Nutritional Status of Sugar Beets As Revealed by Chemical Analyses of Petioles[1]

JAY L. HADDOCK[2]

Chemical analyses of soils and plants have been both intensive and extensive since the time of Davy, De Saussure, Lawes, and Liebig. Although much information has been obtained by the vast amount of effort expended to wrest from nature her secrets of soil fertility and plant nutrition, this entire field of knowledge is still highly empirical. The kinds of nutrients necessary for plant growth have been well established. The effort currently being exerted on soil tests and plant 'tissue tests is towards establishing quantitative nutrient requirements.

Agronomists and plant physiologists have studied the factors influencing the absorption and assimilation of plant nutrient elements. Since this paper deals principally with the absorption of nitrogen and phosphorus, literature citations will be limited to this field.

Excellent reviews of research work dealing with plant analyses have been provided (10)[3], (11), (19), (20). Likewise, summaries of research dealing with absorption and assimilation of nitrogen compounds have been published (14), (4), (12), (1), (2). Special reference to nitrogen and phosphorus composition of the sugar beet is also available (8), (9), (5), (3), (18), (20), (17).

It is generally recognized that nitrogen enters the plant through the fine roots, largely as nitrate-nitrogen. Evidence is available indicating that ammonia-nitrogen may at times constitute a considerable proportion of the total nitrogen entering plants, with nitrite and organic forms of nitrogen playing minor roles. Likewise, here is general understanding that phosphorus is absorbed largely as inorganic orthophosphate.

Nitrate-nitrogen is in a highly oxidized state while protein nitrogen is in a highly reduced condition. The process involved in this transformation of nitrogen from inorganic to organic form has not been established conclusively. It is definitely an endothermic reaction. The reduction of nitrates to organic nitrogen is generally assumed to occur in the leaves or other

Figure 1. (see page 335). Seasonal NO_3-nitrogen content of sugar beet petioles with four different commercial fertilizers.

[1] Contribution from the Division of Soil Management and Irrigation, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Dept. of Agriculture, in cooperation with the Utah Agricultural Experiment Station, Logan, Utah.

[2] Soil Scientist, Division Soil Management and Irrigation.

[3] Figures in parentheses refer to literature cited.

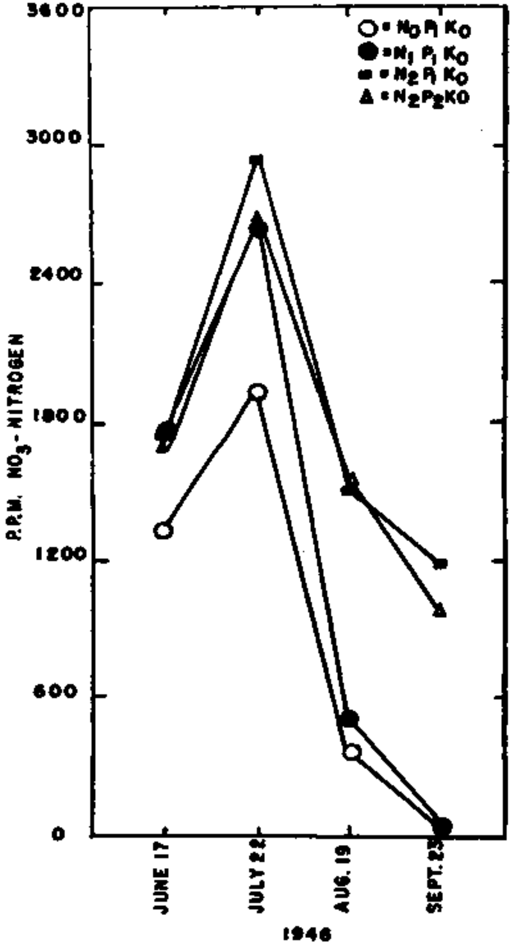

Figure 1 (see preceding page).

aerial portions of plants where the energy from sunlight is available. There is conclusive evidence that under some conditions and with some plants reduction of nitrates and their synthesis to amino acids occurs in the roots. This process may be quite complete in some plants (15), (4), (13), (12). It appears to be of some consequence in the well-developed beet root (21) .

