ASSESSING THE POTENTIAL OF SUGAR BELT SOILS TO SUPPLY NITROGEN FOR PLANT CANE

By R. A. WOOD

Summary

Results are reported of incubation studies carried out on the main soil groups within the Sugar Belt, in order to determine their potential to mineralise nitrogen after ploughing out cane.

Marked variation in mineralising capacity was shown ranging from 200-650 lb. sulphate of ammonia per acre equivalent, over a two week incubation, the magnitude of the release being broadly related to increase in soil organic carbon content.

In most soils the major release of mineralisable nitrogen occurred during the first two weeks of incubation. A marked delay in nitrification was noted in the more acid soil groups.

It was established that the magnitude of mineral nitrogen release for any of the soil groups was directly correlated with the length of time the soil was allowed to remain air dry before being rewetted.

The results are discussed in relation to the time of ploughing and replanting, and the incubation technique is suggested as a possible procedure for assessing nitrogen fertilizer requirements of plant cane.

Introduction

It is well known that in general the requirement of plant cane for, and its response to applied nitrogenous fertilizer is very much less than that found in subsequent ratoons. The data presented in Table 1, illustrate this point.

Table 1

Response of Plant and Ratoon Cane to Applied Nitrogen

Plant Cane		Ratoon Cane	
N applied lb. per acre	* Response tons per acre	N applied lb. per acre	* Response tons per acre
50	2.9	100	12.0
100	4.9	200	15.1
150	5.7	300	16.4

* Average of 15 trials.

The main reason for this large difference in response must lie in the fact that the young cane is obtaining much of its nitrogen from some alternative source, namely the soil, while ratoon cane appears unable to do this to any marked extent.

Numerous workers [1, 2, 7, 9, 14] have shown that when a soil is exposed and allowed to air dry, on subsequent rewetting, usually by rainfall or irrigation, it is able to release by a process called mineralisation, considerable quantities of nitrogen. This pattern of release can be repeated many times on the same soil. Mineralisation is the conversion of non available organic nitrogen by soil micro-organisms into the plant available inorganic forms ammonium (NH_4+) and nitrate (NO_3—), and referred to collectively as mineral nitrogen.

It was realised that this process must occur to a certain extent every time ratoon cane is ploughed out prior to replanting, when the soil is exposed to air drying before the next rains commence. On this basis it was therefore decided to investigate by laboratory incubation studies, the relative capacities of the main soil groups within the Sugar Belt to mineralise nitrogen, in an attempt to provide some index of the amount that might become available for crop use under field conditions.

Materials and Methods

Composite field moist samples representing 13 different soil groups were taken from a depth of 0-6 inches under third ratoon cane due for ploughing out and replanting. They were allowed to air dry in the laboratory and subsequently crushed and passed through a 2 mm. sieve, any gravel or large roots being removed, after which they were stored in bottles. Full chemical analysis was carried out on all samples.

The two principal aspects of N mineralisation investigated were:

(*a*) the relative amounts of mineral N ($NH_4 + NO_3$) released by different soils during incubation.

(*b*) the effect of the length of air drying on the amount of mineral N released on rewetting the soil.

In (*a*), Saunder's procedure[6] was used and is now briefly described. Fixed weights of air dry soil were moistened with 0.1 per cent mono-calcium phosphate solution to half water holding capacity and incubated in stoppered flasks at 35° C. The stoppers were removed at weekly intervals and the flasks aerated. Ammonium and nitrate nitrogen were determined by Nesslerisation simultaneously both before and after a particular incubation period in order to obtain an estimate of the N mineralised. This was expressed initially as parts per million (p.p.m.) on an oven dry basis and subsequently converted to lb. sulphate of ammonia equivalent per acre six inches (2 million pounds soil).

For (*b*) an experiment devised by Birch[2] using a macro-respirometer[3] was employed. The groups of air dry soils were moistened to approximate field capacity and placed in the respirometer at 30° C for 14 days. Then six equal amounts of each group were removed from the respirometer and treated as follows:

(i) was extracted immediately for mineral N;

(ii) was returned to the respirometer for a further 19 days after which additional N mineralised was determined by Nesslerisation;

(iii-vi) were air dried for 3, 6, 9 and 12 weeks, respectively, after which they were moistened as before and returned to the respirometer for 19 days, following which the mineral N produced was determined. Samples were also set aside for checking changes in moisture content over the periods of air drying.

