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NITROGEN MINERALIZATION IN THREE SOIL TYPES USED FOR TOBACCO PRODUCTION IN THE MORETON DISTRICT

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SUMMARY

The results from four studies of nitrogen mineralization in three soil types commonly used for tobacco production in the Moreton district indicate that a regular pattern of nitrogen mineralization exists.

Each study recorded the changes in the quantity of nitrogen mineralized under a grass cover.

The greatest rate of nitrogen mineralization occurred during the October to December period which coincides with the rapid growth of tobacco crops in the Moreton district. At two of the sites, the rate of nitrogen mineralization decreased in January suggesting that a maximum had been reached.

Small quantities of mineralized nitrogen were found in the soil at each site initially.

The pattern and magnitude of the nitrogen mineralization appeared to be primarily a function of the nitrogen status of the organic material from the preceding tobacco crop and the date that this was ploughed under, early in the year.

The implications of this release pattern on the nitrogen nutrition of tobacco planted at different times are briefly discussed.

I. INTRODUCTION

Nitrogen is one of the major elements influencing the commercial production of flue-cured tobacco. In particular, the pattern of absorption of this element in relation to stage of growth has long been recognized as important in determining cured leaf quality (Grizzard, Davies and Kangas 1942; McCants and Long 1971).

The soil nitrogen regime must not impede the uptake of nitrogen during the rapid growth stage of the plant. However, to achieve the desired quality in the cured leaf, it is essential that the rate of nitrogen absorption decrease rapidly as the plant reaches maturity (McCants and Woltz 1967).

It is because of these nutritional requirements that soils considered most suitable for tobacco production are those of low fertility. Such soils allow maximum control of the nitrogen nutrition of the crop and hence afford the best chance of obtaining acceptable leaf quality.

During 1972 and 1973, four studies of nitrogen mineralization were conducted on three soil types of differing fertility. Each study recorded the changes in the level of soil mineral nitrogen under a grass cover. This approach was chosen since it avoided the task of sampling complex soil conditions during continual cultivation. However, it did not account for the likely influence of this cultural practice on the nitrogen mineralization processes.

This paper reports on the pattern and magnitude of nitrogen mineralization in these soils and briefly discusses their likely significance on the nitrogen nutrition of tobacco planted at different times.

II. MATERIALS AND METHODS

Site history and description

A description of the soil type at each site, its location and chemical composition are presented in table 1.

TABLE 1

SOIL DESCRIPTION, LOCATION AND CHEMICAL COMPOSITION

Site No.	Location	Soil Type (after Vallance 1938)	Year of Experiment	Soil Analysis	
				pH (1:2·5 H_2O)	P p.p.m. BSES Method
I	Beerwah Tobacco Research Farm	Beerwah Sand ..	1972	5·5	29
II	Beerwah Tobacco Research Farm	Beerwah Sand ..	1973	5·5	25
III	Beerwah Tobacco Research Farm	Glasshouse Sand ..	1973	5·1	113
IV	E. and J. Reeves, Beerwah	Glasshouse Sandy Loam	1972	5·2	31

The chemical results expressed in table 1 are from soil samples taken during the year of the experiment for each of the first three sites and of the preceding year for site IV. Available phosphorus was determined using the extraction procedure of Kerr and von Stieglitz (1938).

In the Moreton district, two main forms of cover cropping are used. When paddocks are spelled, volunteer species are allowed to grow. However, when paddocks are in continual use, oats are grown during April to June period. These are either grown for the organic matter they produce or for the protection they offer against erosion.

At each of the first three sites, an unfertilized oats crop grew in each fallow period between successive crops of tobacco. At site IV, volunteer species grew between successive crops of tobacco. In each case, the quantity of organic matter from these cover crops was small when ploughed under in June.

TABLE 2

HISTORY OF SITES

Site No.	Tobacco Cropping History		Cropping Practices Prior to Tobacco	Date of Ploughing of Residual Tobacco Crop
	Year Commenced	No. of Years		
I	1970	2	Native pasture	March 1972
II	1972	1	Open sclerophyll forest prior to August 1971	April 1973
III	1970	3	Pineapples and miscellaneous crops. Fertilizer history unknown	April 1973
IV	1970	2	Pineapples followed by native grasses for several years	March 1972

The organic matter ploughed under at the end of a tobacco crop is composed largely of residual plant parts such as stems, suckers, roots and flower heads. The relative contribution of the nitrogen content of these plant parts to the total nitrogen uptake of a tobacco crop appears to vary with location. Penman (1941) found that these accounted for 35% of the total nitrogen uptake of a tobacco crop in Victoria whereas Goodman (1965) found a figure of 73% in north Queensland.

