THE INFLUENCE OF ROOT C/N RATIO ON NITROGEN AVAILABILITY IN SOILS*

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Abstract

Root material of two C/N ratios (50 and 100) was added to three soils at rates of 0.5% and 1.0%. The soils were moistened with water or tagged $(NH_4)_2SO_4$ and incubated for 112 days.

With or without fertilizer N, the time required to attain maximum immobilization increased as C/N ratio and/or rate of root material increased. Amounts of N remineralized were always greatest at the lowest C/N ratio and root level even in the absence of added N. Throughout, the lower C/N ratio stimulated greater mineralization of untagged soil organic N. Following immobilization of tagged N much of the organic N remineralized came from untagged sources. Carbon balance data showed that net gains in organic matter were always greater at the higher C/N ratio.

Root C/N ratio may strongly influence N nutrition of crops with an extensive root system. In N deficient or poorly fertilized soils high root C/N ratios will develop causing net immobilization of N, so aggravating the deficiency.

Introduction

Legg and Allison[9] have pointed out that the per cent N in roots of plants grown at different N levels indicates the wide range in root C/N ratios obtained under such conditions. Their observation is confirmed by the data given in Table I, which shows the marked lowering of sugarcane root C/N ratios that occurred in a pot experiment when levels of fertilizer N were increased on three different soils. Thus, plants grown at low N levels may add large amounts of material with a high C/N ratio to the soil which, through microbial action, could immobilize much mineral N required by the plant. This situation might readily arise under grass leys or sugarcane, both of which develop a dense root mat capable of providing several tons of roots to the acre (Henzell, *et al.*[6]). The work now reported was designed therefore to examine the effects on nitrogen availability of adding different amounts of root material of variable C/N ratio to several sugar belt soils.

Experimental Procedure

Nitrogen immobilization and mineralization were measured in three soils (see Table II) to which sugarcane root material of two different C/N ratios (approximately 50 and 100) had been added at two rates, namely 0.5% and 1.0%. Controls were also taken to which no root material was added. The soils were moistened to 30% water-holding capacity either with water or a solution of tagged $(NH_4)_2SO_4$ equivalent to 50 ppm N on an air dry soil basis. All treatments were incubated at 30 C for 112 days, samples being withdrawn periodically for mineral and organic N determinations. Carbon mineralization was measured throughout the experiment in all treatments using the modified respirometer technique developed by Birch and Friend[1].

Samples were extracted with acidified N K_2SO_4 and analysed for mineral N. Organic N in the extracted soil was determined by the Kjeldhal method. Isotopic N ratio in all samples was obtained by mass spectrometer analysis.

Results

Changes in Mineral N.—In all soils, whether fertilizer N was present or not, the time required to reach maximum immobilization of N increased as the C/N ratio and/or level of root material

TABLE I

Changes in sugarcane root C/N ratios with different levels of fertilizer N

Soil Series	N applied mg per pot								
	Nil			45			112		
	%C	%N	C/N ratio	%C	%N	C/N ratio	%C	%N	C/N ratio
Clansthal sand	40.1	0.48	83.5	40.6	0.60	67.7	40.7	0.88	46.3
Glenrosa sandy loam	44.9	0.30	149.7	44.8	0.45	99.6	42.8	0.54	79.3
Shortlands clay	44.1	0.53	83.2	43.4	0.64	67.8	43.0	0.92	46.7

