to apply nitrogen at the rates indicated previously. The yields obtained from the applied nitrogen were considered relatively high, indicating that no apparent yield loss resulted from fertilizing according to the rapid tissue test.

Conclusions

The rapid tissue test for nitrate-nitrogen in the basal stem is satisfactory for evaluating the nitrogen nutritional status of corn. When used at the 35- to 40-day stage of growth, the test color reading, obtained as an average of 10 to 20 basal stem sections, can be used as a basis for making nitrogen fertilizer recommendations. An average color reading of 4 indicates the presence of adequate nitrogen, while a color reading of less than 4 indicates the plant will become nitrogen deficient and yield will be reduced. Furthermore, the tissue test can evaluate the efficacy of the nitrogen fertilizer programs used during the season. An average color reading of 4 at the soft dough stage of development indicates that too much nitrogen was applied during the season, or that a late application was made, or both. Thus rapid tissue testing for nitrogen in the field can serve as a guide for diagnosing deficiencies, making fertilizer recommendations, and evaluating the fertilizer program for the season.

Rapid tissue testing for evaluating
(2) NITROGEN NUTRITIONAL STATUS OF SORGHUM

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THE STUDIES TO CALIBRATE the rapid tissue test with the nitrogen nutritional status of sorghum were conducted in a nitrogen deficient field on the Rosolia Ranch near Orland. In 1970, initial soil samples were taken and plots laid out in a randomized complete block design with six treatments and three replications. The plots were 15 ft wide and 50 ft long. The treatments consisted of 0, 50, 100, 150, 200, and 250 lbs of nitrogen applied per acre. The nitrogen (as ammonium sulfate) was applied pre-plant and disked into the soil. Sorghum, variety NK 222, was planted on July 4, 1970 by drilling on 12-inch row spacing.

Commencing on August 6, 1970 plant samples were taken from each plot. Midribs from the first fully matured leaf and the whole leaf of similar maturity from different plants were taken for laboratory analysis of NO_3-N and total nitrogen, respectively. A basal 3-inch section of the stem was also taken from the plants from which leaf samples were obtained. The stem section was split lengthwise and one-half was used for the laboratory determination of the NO_3-N content; the other half was used for evaluating the nitrate content using the nitrate reagent powder.

Tissue samples were collected and color readings were made four times during the growing season. Sampling dates roughly corresponded to different stages of growth: vegetative, floral initiation, boot and heading.

The nitrate reagent, color coding, and paint chips used in these tests with sorghum were identical with those used in the corn tests described in the companion article.

In 1971 another field trial was established on the Rosolia Ranch for further evaluation of the rapid tissue testing technique. Experimental design, plot size and cultural practices were the same as in 1970; however, another variety, NK 265, was planted. Treatments were changed to vary timing of application, as well as rate of nitrogen applied. Total nitrogen applied per acre was 0, 50, 100, and 150 lbs. In four treatments the total nitrogen used was applied pre-plant; in four other treatments either 50 or 100 lbs of nitrogen was applied pre-plant and an additional 50 lbs at the six-leaf and boot stage. The final plot was a control. Tissue samples were collected and color readings made at the vegetative, floral initiation and boot stages of growth.

Guidelines

A final field study was conducted in 1972 to determine whether the guidelines developed in the previous studies could be used to make nitrogen fertilizer recommendations. Three treatments were used: a control, 200 lbs of nitrogen applied preplant, and a third treatment to be fertilized in accordance with the results obtained by using the rapid tissue test at the appropriate stage of growth.

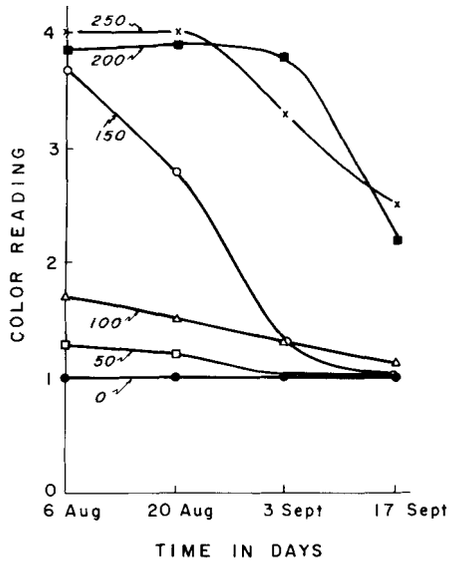
As part of the first study, the changing NO_3-N concentration in various tissues was measured over time. Table 1 shows that regardless of tissue sampled and nitrogen treatment, the nitrogen content decreased with time. In the basal stem, the rate of decrease was more gradual than in the mid-rib, making it more suitable for field use.