An abnormal quantity of organic material from the preceding tobacco crops was ploughed under at sites III and IV in the year of the study. This occurred because approximately 50% and 30% respectively of the total leaf area was not harvested.

At both of these sites, the harvested leaf had immature characteristics when cured. This reflected the higher nitrogen status of the soil at these sites relative to the nitrogen requirements of a tobacco crop for the production of acceptable cured leaf.

Techniques

SAMPLING INTENSITY. Site I was sampled at 14-day intervals whereas sites II, III and IV were sampled at 28-day intervals.

At sites I, II and III, 10 randomly selected quadrats were sampled on each occasion. At sites I and II, quadrats were selected from two portions of ground, each 22 m^2, and 13 m apart. At site III, the 10 samples were selected from four portions of ground, each of $2 \cdot 2$ m^2. These were selected to form the corners of a rectangle, with sides of 40 m and 10 m.

Site IV differed from the other three sites in the number of samples taken at each sampling. One sample was taken from each of five subsites at each sampling. These subsites were 22 m^2 and spaced 30 m apart in a straight line.

SAMPLE HANDLING. At each sampling, five $2 \cdot 5$ cm diameter soil cores were taken from within a square quadrat of side $30 \cdot 5$ cm. Each core was taken to a depth of 23 cm. These were bulked and passed through a $1 \cdot 6$ mm sieve and then thoroughly mixed. After soil sampling, the grass cover (tops and roots) within the quadrat was removed and later dried at 60°C in a forced-draft oven. Dry weights of samples were recorded and the samples then analyzed for nitrogen.

The quantity of nitrogen mineralized at the date of sampling of a quadrat was determined by adding the level of mineral nitrogen in the soil to the grass nitrogen yield.

Bulk density determinations were made at each sampling by taking soil cores to a depth of 23 cm. This enabled the conversion of nitrogen concentrations in the soil to a 'weight per hectare' basis.

SITE CULTIVATION. Ploughing dates for each site are shown in table 2.

In addition to ploughing, sites I, II and III also received a discing in September as part of the normal ground preparation for tobacco. No further cultivation of the sites occurred after September.

Although green panic (*Panicum maximum* var. *trichoglume*) was sown at the beginning of each study at sites I, II and III, the subsequent grass cover was composed largely of volunteer (*Digitaria*) species. At site IV, the grass cover was composed predominantly of red Natal (*Rhynchelytrum repens*).

CHEMICAL ANALYSIS OF SAMPLES. The ammonium and nitrate content of soil samples from sites I and IV was determined by the method of Bremner and Keeney (1965). Soil samples from sites II and III were analysed for these two constituents using specific ion electrodes.

Total nitrogen of the grass samples was determined by the Kjeldahl method.

QUANTIFICATION OF LEACHING. At sites I, II, and III, facilities were available to obtain an estimate of the quantity of nitrogen lost as leachate between samplings.

Two square fibre glass lysimeters of $0 \cdot 813$ m^2 were placed in the field and filled with soil from the neighbouring site 7 days before soil sampling commenced. The lysimeters had 30 cm deep sides with 5 cm deep tapered bottoms. A central drain hole enabled leachate to be collected.

The depth of soil in each lysimeter was the same as the depth of soil under study. The bottom 7 cm of each pot was filled with fine gravel covered by a thin layer of sand. Vegetative cover in the lysimeters was similar to that in the areas sampled.

Weights of leachate samples were recorded and the leachate analysed for nitrate and ammonium.

GENERAL. The approach used to measure soil nitrogen mineralization contains the following assumptions—

1. No volatile losses of nitrogen occurred.
2. The bulk of grass roots were confined to the 23 cm of soil under study.
3. The rate of mineralization and leaching in the disturbed lysimeter soils was the same as that in the cultivated field soil.

