with a 60- or 90-pound N rate. In 1978, figure 7, the 60-pound N rate, optimum, failed to lift petiole nitrate to the critical level for any of the four sampling dates. In 1979, figure 8, petiole-nitrate levels responded greatly to July rains but were below the critical levels after August 13 for the 60- and 90-pound N rates, optimum. These data fail to identify a critical petiole-nitrate level for maximum yield. Petiole-nitrate levels that were adequate in 1978 proved to be deficient in 1979.

G. E. Barring farm, Lauderdale County, figure 9. An experiment in 1978 on an Etowah silt loam showed that maximum yield was achieved with a 90-pound rate of preplant-applied N. However, all N rates supported petiole-nitrate levels well below the critical levels throughout the season. Rainfall data were not collected.

Sykes Martin farm, Lawrence County, figures 10, 11. Experiments were conducted on a Decatur silt loam with four rates of preplant-applied N in 1979 and with five rates in 1980. In 1979, figure 10, all petiole-nitrate levels were below the critical value for all N rates after July 17, yet yields indicated that none was N deficient. Rainfall data were not collected. In 1980, figure 11, optimum N rate was 60 pounds per acre, but only at the no-N rate was petiole nitrate below the critical level. The 2 years of data on this farm showed unbelievable differences in petiole-nitrate levels of N-sufficient plants. Still, yields were about the same both years. This marked difference in petiole-nitrate level is not readily rationalized.

Don Newbern farm, Lauderdale County, figures 12, 13. A 2-year experiment on a Bewleyville silt loam was conducted with four N rates in 1979 and five in 1980. In 1979, figure 12, the optimum N rate was 30 pounds per acre. Yet, all N rates showed petiole-nitrate levels well below the critical level for almost the entire growing season. Rainfall data were not collected. In 1980, figure 13, maximum yield was achieved by the no-N rate; yet, it had petiole-nitrate levels below the critical level for most of the season. In addition, foliar applications of urea at 10 pounds per acre of N were made when petiole analysis suggested N was deficient. These applications failed to affect yield or petiole-nitrate levels. The remarkably different petiole-nitrate patterns for the 2 years preclude any conclusion relative to N deficiency and petiole nitrate at any time during the season.

Hollis Isbell farm, Colbert County, figure 14. A 1980 experiment with three rates of preplant N fertilizer on a Decatur silt loam showed that the optimum N rate was zero. Petiole-nitrate content of this treatment remained above the critical level for most of the season. There was a strong, positive response in petiole nitrate to a July 22 rain.

Sam Harris farm, Madison County, figure 15. A 1980 experiment with four rates of preplant N fertilizer on a Decatur silt loam showed that the optimum fertilizer-N rate was zero. In spite of that, all petiole-nitrate levels were below the critical level at every sampling date for each N rate. This contrasts starkly with results on the Isbell farm on the same soil type, figure 14, where petiole nitrate was much higher, but yields were somewhat lower.

Tennessee Valley Substation, Alfalfa Rotation, 1979-1980, figures 16-18. In an experiment on Decatur silt loam, in which cotton followed alfalfa, petiole-nitrate levels in 1979 followed the rainfall pattern, rising very sharply after a 5-inch rain in July, figure 16. However, the optimum N rate for maximum yield was zero, but the petiole-nitrate level never reached the sufficiency range at any sampling date. Even though the 60- and 90-pound N rates were excessive and reduced yields, petiole nitrates were indicating a N deficiency in mid-July. In

1980, the optimum N rate for maximum yield following alfalfa was 60 pounds per acre in two separate experiments, figures 17, 18, yet petiole-nitrate levels were within the deficient range at all N rates and all dates, with one exception.

Two Extremes in Petiole Nitrates, figure 19. The unreliability of petiole-nitrate levels to predict N needs of a cotton crop is illustrated in figure 19 by data taken from figures 4 and 11. In the Prattville experiment, petiole-nitrate levels predicted a N deficiency at every sampling date when there was no deficiency. In the Martin experiment, petiole-nitrate levels predicted a N sufficiency at every sampling date when there was actually a deficiency of N for maximum yield.

The most remarkable thing about these 18 experiments was the poor yield responses to N fertilizer. Three produced maximum yield with no N fertilizer, seven needed 30 pounds of N, three needed 60, and one needed 90. Some of this poor response was undoubtedly due to dry growing conditions, but a major portion was apparently because of a buildup of available soil N through a high fertilization program in previous years.

Another outstanding feature of these data was the obvious contradictions in predicted N needs according to petiole-nitrate contents. Even where fertilizer N failed to affect yield, figures 6, 13, 14, 15, petiole nitrate predicted a N deficiency at each sampling date after July 8 in three of the four experiments. Where the 30-pound-N rate was optimum, petiole nitrate showed a N deficiency at every sampling date in four experiments, figures 1, 3, 4, 5; in all but one sampling date in two experiments, figures 10, 12; and in all but two sampling dates in one experiment, figure 2. Where the 60-pound-N rate was optimum, petiole-nitrate predicted a N deficiency at each sampling date in one experiment, figure 7; in all but four sampling dates in one, figure 8; and at no sampling date in one, figure 11. In the one experiment where the 90-pound-N rate was optimum, petiole nitrate predicted a N deficiency at each sampling date, figure 9.

Where rainfall data at the test site were recorded, it is shown quite clearly that petiole-nitrate levels were a function of rainfall frequency and intensity. Except for one experiment, figure 9, petiole-nitrate levels did not steadily decrease with the passage of time, as predicted by the idealized deficiency curve. Instead, nitrate levels would often drop rapidly, followed by an abrupt increase after a rain that exceeded 0.5 to 1 inch. Striking nitrate increases following significant rainfalls are shown in figures 2, 3, 5, 8, and 14.