It appears that either the NO_3-N content of the basal stem, or the total nitrogen content of the first fully matured leaf, could be used to evaluate plant nitrogen nutritional status, since both reflect the applied nitrogen treatments throughout the growth period sampled. Between the floral initiation stage (Aug. 20), and boot stage (Sept. 3), total nitrogen content tended to level off in the leaf tissue. This period is also one of rapid nutrient uptake, indicating that the plant is growing rapidly and storing nitrogen for use during maturation of the head. Further evidence for this is the drop in total nitrogen content that occurs between the boot and heading stages of growth. At heading, the growth of the plant is practically complete and further gains in dry matter production are the result of carbohydrate accumulation rather than cell development.

In comparing the color readings obtained at the four sampling times (see graph 1), it became apparent that the values from the rapid tissue test follow the same general trend as observed in the NO_3-N concentration in the stem tissue. Data from the 1971 study show a greater range of NO_3-N concentrations in the basal stem, which corresponded well with the color readings taken (see graph 2).

Fitting the data to the Mitscherlich equation, a correlation coefficient of $r = 0.965$ was obtained between the color reading and the NO_3-N content in the basal stem. At low NO_3-N concentrations

GRAPH 1. CHANGE IN COLOR READING IN BASAL STEM OF SORGHUM WITH RATE OF NITROGEN AND TIME, 1970

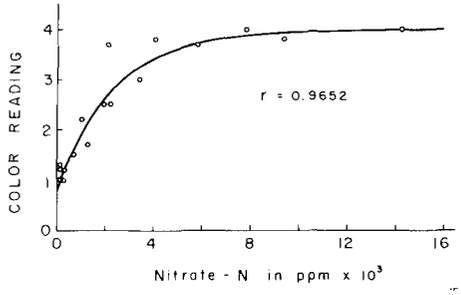


in the stem tissue, the color reading was the most sensitive; as the NO_3-N concentration approached 6000 ppm, color differences were more subtle and finally could not be detected. The upper limit of the reagent to reflect changing NO_3-N concentration had been reached.

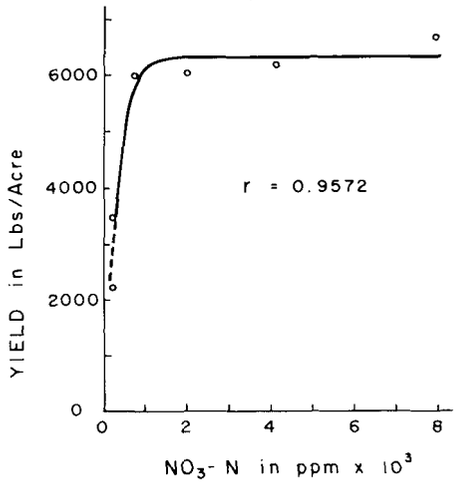
Indications are that the NO_3-N concentration in the stem tissue does not have to be at the higher concentrations to have adequate nitrogen for attaining the yield possibility. Graph 3 shows the relationship between the NO_3-N concentration in the basal stem and the calculated yield of sorghum per acre. Since there was good agreement between NO_3-N content in the stem, yield and color reading, it follows that the color reading would be a good indication of the nitrogen nutritional status of the plant.

The relationship between the color reading at the 35- to 40-day stage of growth and yield is shown in graph 4. As the color reading approaches 2 (light pink), the yield reaches a maximum. Based on these data and similar results obtained in the 1971 field study, it appears that the color reading at the 35- to 40-day stage of growth was a good index of the nitrogen nutritional status of the sorghum plant. The tissue test can be used early enough in the development of the plant so that if a correctional application of nitrogen is required, it could be made when the plants are small enough to be fertilized in any manner.