Results

The incubation studies verified several important points.

1. It was shown quite conclusively that all the soils examined were capable of mineralising substantial quantities of nitrogen once they had been exposed and allowed to thoroughly air dry. Their capacity to mineralise, however, showed marked variation depending on the soil group and ranged from about 200-650 lb. sulphate of ammonia equivalent per acre over a two week incubation period. A typical set of release figures are given in Table 2.

Table 2

Mineral N Release After 2 Week Incubation Period

Soil Group	% Organic C	Mineral N ($NH_4 + NO_3$) p.p.m. before incubation	Mineral N ($NH_4 + NO_3$) p.p.m. after 2 weeks incubation	N mineralised as S/A equivalent lb./acre 6 inch	Total Min. N present as S/A equivalent lb./acre 6 inch
T.M.S. (ord.)	1.07	10.5	30.0	195	300
Grey Sand	0.93	13.0	34.0	210	340
Beaufort	1.32	17.0	44.0	270	440
M. Ecca	2.11	14.0	46.0	320	460
Dwyka	2.07	34.0	68.0	340	680
L. Ecca	3.78	19.5	56.5	370	565
T.M.S. (mist.)	5.94	18.0	55.5	375	555
Red Sand	0.96	9.5	51.5	420	515
Granite	2.27	12.0	56.0	440	560
T. Schist	2.82	23.0	67.0	440	670
R. Dolerite	3.63	24.0	75.0	510	750
B. Dolerite	5.53	30.0	85.0	550	850
Alluvium	3.11	47.0	111.0	640	1,110

It will be observed that the magnitude of the release is broadly related to the soil organic carbon content with one or two noticeable exceptions. If the available nitrogen present before incubation is also taken into account the total mineral N found after two weeks incubation covers a range of 300-1,100 lb. sulphate of ammonia equivalent per acre.

Table 3

N Mineralised After Incubation for Varying Periods

Soil Group	ppm N mineralised ($NH_4 + NO_3$) after incubation for 2 weeks	4 weeks	6 weeks	8 weeks
T.M.S. (ord.)	14.5	27.5	31.5	36.5
Grey Sand	19.5	27.5	29.5	37.0
Dwyka	22.5	31.5	49.5	65.0
T. Schist	28.5	43.0	61.0	71.0
R. Dolerite	30.5	40.0	53.0	61.5
Alluvium	26.0	36.5	73.0	81.4
B. Dolerite	30.5	44.0	79.5	92.3

2. The major release of mineral N took place in most soils during the first two weeks of incubation, though mineralisation continued at a steady but somewhat reduced rate after this. (See Table 3.)

   Previous work on other crops has shown that N mineralised during this period is approximately of the same order as that released under field conditions during a cropping season and this might apply to plant cane. Saunders[6] notes however that delayed release of N may occur on some of the heavier textured soils soon after ploughing and this would seem to be the case in the Alluvium and Black Dolerite soils shown in Table 3, though after lengthy air drying this effect is not apparent.

3. While ammonification usually proceeded rapidly, some of the soils showed a marked delay in nitrification even after several weeks, and comparative figures are given in Table 4.

Table 4

Delayed Nitrification during Mineralisation of Nitrogen

Soil Group	pH	Total Mineral N (NH_4 + NO_3) produced (p.p.m.)									
		Initial		after 2 weeks		after 4 weeks		after 6 weeks		after 8 weeks	
		NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
No Delay—											
Alluvium	5.50	1.0	34.0	—	67.5	—	78.0	—	114.5	—	122.5
B. Dolerite	5.90	18.0	4.0	—	56.0	—	69.5	—	105.0	—	117.5
T. Schist	5.80	10.0	7.5	—	47.0	—	62.0	—	80.0	—	89.5
L. Ecca	5.80	5.5	8.0	—	29.5	—	41.5	—	51.0	—	61.5
Complete Delay—											
Red Sand	4.80	3.5	3.5	46.5	4.0	54.0	4.0	65.0	4.0	75.5	6.0
Partial Delay—											
Granite	5.10	4.5	2.5	37.0	7.0	28.5	22.5	34.5	21.5	39.5	24.5
M. Ecca	5.20	5.5	2.5	33.0	5.0	44.0	7.0	48.0	8.0	44.0	16.5
T.M.S. (ord.)	4.85	5.5	1.0	16.0	5.0	28.5	6.0	31.5	6.5	35.0	8.5

This was almost certainly due to the higher acidity of the soils concerned assuming that other conditions such as soil moisture, temperature, oxygen supply, etc., were near optimum for nitrate production. The presence of only small numbers of nitrifying bacteria under these conditions initially might well be responsible for the delay noted. As it is believed that cane readily utilizes both ammonium and nitrate nitrogen[8] this delay may be of no great significance, but this aspect of the soil nitrogen problem would probably be worth further investigation.