It appears that rainfall after August 1 had no stimulating effect on petiole nitrate, in contrast to the effect of July rains. This suggests that the erratic behavior of petiole-nitrate levels caused by uneven rainfall distribution occurs prior to peak bloom. According to Sunderman et al. *(13)* in a Texas study of irrigated cotton, a N deficiency must be corrected prior to peak bloom. Thus, dryland cotton growers are faced with an apparently unsolvable dilemma: N deficiency must be corrected before peak bloom, the same period during which nitrate levels of petioles are most subject to wide fluctuations because of rainfall patterns. Sunderman et al. *(13)* also concluded that by the time N deficiency was positively identified in north Texas through petiole analysis, it was too late to correct it for the current crop. Baker et al. *(3)* had previously reached the same conclusion for irrigated cotton in Oklahoma.

Petioles from the experiments reported here were not analyzed for phosphorus. However, petiole nitrate fluctuated too much for petiole phosphate to have made any difference in our conclusion that N needs were not predictable from petiole-nitrate levels.

CONCLUSION

The published research reports dealing with nitrate contents of cotton petioles during the fruiting stage have been primarily restricted to irrigated fields. Even where soil moisture can be maintained near optimum levels by irrigation, petiole monitoring of nitrates for predicting the need for a subsequent N fertilization has not been an unqualified success. As noted by Texas and Oklahoma researchers, by the time a N deficiency is identified through petiole analysis, it is too late to correct it.

Research on nonirrigated cotton in Alabama has shown that the nitrate content of petioles is very erratic. It varies greatly with changes in soil moisture, probably even more than it does with available N rates. Our data could not distinguish between low petiole nitrate due to low N supply and low petiole nitrate due to other factors, including moisture stress.

Cotton growers of Alabama are not likely to benefit from a cotton-petiole-nitrate monitoring service because of the erratic behavior of nitrate levels during the period that is essential for identifying a deficiency of N. The best fertilizer N program at present is to follow recommended N rates, which are based on years of results from field experiments. A promising program for the future may be a soil testing program in which available soil N will be measured. This program is yet to be proven.

ACKNOWLEDGMENT

This report also includes data obtained through the efforts of C. E. Scarsbrook, B. R.Bock, Alan Waggoner, W. B. Webster, Fred Glaze, John T. Eason, S. M. Eich, and J. G. Link.

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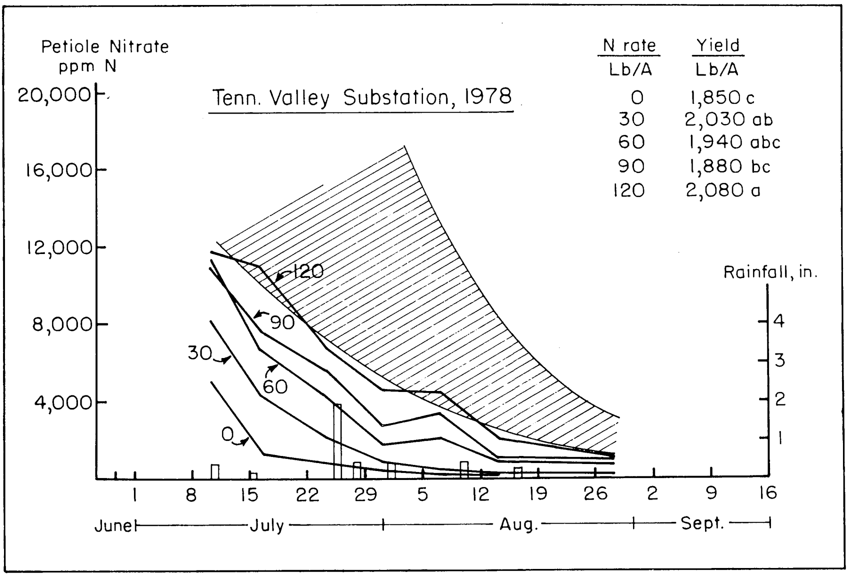
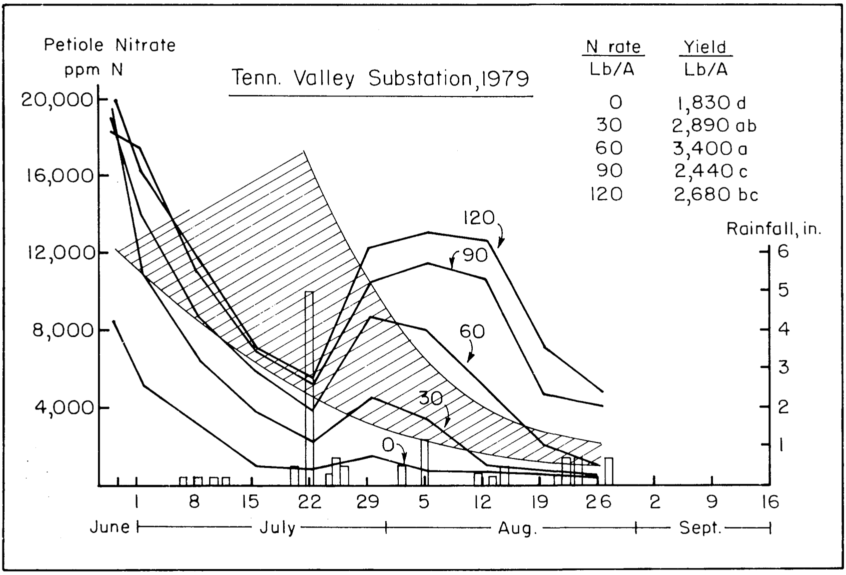
APPENDIX



N rate Lb/A	Yield Lb/A
0	1,850 c
30	2,030 ab
60	1,940 abc
90	1,880 bc
120	2,080 a

FIG. 1.