It is by no means certain that the nitrate-nitrogen content of sugar beet petioles will give one a complete picture of the nitrogen-nutritional-status of the sugar beet plant. It is quite probable that some of the nitrate-nitrogen is synthesized in the roots of sugar beets to soluble organic nitrogen compounds and moved through the petioles to the aerial portions of the plant for complete assimilation. To the extent this is true nitrate determinations fail to *gi\e* the complete picture of the nitrogen nutritional status of the plant. Nevertheless, most of the tissue tests now in current use are based upon nitrate-nitrogen determinations in the petioles or other portions of the plant (16), (10), (20), (15).

MATERIALS AND METHODS

The objective of this study was to follow the effects of various irrigation, fertilizer, and spacing treatments on the uptake of specific nutrients (nitrates and phosphates) by the sugar beet plant. The data presented in this paper were obtained incident to a study of the interrelations of soil moisture, plant population, and soil fertility level to yield and quality of sugar beets.

The procedures used in this study for sampling, drying and extracting the plant materials are similar to those suggested by Ulrich (19) . Some modifications were made in the chemical determinations.

This study was conducted on Millville fine sandy loam in 1946, and Millville silt loam in 1947 and 1948. Both soils are well-drained. All plots were uniformly sprinkle-irrigated twice in 1946 (June 26 and July 15) and three times in 1947 (April 18, May 6, and June 26) before soil moisture variables were initiated. Commercial fertilizers and manure treatments used are symbolized and described as follows:

N_0—No nitrogen.
N_1—80 pounds nitrogen per acre.
N_2—160 pounds nitrogen per acre.
P_0—No phosphoric acid.
P_1—100 pounds phosphoric acid per acre.
P_2—200 pounds phosphoric acid per acre.
M_0—No manure.
M_1—15 tons barnyard manure per acre.

Nitrate-nitrogen Content of Sugar Beet Petioles

The analytical data on the chemical composition of the sugar beet petioles are presented graphically. By means of these graphs one can obtain a fair estimate of the nutritional status of the sugar beet plant at various periods during the growing season. Ulrich (17) (20), has established a value of 600-800 parts per million of phosphate-phosphorus in sugar beet petioles as the critical level. For nitrate-nitrogen the critical level has been set at about 1,000 parts per million.

Figure 2. (see page 337). Seasonal $N0_3$-nitrogen content of sugar beet petioles with three different commercial fertilizers.

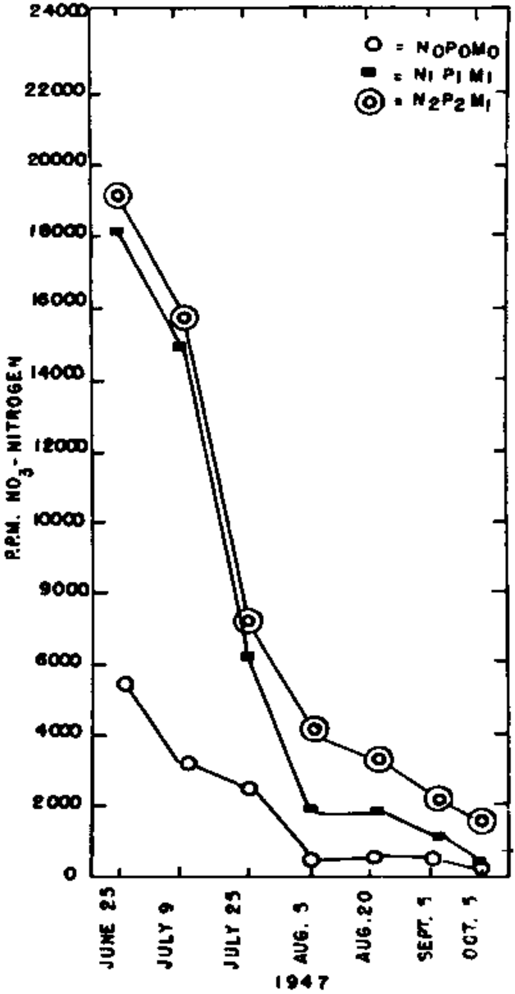

Figure 2 (see preceding page).