GRAPH 2. RELATIONSHIP BETWEEN MEAN COLOR READING AND MEAN NO_3-N IN BASAL STEM FOR SORGHUM, 1971



GRAPH 3. RELATIONSHIP BETWEEN CALCULATED YIELD OF SORGHUM AND NO_3-N CONCENTRATION IN BASAL STEM AT 35- TO 40-DAY STAGE OF GROWTH, AUGUST 20, 1970



To further test the technique as a means of recommending fertilizer applications, a field study was established in which one of the treatments consisted of taking a color reading at the 35- to 40-day stage of growth and using that to determine whether additional nitrogen was required. As can be seen in table 2, both the untreated control and the treatment plots showed a color reading of 1 (no color). Since a color reading of 2 (light pink) is required to assure adequate nitrogen for achieving the yield possibility, it was determined that nitrogen fertilizer must be applied.

Nitrogen in the form of ammonium nitrate was applied at the rate of 100 lbs per acre by broadcasting it on the soil surface just prior to an irrigation. There was no statistically significant yield difference between the plots fertilized with all the nitrogen pre-plant or less nitrogen applied according to the color reading. Both yields were greater than the control yield. An interesting aspect of the study can be seen by comparing the color readings in the basal stem at the soft dough stage of growth for all the treatments. There was a high reading in the treatment receiving 200 lbs of nitrogen pre-plant at that stage of growth. The data in graph 1 show that high color readings late in the growing season of the plant are indicative of nitrogen applied in excess of that required to achieve maximum yield. So a useful corollary of the study appears to be the ability to detect when excess nitrogen was applied during the growing season.

Conclusions

The rapid tissue testing for NO_3-N was shown to be a useful tool for evaluating the nitrogen nutritional status of the sorghum plant. When color readings are made at the 35- to 40-day stage of growth, the color obtained can be used as a basis for making nitrogen fertilizer recommendations in mid-season. An average reading below 2 (light pink) from 10 to 20 basal stem sections indicates the plants will become nitrogen deficient. The plants at that stage of growth are small enough so a correctional application of nitrogen can be made. Making the nitrogen application at this stage of growth insures more efficient use of the fertilizer resource and does not result in yield loss. An average reading greater than 2 (light pink) at the soft dough stage of growth indicates too much nitrogen was applied during the season.

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TABLE 1. NITROGEN CONTENT OF SORGHUM TISSUE AS INFLUENCED BY APPLIED NITROGEN, 1970

Sampling date	Pounds of nitrogen applied					
	0	50	100	150	200	2
	Whole leaf—% N*					
6 Aug.	2.00	2.30	2.71	3.04	3.00	3.
20 Aug.	1.39	1.66	2.21	2.40	2.67	2.
3 Sept.	1.11	1.61	2.10	2.21	2.54	2.
17 Sept.	1.22	1.26	1.61	1.76	2.00	2.
	Mid-rib—NO_3-N, PPM*					
6 Aug.	364	529	3215	4853	9533	106
20 Aug.	148	148	243	494	849	24
3 Sept.	117	117	108	135	238	5
17 Sept.	78	135	100	109	82	1
	Basal stem—NO_3-N, PPM*					
6 Aug.	447	1300	3449	5824	9412	143
20 Aug.	225	208	728	1993	4117	78
3 Sept.	144	139	182	325	2149	34
17 Sept.	148	144	200	295	1049	22

* Values are means of three replications.

TABLE 2. SORGHUM YIELD AND COLOR READINGS AS INFLUENCED BY APPLIED NITROGEN, 1972

Treatments	Color readings		Yield*
	10 July	10 Oct.	
lbs N/a			lbs/a
Control	1.0	1.0	4310 a**
100 (CR)†	1.0	1.0	6106 b
200	4.0	2.3	5796 b

* Yield was calculated from plot weights.

** Values followed by the same letter are not significantly different at the 5% probability level according to the Duncan Multiple Range Test.

† This treatment was applied based on the average color reading at the 35- to 40-day stage of growth.

GRAPH 4. RELATIONSHIP OF COLOR READING IN BASAL STEM OF SORGHUM TO YIELD, 1970