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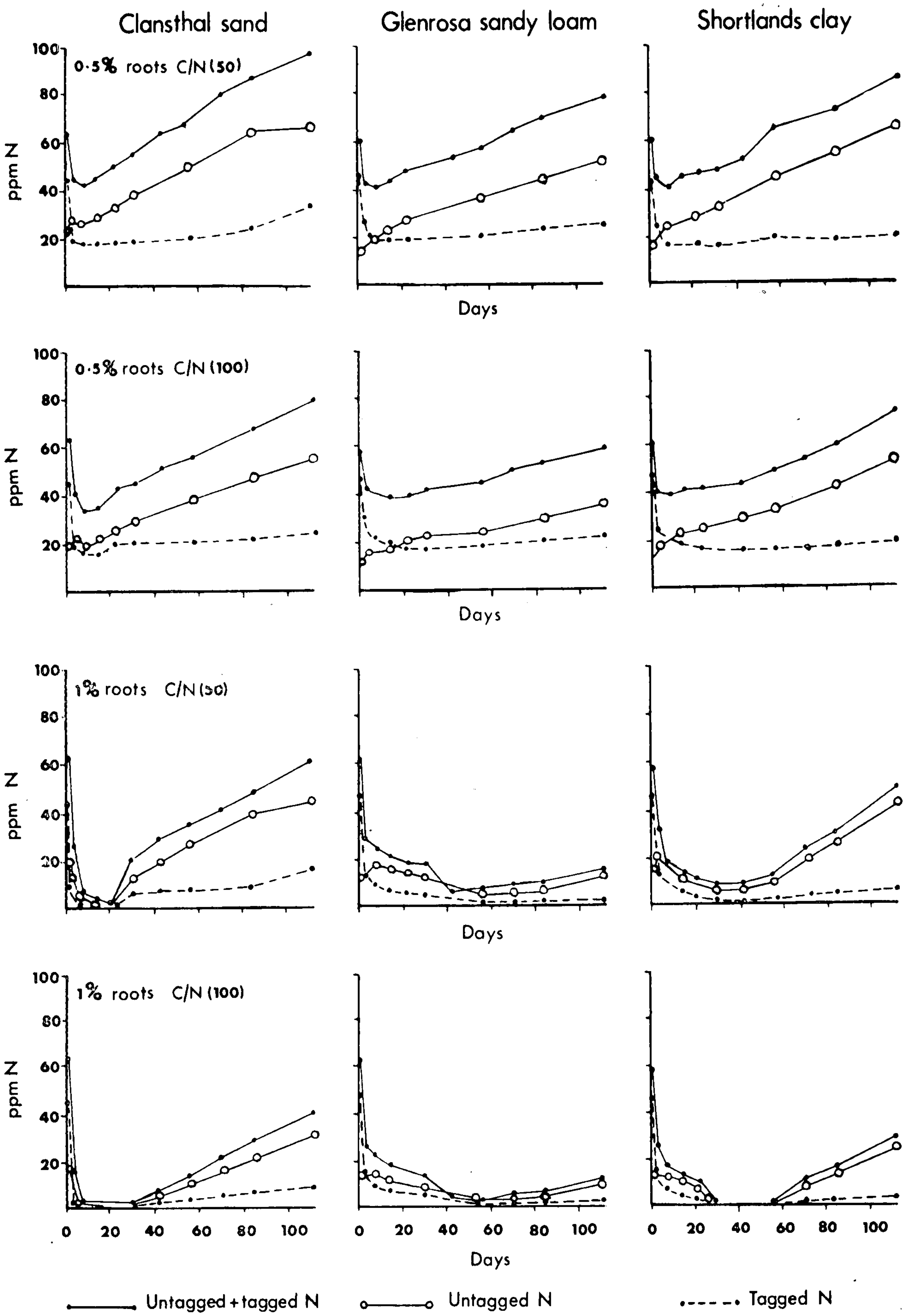

FIGURE 1: Changes in mineral N (NH_4 + NO_3) in three soils receiving tagged $(NH_4)_2SO_4$ and root material of different C/N ratios.

TABLE II
Soils and root material—analytical data

Soil Series	Initial pH	%C	%N	C/N ratio
Clansthal sand	7.2	0.58	.452	11.2
Glenrosa sandy loam	5.3	1.02	.054	18.9
Shortlands clay	6.2	2.52	.186	13.5
Low C/N root ratio		40.0	.785	50.9
High C/N root ratio		44.0	.438	100.5

increased. This is illustrated graphically in Figure 1 by the differences in total amounts of inorganic N present in the fertilized treatments at the end of the incubation period. Where treatments were similar, amounts of immobilized N remineralized differed considerably between one soil and another, but were always greatest at the lower C/N ratio and level of root application, even in the absence of added N as shown in Table III. In all soils at both rates of root addition, the lower C/N ratio stimulated greater mineralization of untagged soil organic N than the higher C/N ratio, over the same period. Where tagged N was immobilized it would appear from Figure 1 that the greater part of the organic N subsequently mineralized in all soils came from untagged sources.