N rate Lb/A	Yield Lb/A
0	1,830 d
30	2,890 ab
60	3,400 a
90	2,440 c
120	2,680 bc

FIG. 2.

FIG. 1-18. Petiole-nitrate levels as affected by date of sampling and applied N rate. Fertilizer N rates and seed-cotton yields are shown in upper righthand corner. Rainfall data are shown as vertical bars. Numbers assigned to lines are fertilizer-N rates. The shaded area shows "critical" petiole-nitrate levels by dates according to the Arkansas standard.

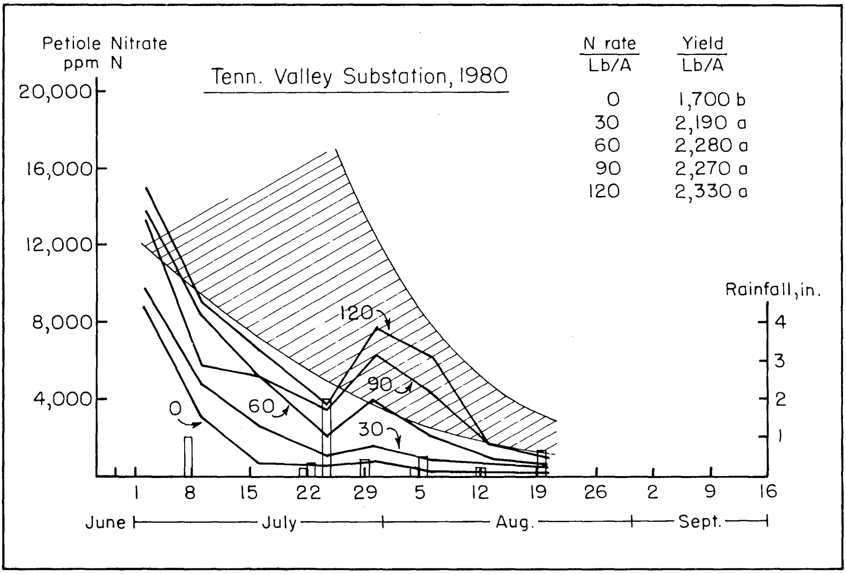

Petiole Nitrate
ppm N
Tenn. Valley Substation, 1980
20,000
16,000
12,000
8,000
4,000
N rate Lb/A
Yield Lb/A
0 1,700 b
30 2,190 a
60 2,280 a
90 2,270 a
120 2,330 a
120
90
60
30
0
Rainfall, in.
4
3
2
1
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 3.

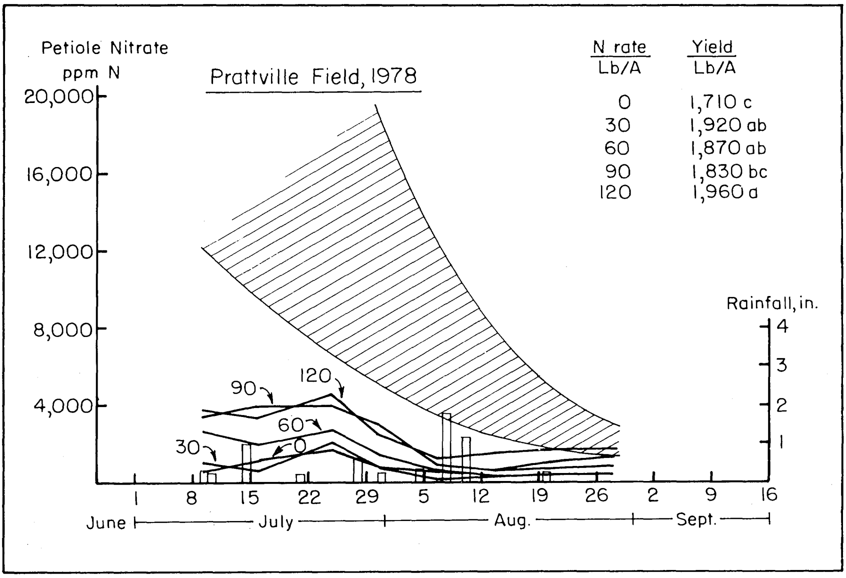

Petiole Nitrate
ppm N
Prattville Field, 1978
20,000
16,000
12,000
8,000
4,000
N rate Lb/A
Yield Lb/A
0 1,710 c
30 1,920 ab
60 1,870 ab
90 1,830 bc
120 1,960 a
120
90
60
30
0
Rainfall, in.
4
3
2
1
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 4.

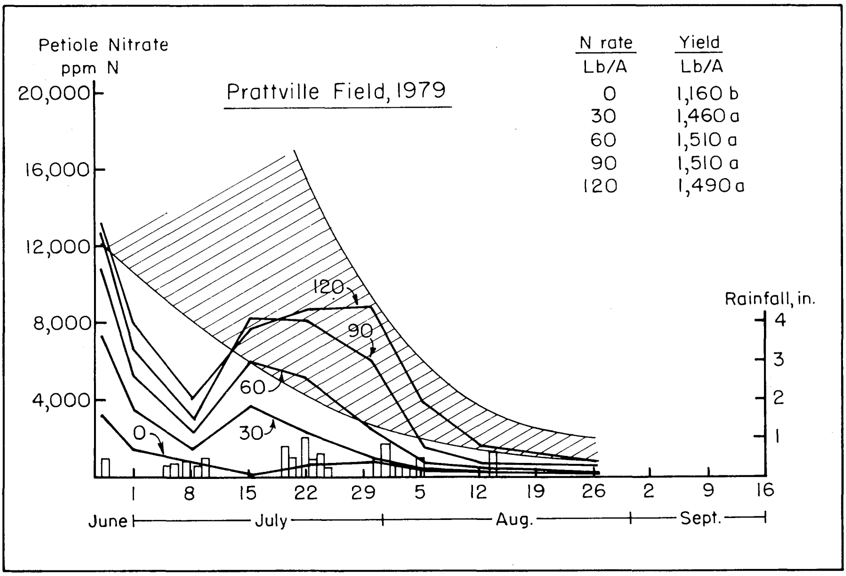

Petiole Nitrate
ppm N
Prattville Field, 1979
20,000
16,000
12,000
8,000
4,000
N rate Lb/A
Yield Lb/A
0 1,160 b
30 1,460 a
60 1,510 a
90 1,510 a
120 1,490 a
120
90
60
30
0
Rainfall, in.
4
3
2
1
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 5.