The results of the respirometer work were in agreement with those obtained by Birch[2], and could be of considerable importance when assessing the potential soil nitrogen supply of plant cane. Table 5 presents the data obtained for the various soil groups.

Table 5

N Mineralisation Data as Pounds Sulphate of Ammonia per Acre 6 Inch After Various Air Drying Treatments

Soil Group	Percentage Organic C.	During 19 Days Moist	Weeks Air-dried Prior to Rewetting				
			0	3	6	9	12
Alluvium	3.11	Amount mineralised	265	613	800	974	1,058
		Percentage moisture before rewetting	—	4.08	3.63	4.49	4.67
Black Dolerite	5.53	Amount mineralised	311	466	628	747	891
		Percentage moisture before rewetting	—	9.81	7.83	8.66	4.67
Lower Ecca	3.78	Amount mineralised	98	455	—	619	744
		Percentage moisture before rewetting	—	3.87	3.32	2.72	3.18
Red Dolerite	3.63	Amount mineralised	133	340	352	606	709
		Percentage moisture before rewetting	—	4.65	4.30	5.34	3.58
Dwyka	2.07	Amount mineralised	98	405	426	553	679
		Percentage moisture before rewetting	—	1.73	1.51	1.30	1.59
T.M.S. (mist.)	5.94	Amount mineralised	139	376	475	590	677
		Percentage moisture before rewetting	—	6.13	5.40	4.46	5.42
T. Schist	2.82	Amount mineralised	153	312	432	503	596
		Percentage moisture before rewetting	—	3.79	2.35	2.53	1.58
Middle Ecca	2.11	Amount mineralised	194	205	287	384	553
		Percentage moisture before rewetting	—	1.32	1.63	1.87	1.38
Granite	2.27	Amount mineralised	169	235	312	394	543
		Percentage moisture before rewetting	—	1.57	1.33	1.50	1.47
Red Sand	0.96	Amount mineralised	69	237	313	409	519
		Percentage moisture before rewetting	—	0.33	0.93	0.49	1.31
Beaufort Sand	1.32	Amount mineralised	37	190	305	373	473
		Percentage moisture before rewetting	—	2.43	1.51	2.31	1.02
T.M.S. (ord.)	1.07	Amount mineralised	151	178	188	370	436
		Percentage moisture before rewetting	—	0.65	0.29	0.54	0.70
Grey Sand	0.93	Amount mineralised	88	168	269	330	380
		Percentage moisture before rewetting	—	0.45	0.36	0.35	0.77

Clearly the amount of N mineralised on rewetting depends on the length of time the soil is allowed to remain air dry after ploughing, while the capacity to mineralise generally increases with increase in carbon content of the soil, as found earlier. The anomalous behaviour of the Table Mountain Sandstone (mist belt) soil can probably be attributed to the fact that only part of the carbon is decomposable, much undecomposable material inert to microbial attack having accumulated under moist, acid field conditions. The lack of significant decreases in moisture content of the soils at the time of rewetting indicate that it is the persistence of the dry state that must be responsible for the increased mineralisation that occurs. Birch[2] has discussed in detail the possible mechanism involved in this effect.

Discussion and Conclusions

The results provide an explanation for the negative or small response to applied nitrogen shown by plant cane in most of the Sugar Belt soils, and also a basis for assessing approximately plant cane fertilizer nitrogen requirements. Obviously much will depend on when the old ratoon cane is ploughed out, and how long and to what degree the soil is left to dry before replanting, as this affects the magnitude of the mineral N release on rewetting. The indications are that earlier winter ploughing than generally practised would be beneficial, particularly on those soils with a relatively low capacity to mineralise nitrogen. The data also suggest that spring planting is likely to be more effective than autumn planting, particularly if the former is completed just before the onset of the main rains. In the latter case the soil is seldom exposed long enough after ploughing out to allow for adequate drying to occur and planting must often take place under moist conditions thereby preventing any large scale mineralisation.