Changes in Organic N.—The amount of added N immobilized by the different treatments in each of the soils may be seen from the tagged N found in the organic phase as shown in Figure 2. This confirms that the extent of immobilization increased as the level of added root material rose and the C/N ratio widened. Following the initial rapid transformation of the fertilizer N from the inorganic to the organic form its comparatively slow remineralization is apparent in all treatments suggesting that it may be retained in this phase over a long period.

Carbon Mineralization.—Carbon balance data for the three soils presented in Table IV, show that apart from the controls, net gains in organic matter were obtained in all treatments and were always greater at the higher C/N ratio. Despite the early positive effect of added N on carbon mineralization this was generally shortlived and after 112 days large negative effects were apparent in most treatments and are reflected in Table IV by the lower net gains in organic matter obtained in the absence of $(NH_4)_2SO_4$. Jansson[7] attributes this to the effect of

TABLE III
Remineralization of N under various treatments (fertilizer N absent)

Root C/N ratio	% root material added	ppm mineral N present after 112 days		
		Clansthal	Glenrosa	Shortlands
50	0.5	59	29	50
100	0.5	45	9	38
50	1.0	53	12	30
100	1.0	22	trace	6

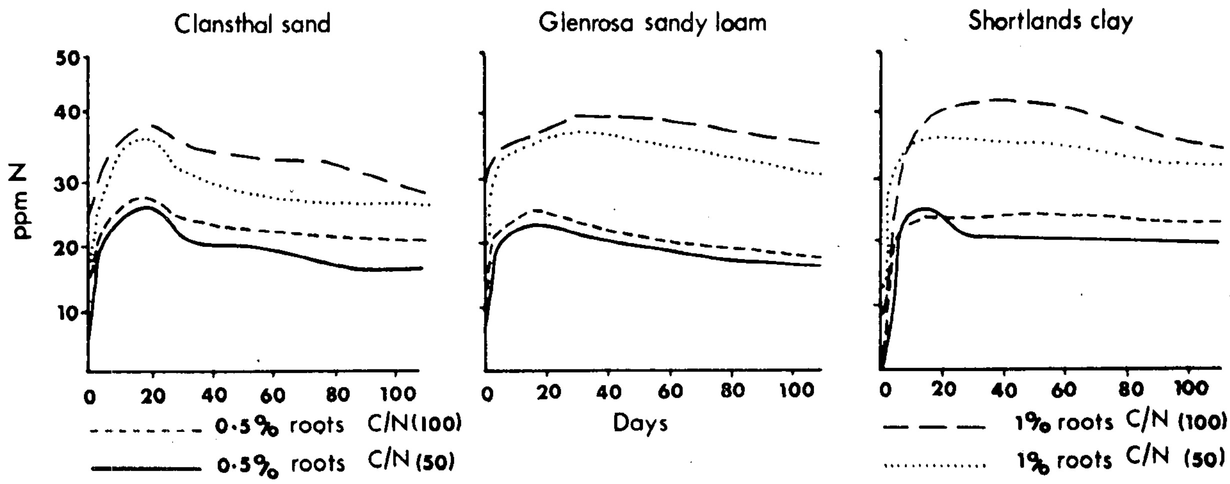

FIGURE 2: Changes in tagged organic N with rate of applied root material and C/N ratio.