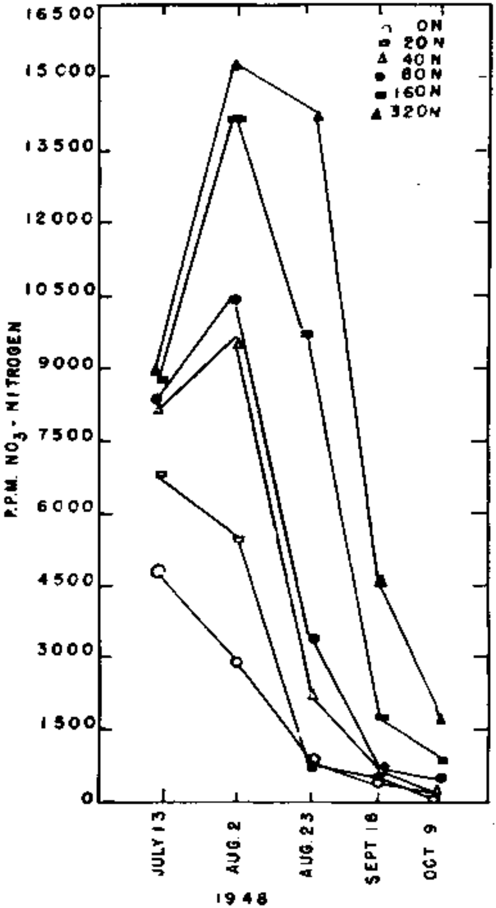

Figure 3. Seasonal NO_3-nitrogen content of sugar beet petioles with six levels of commercial nitrogen.

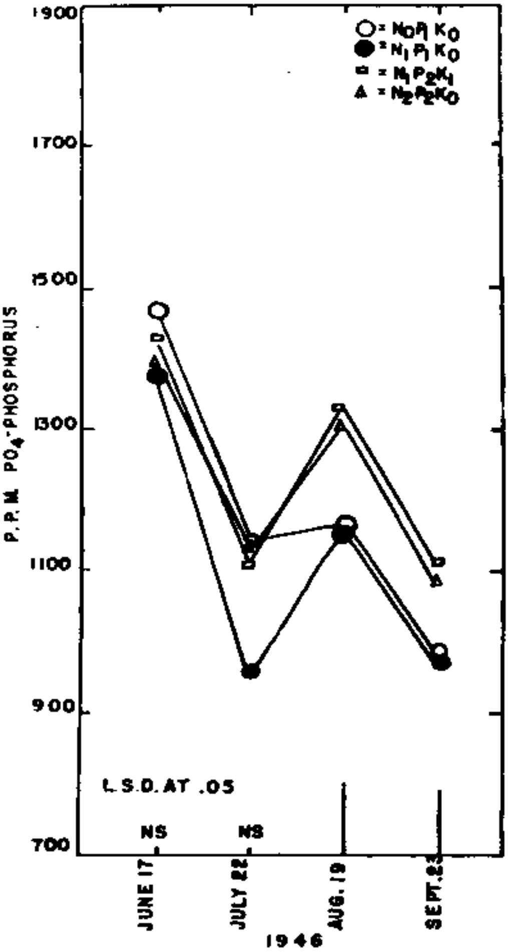

Figure 4. Seasonal PO_4-phosphorus content of sugar beet petioles as influenced by commercial fertilizers.

Data on the yield and quality of sugar beets as influenced by fertilizers, plant population, and soil moisture may be obtained by referring to previous publications (6), and (7). This information may be of value to those interested in comparing petiole composition and yield.

The data presented in the figures which follow are means of all treatments used in the experiment, other than those being compared in each figure.

The data presented in Figures 1, 2 and 3 are what would be expected if fertilizer materials supplied to the soil were actually available to sugar beet plants. Significant differences between fertilizer treatments were obtained at all sampling dates.

It will be observed in Figure 1 that petioles of plants taken from plots receiving no nitrogen were relatively low in nitrogen throughout the season, while petioles of plants which received large quantities of nitrogen were relatively high. Likewise, the data in Figure 2 show that without additions of commercial nitrogen to soils low in available nitrogen, plant petioles will tend to be relatively low all season. It is interesting to observe the wide difference in the composition of petioles from plants receiving no commercial nitrogen and those receiving 80 or 160 pounds of nitrogen per acre (N_1 and N_2). The small differences in the composition of petioles from plots receiving 80 and 160 pounds of nitrogen are also of much interest. The yields of sugar beets on these plots were 20.3, 25.8, and 26.0 tons per acre for 0, 80, and 160 pounds of nitrogen respectively.