Climatic Data

The means of the monthly maximum and minimum temperatures recorded at Brisbane and Nambour over 12 years are presented in table 3 for comparison with those recorded at the sites during the period of investigation. Rainfall data are also presented.

TABLE 3
CLIMATIC DATA

Month	1972–73				1973–74				12 Year Mean	
	Monthly Temp. °C		Rainfall mm	No. Wet Days	Monthly Temp. °C		Rainfall mm	No. Wet Days	Monthly Temp. °C	
	Mean Max.	Mean Min.			Mean Max.	Mean Min.			Mean Max.	Mean Min.
March . .	29	18	173	14	33	24	93	10	28	19
Apr . .	27	15	234	4	33	19	106	10	26	16
May . .	22	14	197	12	32	15	51	3	23	12
Jun	20	12	50	11	27	12	39	9	21	10
Jul	20	6	1	2	24	13	725	16	21	9
Aug . .	23	9	Nil	Nil	29	13	14	2	22	9
Sep	24	11	Nil	Nil	29	15	40	6	24	12
Oct	28	14	308	14	30	17	226	10	26	15
Nov . .	28	17	239	5	32	19	59	5	28	17
Dec . .	32	23	10	4	32	20	164	10	29	19
Jan	32	26	219	11	30	22	1 064	19	29	20
Feb . .	32	25	493	15	31	21	283	10	29	20

III. RESULTS

At sites I, II and III, the quantity of nitrogen mineralized by each sampling date was determined by measuring the relative contributions of the soil, grass and leachate components (figures 1, 2 and 3). However, at site IV the leachate component was not estimated. The results presented in figure 4 show only the relative contribution of the soil and grass components.