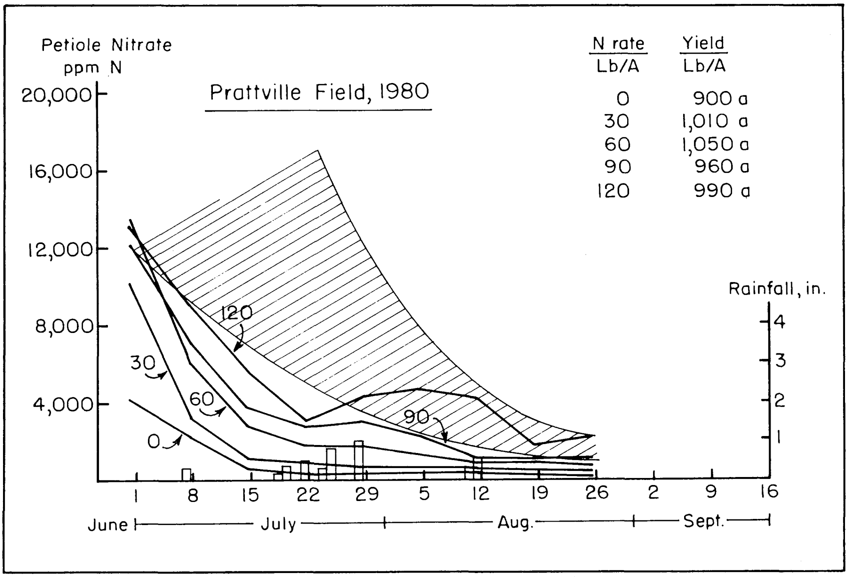

Petiole Nitrate
ppm N
Prattville Field, 1980
20,000
16,000
12,000
8,000
4,000
N rate Lb/A
Yield Lb/A
0 900 a
30 1,010 a
60 1,050 a
90 960 a
120 990 a
120
30
60
0
90
Rainfall, in.
4
3
2
1
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 6.

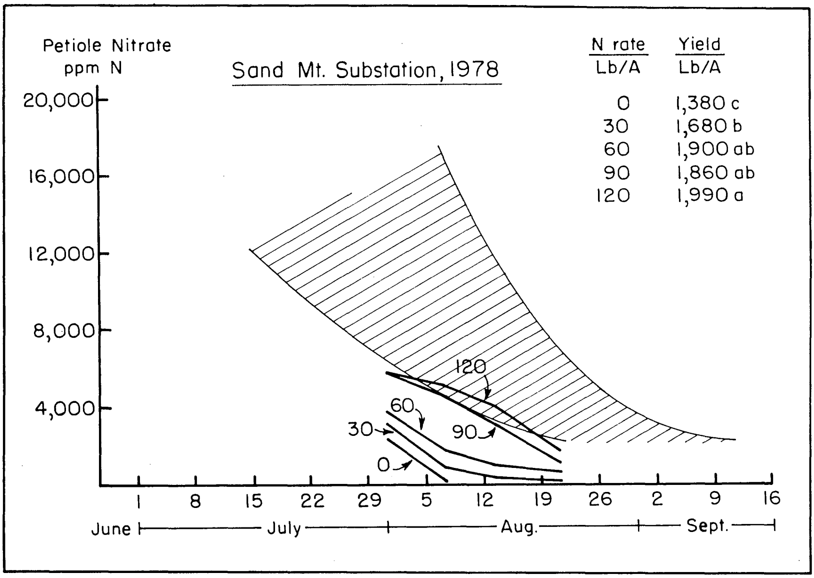

Petiole Nitrate
ppm N
Sand Mt. Substation, 1978
N rate Lb/A
Yield Lb/A
0 1,380 c
30 1,680 b
60 1,900 ab
90 1,860 ab
120 1,990 a
20,000
16,000
12,000
8,000
4,000
120
60
90
30
0
1 8 15 22 29 5 12 19 26 2 9 16
June July Aug. Sept.

FIG. 7.