The data in Figure 3 are of considerable interest in that the six increments of nitrogen fertilizer show successive increases in nitrate-nitrogen content in the sugar beet petioles. All show relatively low nitrate-nitrogen content at the October sampling. There were no significant differences in yield beyond the nitrogen treatment of 20 pounds per acre. Apparently luxury consumption of nitrogen occurred on the four highest fertilized plots.

The data in Figures 4, 5, and 6 show the effect of various fertilizers upon the phosphorus content of sugar beet petioles throughout the growing season. Here again, one may observe a phenomenon which is neither new nor striking, but nevertheless interesting. The percentage composition of phosphorus found in the sugar beet petiole may depend somewhat upon the amount of available nitrogen in the soil. Confirmation of this is shown in Figure 4. Although the same amount of phosphorus is available *in* the treatments $N_0P_1K_0$ and $N_1P_1K_0$, there is always a larger percentage of phosphorus in petioles taken from plots receiving $N_0P_1K_0$ than from those receiving $N_1P_1K_0$. This is shown more convincingly in Figure 5. It will be noted that the same amount of commercial phosphorus is applied with treatments $N_0P_1M_1$ and $N_2P_1M_0$. Likewise, when one compares the composition of petioles taken from plots receiving $N_2P_1M_0$ with petioles taken from plots receiving $N_2P_2M_0$, it will be seen that petioles from plots receiving $N_2P_2M_0$ contain significantly more phosphorus than petioles from plots receiving the same amount of nitrogen and one-half as much phosphorus ($N_2P_1M_0$).

Figure 5 (see page 341). Seasonal $P0_4$-phosphorus content of sugar beet petioles as influenced by commercial fertilizers.

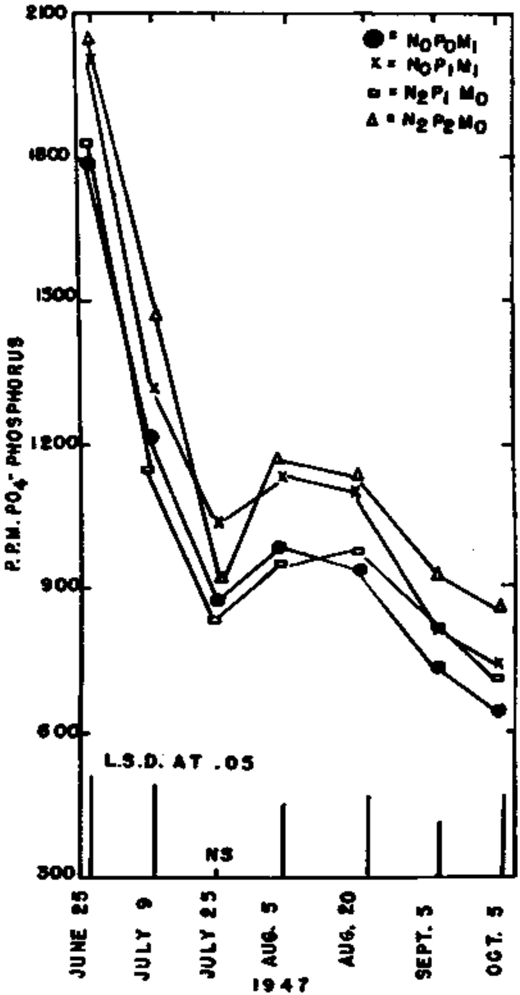

Figure 5 (see preceding page).

It will be observed in Figure 6 that there is a tendency for petioles from plots treated with $N_1P_1M_1$ to contain more phosphorus than from plots treated with $N_2P_1M_1$. Petioles from untreated plots in 1948 tended to show less phosphorus than those from phosphorus-treated plots, even though nitrogen was present as part of the treatment.

From observations noted above one must expect the phosphate-phosphorus content of sugar beet petioles to vary with the age of the plant and season of the year as well as the available nitrogen and phosphorus in the soil.

It has been shown in work at the Utah Station that the uptake of phosphorus is hindered to a much greater extent than the uptake of nitrogen by high soil moisture tension.

Because of limited space it is not possible to present data on the effects of plant population and soil moisture tension on petiole composition. These data will be published elsewhere.