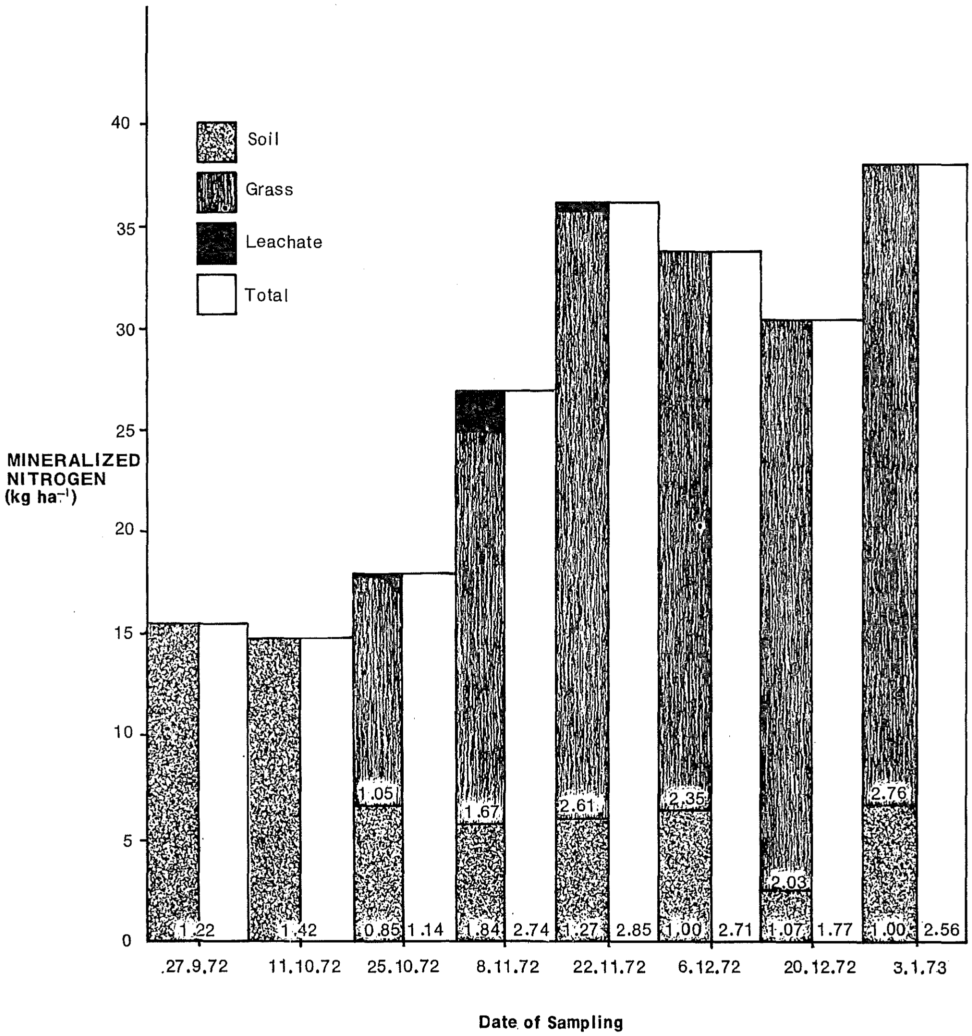

Figure 1.—Relative contribution of soil, grass and leachate to the level of mineralized nitrogen recorded at Site I. Figures in columns are standard errors of the means.

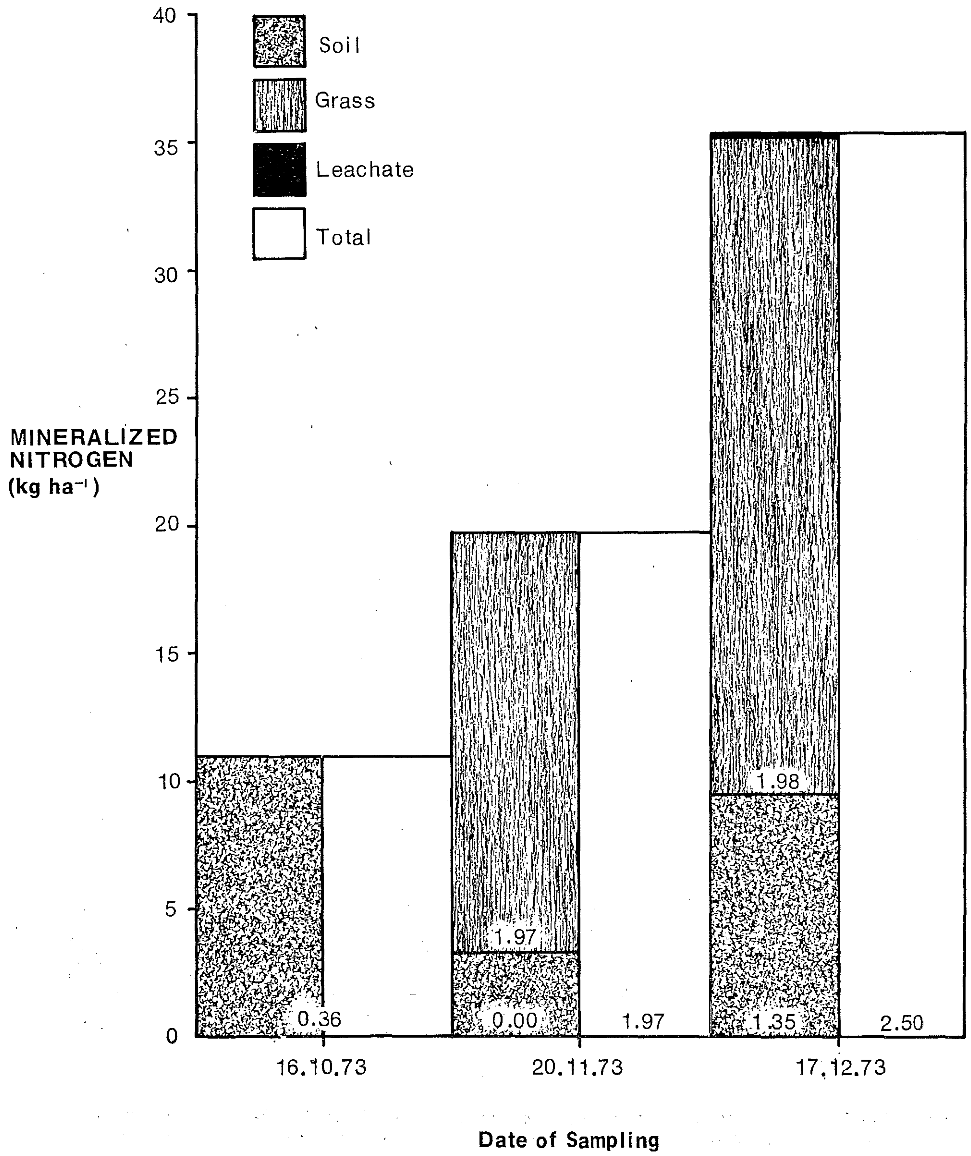

Figure 2.—Relative contribution of soil, grass and leachate to the level of mineralized nitrogen recorded at Site II. Figures in columns are standard errors of the means.