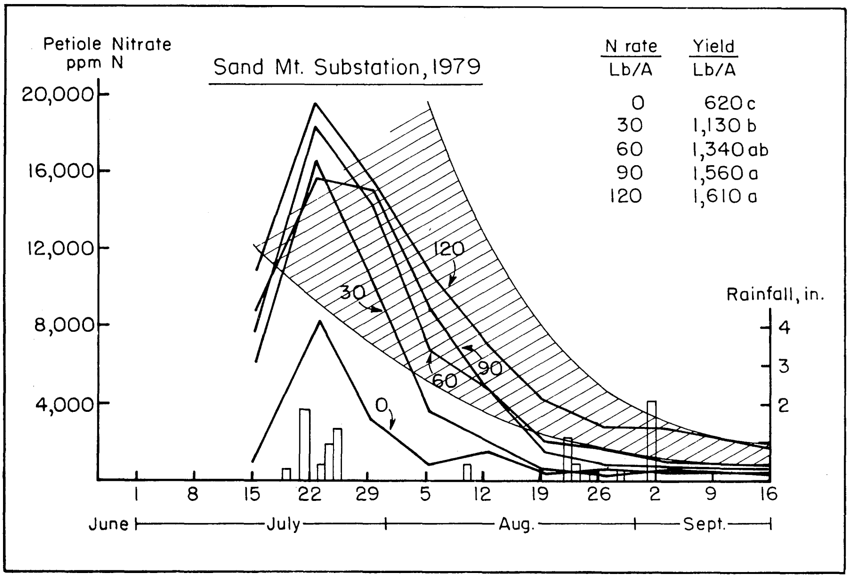

Petiole Nitrate
ppm N
Sand Mt. Substation, 1979
N rate Lb/A
Yield Lb/A
0 620 c
30 1,130 b
60 1,340 ab
90 1,560 a
120 1,610 a
20,000
16,000
12,000
8,000
4,000
120
30
60
90
0
Rainfall, in.
4
3
2
1 8 15 22 29 5 12 19 26 2 9 16
June July Aug. Sept.

FIG. 8.

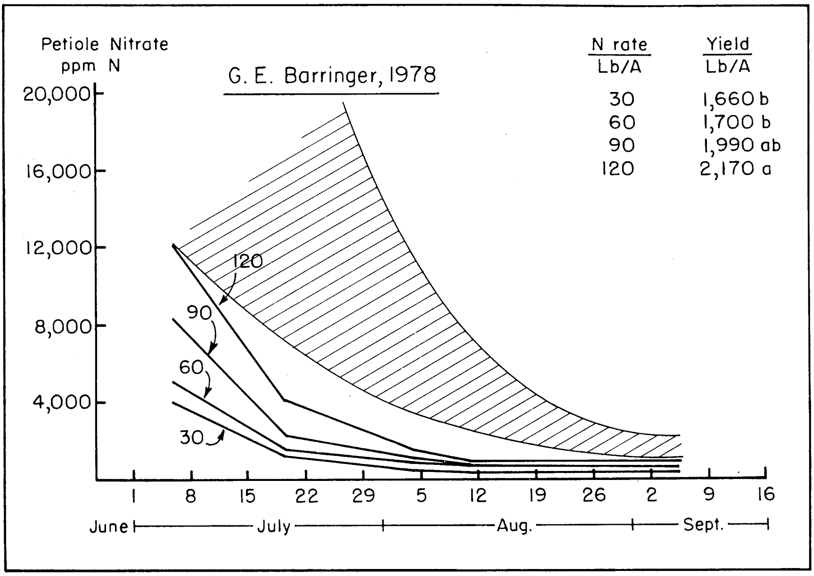

Petiole Nitrate
ppm N
G. E. Barringer, 1978
N rate Lb/A
Yield Lb/A
30 1,660 b
60 1,700 b
90 1,990 ab
120 2,170 a
20,000
16,000
12,000
8,000
4,000
120
90
60
30
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 9.

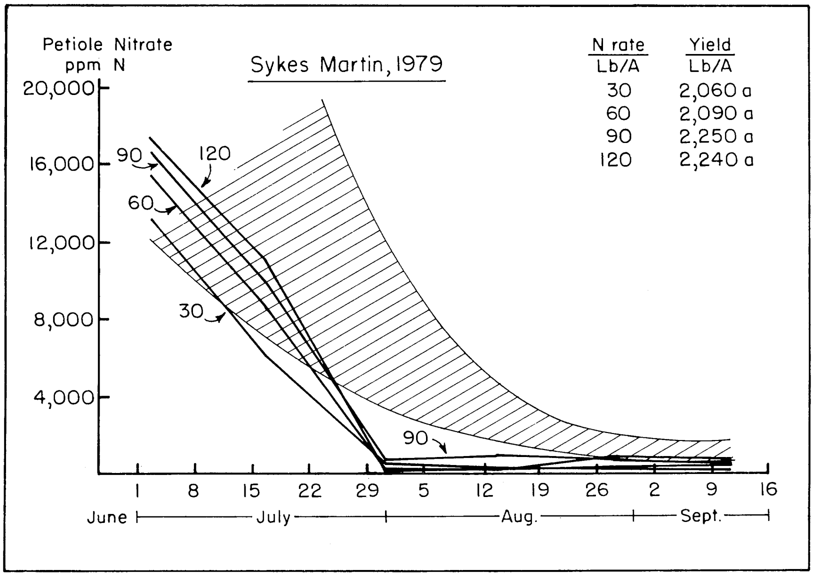

Petiole Nitrate
ppm N
Sykes Martin, 1979
N rate Lb/A
Yield Lb/A
30 2,060 a
60 2,090 a
90 2,250 a
120 2,240 a
20,000
16,000
12,000
8,000
4,000
90
120
60
30
90
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 10.