The importance rainfall plays in determining the amount of mineral N produced from a soil in any season must not be overlooked, and should be taken into account when interpreting the results of nitrogen fertilizer trials. For instance excessive winter rains may delay soil drying prior to the arrival of the main rains thus reducing the amount of nitrogen made available to the young cane. On the other hand long dry spells during the main rains may lead to the production of additional nitrogen, at least in the case of plant cane.

It is likely that mineralisation effects persist for some time under ratoon cane especially in some of the heavier soils with high organic matter content, but generally insufficient quantities of nitrogen are mineralised to produce optimum yields and considerable amounts of fertilizer are required. This is probably due to retardation and eventual suppression of mineralisation which apparently occurs under cane as the rhizosphere becomes fully established[15]. Other workers [4, 5, 12, 13] have reported a similar effect under permanent grass leys. In addition, the effect of trashing in reducing mineralisation must be considerable as in many soils this will prevent any marked drying out from occurring, and also reduce soil temperatures, once the trash layer has been formed. In this connection the effects on mineralisation of interrow cultivation of ratoons during the dry season may be worth investigating.

The incubation data obtained indicate that the nitrogen supplying power of some of the sandier soils of low organic carbon content is likely to be insufficient to meet the demands of young cane if maximum yields are to be obtained. This is partially confirmed by past fertilizer trials on some of these soils [10], [11]. N release may also be inadequate in the mist belt soils for reasons given earlier. Future work will therefore be mainly concerned with attempting to establish a closer correlation between mineral N released during laboratory incubation and the amounts of additional nitrogen fertilizer if any, required to produce optimum yields of plant cane within the various soil groups.

References

1. Birch, H. F. (1958). The effect of soil drying on humus decomposition and nitrogen availability. Plant and Soil, 10:9-31.
2. Birch, H. F. (1960). Nitrification in soils after different periods of dryness. Plant and Soil, 12:81-96.
3. Birch, H. F. and Friend, M. T. (1956). Humus decomposition in East African soils. Nature, 178:500-501.
4. Botha, A. D. P. (1963). The influence of grass (Eragrostis curvula) on the ammonium and nitrate nitrogen content of a black clay soil. S.A. Afr. J. Agric. Sci. 6:3-17.
5. Richardson, H. L. (1938). The nitrogen cycle in grassland soils with special reference to the Rothamsted Park grass experiment. J. Agric. Sci., 28:73-121.
6. Saunder, D. H. (1959). Laboratory incubation studies to determine rates of mineralisation of nitrogen and carbon in Rhodesian soils. Proc. 3rd Inter Afr. Soils Conf. Vol. I: 501-511.
7. Saunder, D. H., Ellis, B. S. and Hall, A. (1957). Estimation of available nitrogen for advisory purposes in Southern Rhodesia. J. Soil Sci., 8:301-312.
8. Stanford, G., Ayres, A. S. and Doi, M. (1962). Report Hawaiian Sug. Tech. Conf.:114-120.
9. Stevenson, I. L. (1956). Some observations on the microbial activity of remoistened air-dried soils. Plant and Soil 8: 170-182.
10. Sugar Experiment Station, Mount Edgecombe, Natal (1960). Annual Report for 1959-60, p. 16.
11. Sugar Experiment Station, Mount Edgecombe, Natal (1961). Annual Report for 1960-61, pp. 13-15.
12. Theron, J. J. (1963). The mineralisation of nitrogen in soils under grass. S Afr J. Agric. Sci. 6:155-164.
13. Theron, J. J. and Haylett, D. G. (1953). The regeneration of soil humus under a grass ley. Emp. J. Exp. Agric. 11; 113-124.
14. Winsor, G. W. and Pollard, A. G. (1956). Carbon and nitrogen relationships in soils. IV. Mineralisation of carbon and nitrogen. J. Sci. Food Agr. 7:618.
15. Wood, R. A. (1964). Analogous nitrogen mineralisation effects produced by soils under grass leys and sugar cane. Trans. 8th int. Congr. Soil Sci. (in press).

For discussion on this paper see page 187