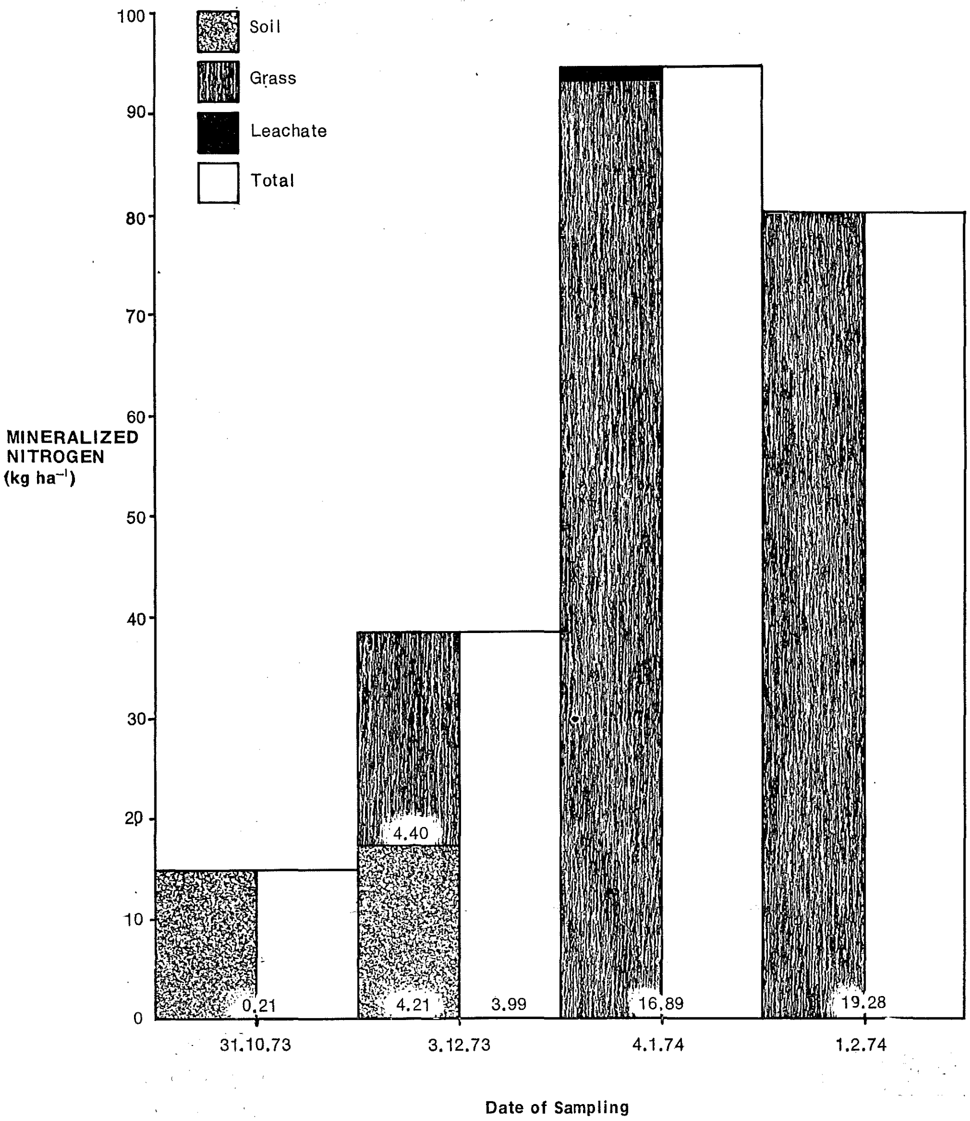

Figure 3.—Relative contribution of soil, grass and leachate to the level of mineralized nitrogen recorded at Site III. Figures in columns are standard errors of the means.