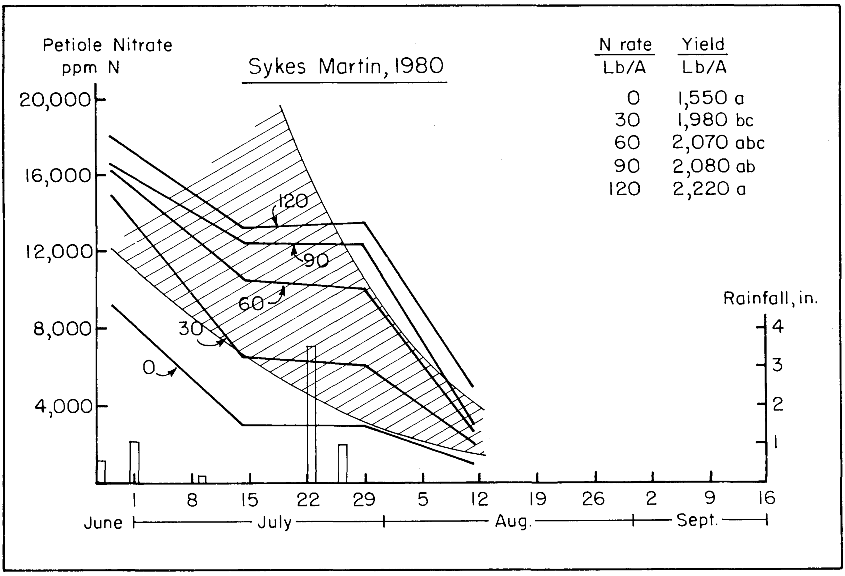

Petiole Nitrate
ppm N
Sykes Martin, 1980
N rate Lb/A
Yield Lb/A
0 1,550 a
30 1,980 bc
60 2,070 abc
90 2,080 ab
120 2,220 a
20,000
16,000
12,000
8,000
4,000
120
90
60
30
0
Rainfall, in.
4
3
2
1
1 8 15 22 29 5 12 19 26 2 9 16
June
July
Aug.
Sept.

FIG. 11.

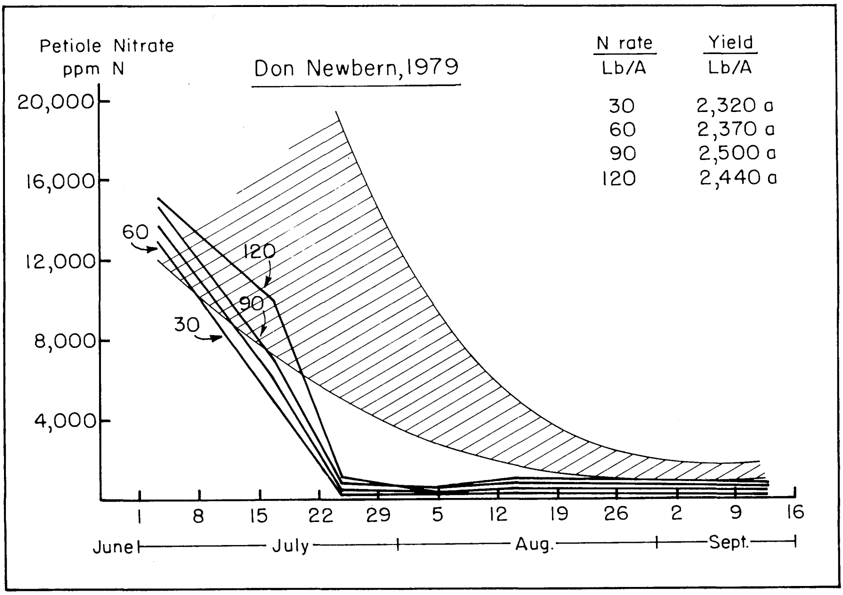

Petiole Nitrate
ppm N
Don Newbern, 1979
N rate Lb/A
Yield Lb/A
30 2,320 a
60 2,370 a
90 2,500 a
120 2,440 a
20,000
16,000
12,000
8,000
4,000
60
120
90
30
1 8 15 22 29 5 12 19 26 2 9 16
June
July
Aug.
Sept.

FIG. 12.

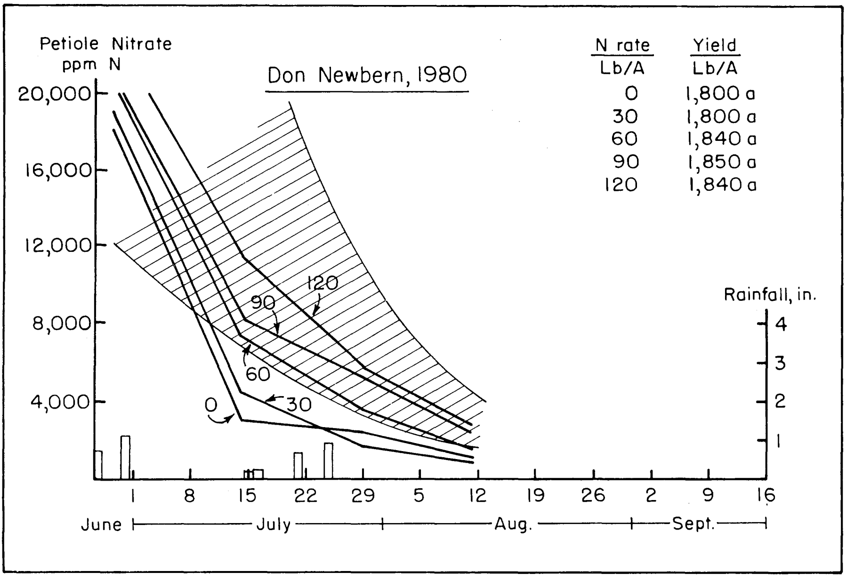

Petiole Nitrate ppm N
Don Newbern, 1980
N rate Lb/A
Yield Lb/A
0 1,800 a
30 1,800 a
60 1,840 a
90 1,850 a
120 1,840 a
20,000
16,000
12,000
8,000
4,000
120
90
60
30
0
Rainfall, in.
4
3
2
1
1 8 15 22 29 5 12 19 26 2 9 16
June July Aug. Sept.

FIG. 13.