Figures 7 and 8 are presented in this paper with the hope that the data given may be useful to those who may be using either green or dry tissue analyses alone. A considerable amount of valuable and reliable information may be obtained from either dry or green plant tissue analyses. Correlation is far from perfect but about the same general conclusions would be drawn from a study of either set of data. There appears to be less fluctuation from sample to sample taken from the same plot with the dry tissue than with the green tissue. Where a large number of samples must be run it is often more convenient to prepare the dry samples at one time and analyze them at another. The big advantage for green tissue analysis is that one can follow current changes in plant nutrition.

DISCUSSION

The data presented in this paper were obtained incident to a detailed study of the influence of several controllable and measurable plant growth factors upon the yield and quality of sugar beets. Since critical levels for both phosphate-phosphorus and nitrate-nitrogen had been established for sugar beet petioles, it was assumed that these levels might be used as a measure of the adequacy or inadequacy of the several treatments used in field experiments. Frequently treatments are applied to field or greenhouse pot experiments without measurable yield response. One is left to guess whether lack of response is a result of unavailability or failure of the particular treatment to stimulate yields under the condition of the experiment.

If one plans to use petiole analysis as an indication of soil fertility or nutritional status conditions he must certainly keep in mind the influence of seasonal changes. Ths is a very striking phenomenon even though petioles of the same physiological age are used. One should give some consideration to soil moisture conditions, plant population, and the relative abundance of other available plant nutrients in the soil. The seasonal factor is by far the most important factor but the other factors mentioned are not unimportant.

One may well inquire as to the significance of the rapid seasonal decrease in nitrate-nitrogen and phosphorus. There are at least two things

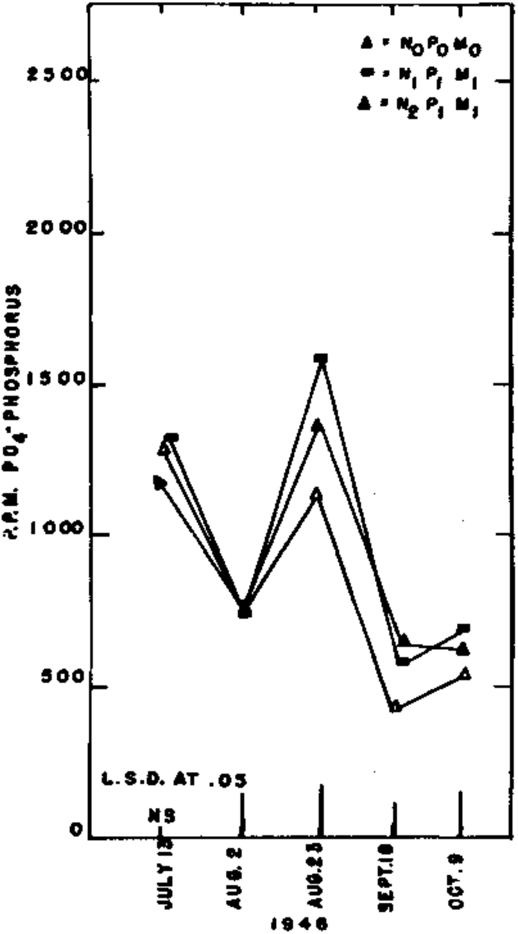

Figure 6. Seasonal PO_4-phosphorus content of sugar beet petioles as influenced by manure and commercial fertilizers.