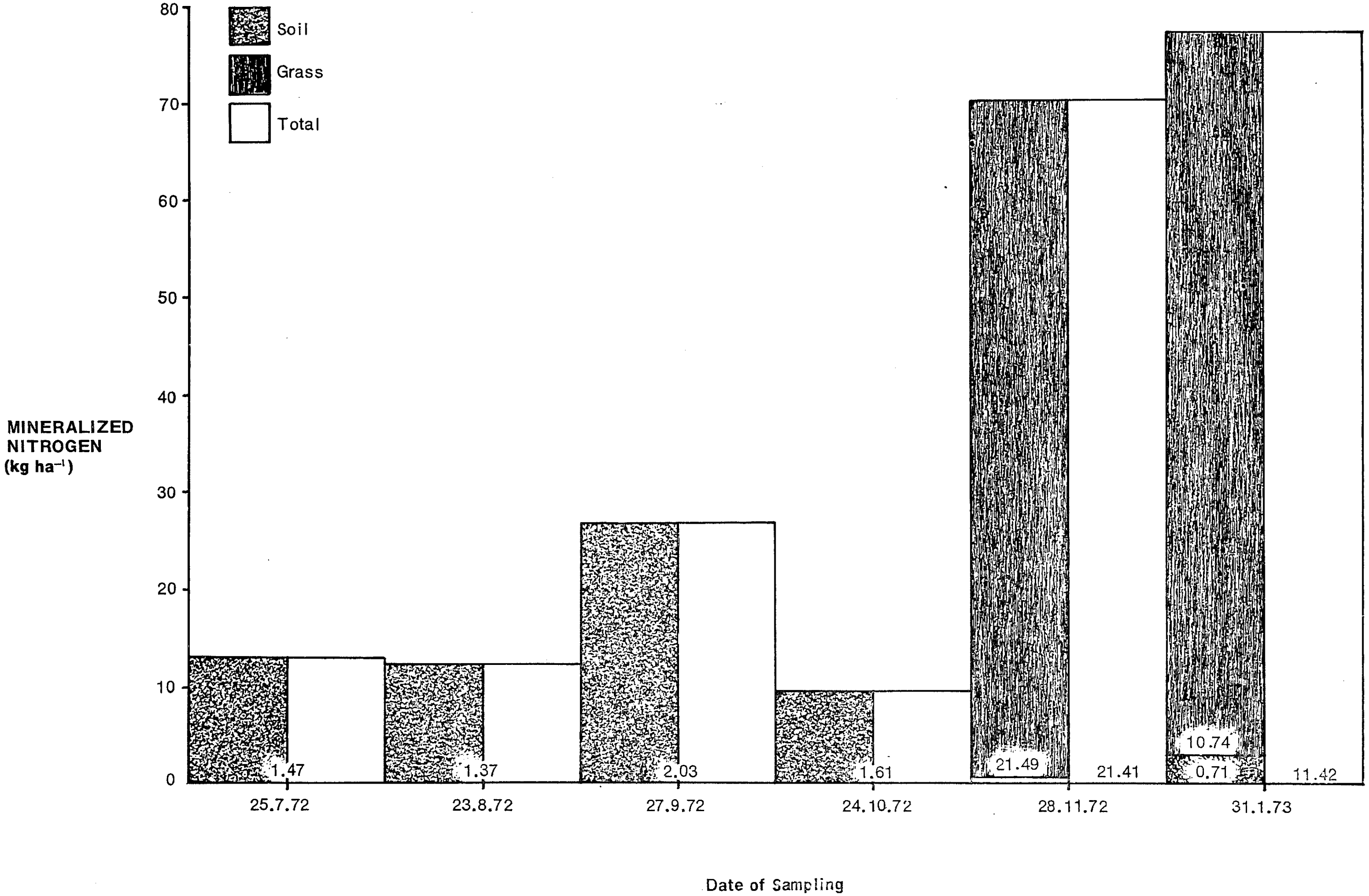

Figure 4.—Relative contribution of soil and grass to the level of mineralized nitrogen recorded at Site IV. Figures in columns are standard errors of the means.

The decrease in the quantity of nitrogen mineralized in October (figure 4) appears to be due to leaching by heavy rainfall (table 3). Since no grass cover existed at site IV during this month, the impact of leaching on the quantity of mineralized nitrogen recorded would be magnified.

Before the last sampling at site III (figure 3), prolonged heavy rainfall (table 3) resulted in the collection of a large quantity of leachate. However, the loss of a considerable portion of this leachate prevented an assessment being made of the quantity of mineralized nitrogen lost.