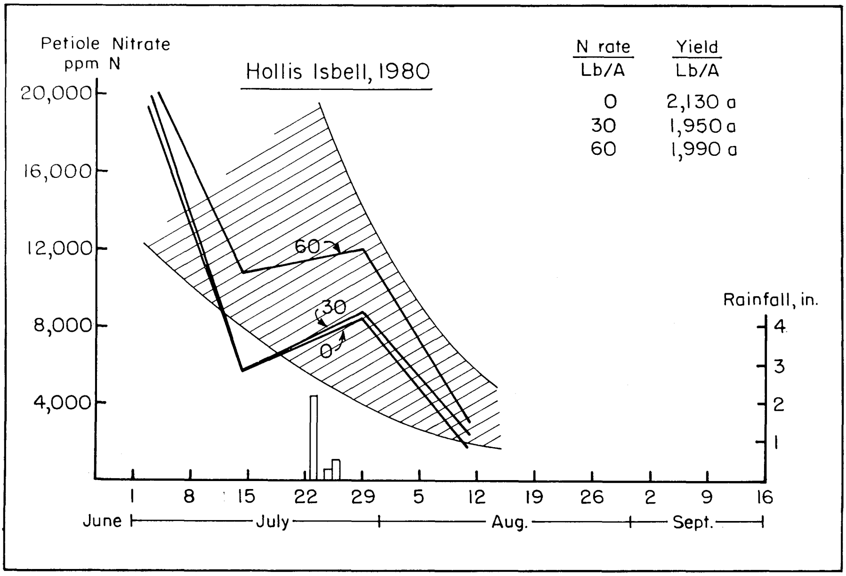

Petiole Nitrate ppm N
Hollis Isbell, 1980
N rate Lb/A
Yield Lb/A
0 2,130 a
30 1,950 a
60 1,990 a
20,000
16,000
12,000
8,000
4,000
60
30
0
Rainfall, in.
4
3
2
1
1 8 15 22 29 5 12 19 26 2 9 16
June July Aug. Sept.

FIG. 14.

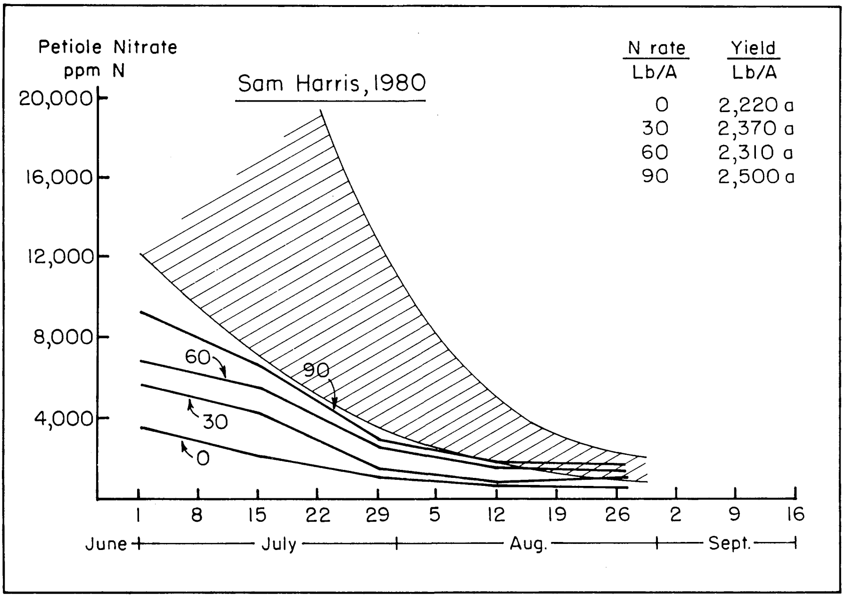

Petiole Nitrate
ppm N
Sam Harris, 1980
N rate Lb/A
Yield Lb/A
0 2,220 a
30 2,370 a
60 2,310 a
90 2,500 a
20,000
16,000
12,000
8,000
4,000
60
90
30
0
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 15.

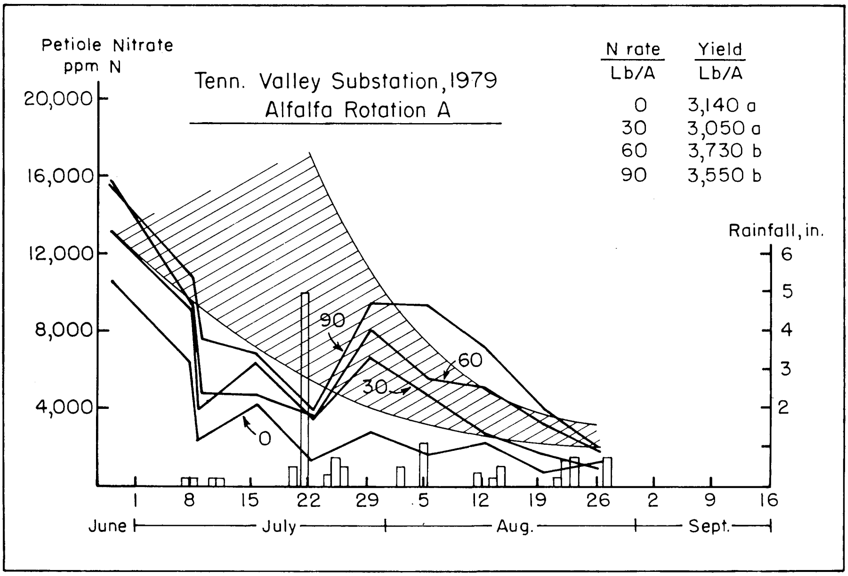

Petiole Nitrate
ppm N
Tenn. Valley Substation, 1979
Alfalfa Rotation A
N rate Lb/A
Yield Lb/A
0 3,140 a
30 3,050 a
60 3,730 b
90 3,550 b
Rainfall, in.
6
5
4
3
2
20,000
16,000
12,000
8,000
4,000
90
60
30
0
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 16.