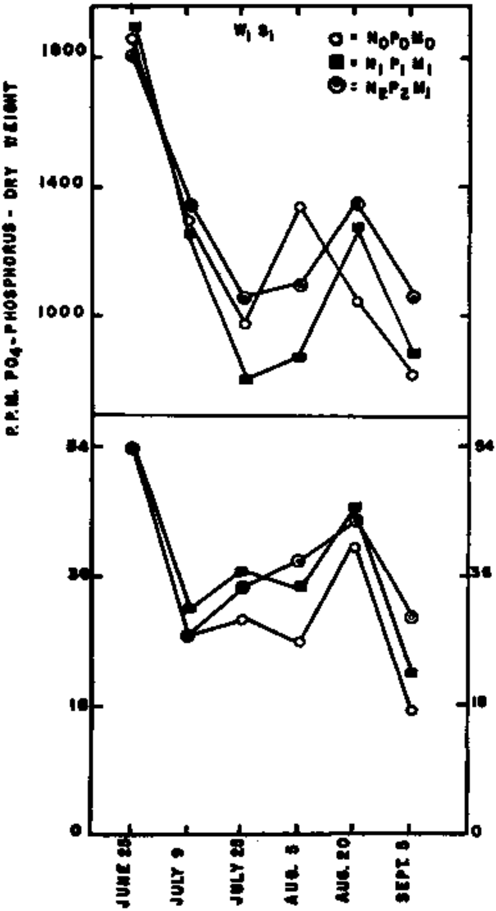

Figure 7. Seasonal $P0_4$-phosphorus content of sugar beet petioles as determined on oven dry samples and fresh green samples with three fertilizers (1947).

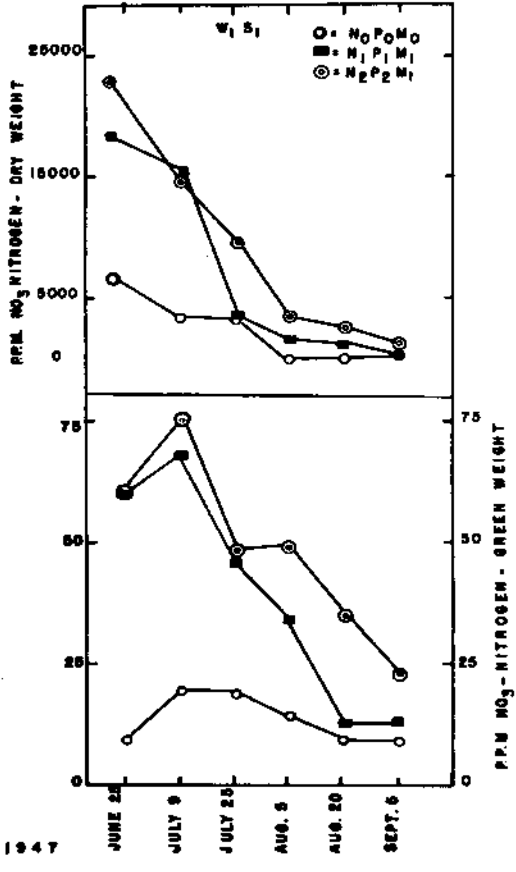

Figure 8. Seasonal NO_3-nitrogen content of sugar beet petioles as determined on oven dry samples and fresh green samples with three fertilizers (1947).

which may account for this. *First, petioles of the same physiological age increase in size as the season advances.* This increased plant material may have the effect of diluting the chemical composition. *Second, as the season advances the sugar beet roots grow larger and become charged with an abundance of soluble sugars.* This may be a favorable environment for reduction of nitrates to amino nitrogen. Whereas nitrogen may enter the plant and move up the petioles principally as nitrate-nitrogen early in the season it may be reduced in the root and move up the petioles largely as amino or noncolloidal organic nitrogen in September and October. Evidence obtained at the Logan Station strongly supports the latter possibility. It is entirely probable that some dilution may occur. Plans are underway to study the effect of dilution.

SUMMARY AND CONCLUSION

1. Irrespective of moderate variability in soil moisture conditions, plant populations and fertilizer treatment sugar beet petioles are relatively high in $N0_3$-nitrogen early in the season. The percentage of $N0_3$-nitrogen decreases rapidly from June to the last of July, after which the rate of decline in $N0_3$-nitrogen composition becomes very gradual until it reaches a minimum in October.

2. The general seasonal trend in $N0_3$-nitrogen composition of sugar beet petioles described in (1) above may be modified slightly by extreme soil-moisture conditions and available plant nutrients.

3. The PO_4-phosphorus content of sugar beet petioles follows the same general seasonal trend as described in (1) above for NO_3.-nitrogen. The absolute amount of $P0_4$-phosphorus is much smaller than the $N0_3$-nitrogen content early in the season but becomes greater by harvest time.

4. The uptake of phosphorus by the sugar beet plant is influenced to a much greater extent by the amount of available nitrogen in the soil than is the uptake of nitrogen influenced by the amount of available phosphorus.

5. A fair picture of the nutritional status of sugar beet plants as measured by $N0_3$-nitrogen and $P0_4$-phosphorus can be had by chemical analysis of either dry plant tissue or green tissue.

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