The standard errors of the means shown in figures 3 and 4 indicate the high degree of variability which existed between the quantities of mineralized nitrogen recorded at each site for the last two samplings. This variability was confirmed in the neighbouring tobacco crops in the form of uneven growth at each site.

The decrease in the quantity of mineralized nitrogen recorded at site I in December (figure 1) was due to a partial removal of the grass cover by grazing animals. The extent of this damage was thought to be small.

Small quantities of mineralized nitrogen were found in the soil at each site initially (figures 1, 2, 3 and 4). This corresponded to the months of September and October for sites I, II and III and to the months of July and August for site IV.

At all sites, the rate at which nitrogen was mineralized increased sharply during the October to December period.

At sites III and IV, the rate of nitrogen mineralization decreased in January. The study at site II was discontinued before this period without showing any evidence of this trend. At site I, the interpretation of the results for the later samplings was complicated by the grazing damage to the grass cover.

IV. DISCUSSION

The results presented in figures 1, 2, 3 and 4 indicate that a regular pattern of nitrogen mineralization exists in tobacco soils of the Moreton district.

In each of the studies, this pattern was characterized by an increase in the rate of mineralization during the October to December period, which coincides with the rapid growth stage of tobacco crops in the area. During the pre-planting months of July and August and the post-planting months of September and October, the level of nitrogen mineralized was found to remain low.

At two of the sites where sampling was extended into January, the rate of release showed a decline suggesting that a maximum level of nitrogen mineralized had been reached. In the Moreton district, tobacco crops usually reach maturity in December-January.

Factors which are likely to have determined this pattern of release are those which regulate the initial process of nitrogen mineralization. Soil temperature (Thompson 1950; Campbell and Biederbeck 1972), soil moisture (Campbell and Biederbeck 1972; Stanford and Epstein 1974) and the carbon to nitrogen ratio of added organic matter (Harmsen and Van Schreven 1955) are three factors which directly affect the ammonification process. Date of ploughing can exert an indirect effect on this process.

The methods used in the above studies determined both ammonium and nitrate ion concentrations in the soil. Any inhibition of the nitrification process by one or more factors would manifest itself as an accumulation of ammonium ions. This would not influence the overall result of any sampling, however, unless the factor was limiting for both the nitrification and ammonification processes.

The temperature and moisture range at which ammonification occurs has been found to be much wider than the range for nitrification (Robinson 1957; Justice and Smith 1962).

A comparison of the ambient temperatures presented in table 3 with those reported by Thompson (1950) and Campbell and Biederbeck (1972) as having an effect on nitrogen mineralization suggests that temperature was a limiting factor for this process during the winter months of 1972 and 1973. Because of the lower winter temperatures in 1972, the degree of limitation may have been greater in that year.

Although no soil moisture data were collected, an analysis of the rainfall data of the 2 years (table 3) shows that winter rainfall during 1973 was much higher and more conducive to nitrogen mineralization than in 1972. However, in spite of this and the higher winter temperatures for this year, the greatest rates of mineralization at sites I and IV conducted in 1972 (figures 1 and 4), occurred one month earlier than at sites II and III conducted in 1973 (figures 2 and 3). This difference in the pattern of mineralization appeared to be a response to the date of ploughing of the residual tobacco crop (table 2).

It is therefore concluded that the pattern and magnitude of the nitrogen mineralized at each site were primarily a function of the nitrogen status of the organic material from the preceding tobacco crop and the date that this was ploughed under early in the year.

Before extrapolating the results of these studies to the tobacco crop situation, it should be noted that the effect of a tobacco root system on nitrogen immobilization and nitrogen uptake patterns may be quite different from that of a grass cover.

Bearing this in mind, the results of the above studies highlight the possible consequences of overlooking the nitrogen mineralizing power of a soil when it is used for tobacco cropping. For example, field planting of tobacco earlier than September should be avoided since plants would reach maturity as the rate of mineralized nitrogen was increasing. For soils with a high nitrogen status relative to the requirements for tobacco, later plantings appear more suitable. By planting in November on these soils, the periods of rapid plant growth and the greatest rate of nitrogen mineralization coincide more closely, and the need to apply an initial nitrogen application may be eliminated.

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