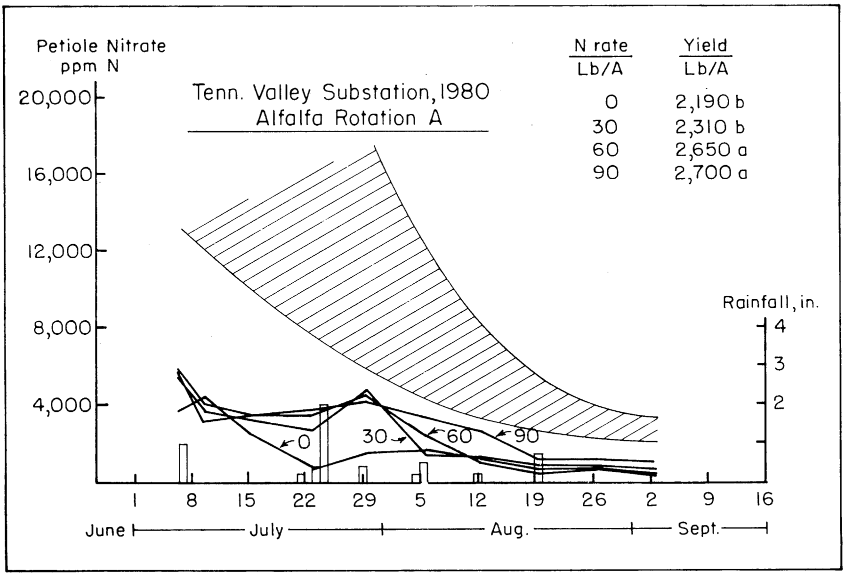

Petiole Nitrate
ppm N
20,000
16,000
12,000
8,000
4,000
Tenn. Valley Substation, 1980
Alfalfa Rotation A
N rate Lb/A
Yield Lb/A
0 2,190 b
30 2,310 b
60 2,650 a
90 2,700 a
Rainfall, in.
4
3
2
0
30
60
90
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 17.

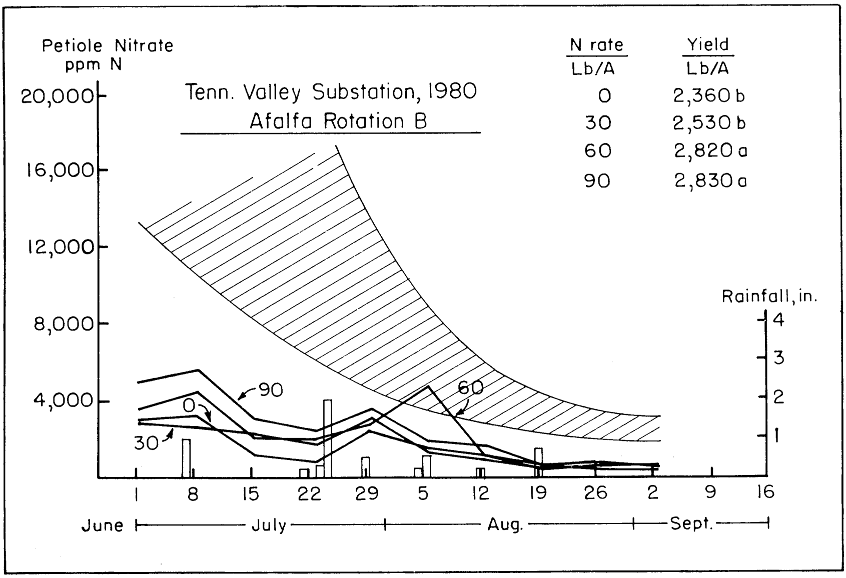

Petiole Nitrate
ppm N
20,000
16,000
12,000
8,000
4,000
Tenn. Valley Substation, 1980
Afalfa Rotation B
N rate Lb/A
Yield Lb/A
0 2,360 b
30 2,530 b
60 2,820 a
90 2,830 a
Rainfall, in.
4
3
2
1
90
0
30
60
1
8
15
22
29
5
12
19
26
2
9
16
June
July
Aug.
Sept.

FIG. 18.

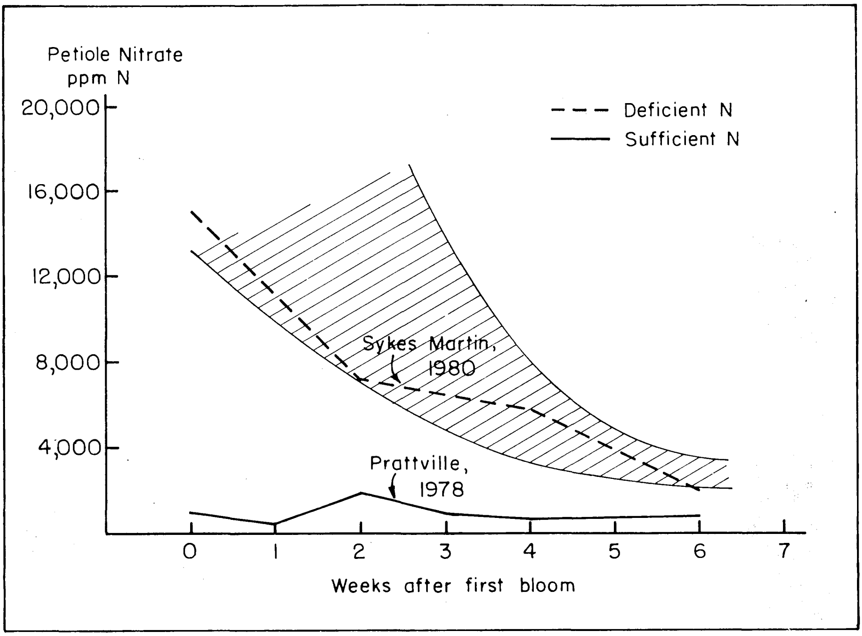


FIG. 19. Petiole-nitrate levels from two experiments as affected by date of sampling. The Prattville experiment was from a N rate that was N sufficient according to yields; the Sykes Martin experiment was from a N rate that was N deficient according to yields.