TABLE IV
Carbon balance after incubation for 112 days

Soil carbon mg/100 g	Root C/N ratio	% root material added	C added from roots mg/100 g	$(NH_4)_2SO_4$ present: C mineralized (mg/100 g soil)	$(NH_4)_2SO_4$ present: Nett loss or gain in C (mg/100 g soil)	$(NH_4)_2SO_4$ absent: C mineralized (mg/100 g soil)	$(NH_4)_2SO_4$ absent: Nett loss or gain in C (mg/100 g soil)
				Clansthal sand			
580	–	0	0	48.6	−48.6	54.6	−54.6
	50	0.5	200	138.9	+61.1	188.8	+11.2
		1.0	400	279.8	+120.2	342.5	+57.5
	100	0.5	220	133.9	+86.1	195.3	+24.7
		1.0	440	260.9	+179.1	348.7	+91.3
				Glenrosa sandy loam			
1020	–	0	0	32.1	−32.1	38.4	−38.4
	50	0.5	200	85.0	+115.0	144.1	+55.9
		1 0	400	161.5	+238.5	236.3	+163.7
	100	0.5	220	86.6	+133.4	126.3	+93.7
		1.0	440	172.3	+267.7	156.4	+283.6
				Shortlands clay			
2520	–	0	0	62.7	−62.7	76.8	−76.8
	50	0.5	200	156.9	+43.1	189.9	+10.1
		1.0	400	249.0	+151.0	260.8	+139.2
	100	0.5	220	152.9	+67.1	169.8	+50.2
		1.0	440	222.4	+217.6	207.9	+232.1

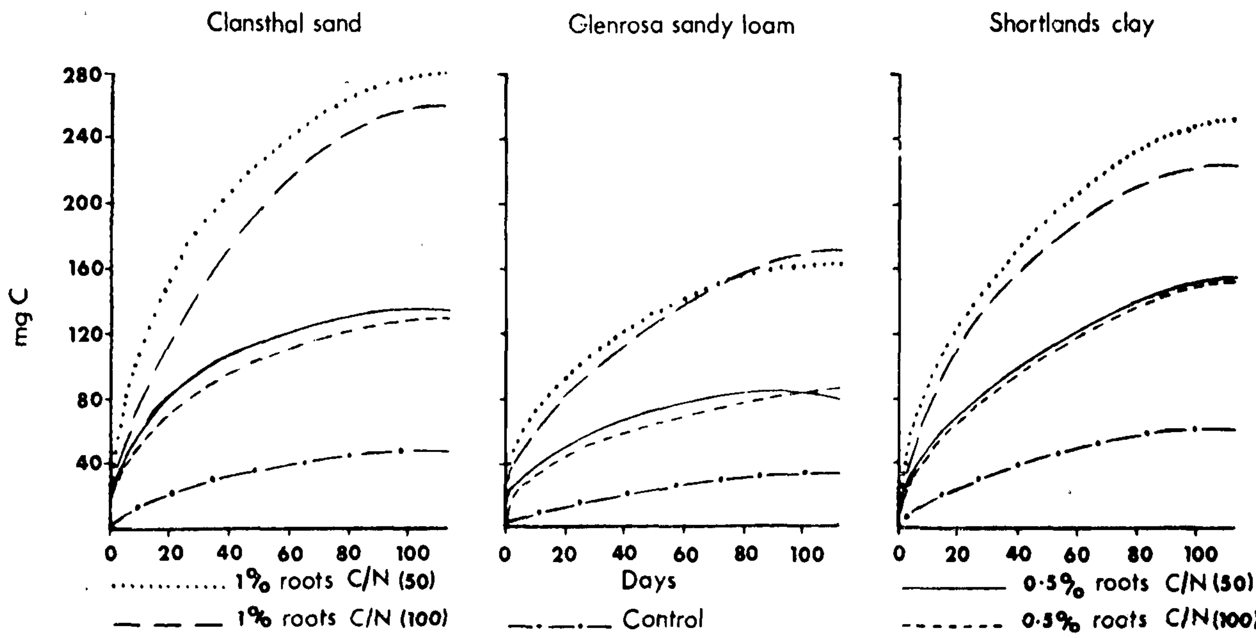

FIGURE 3: Influence of C/N ratio and added root material on carbon mineralization (fertilized soils).

sulphate in lowering pH, thereby reducing microbial activity.

Throughout the greater part of the incubation period carbon mineralization in all soils was enhanced at the lower C/N ratio with or without added N and at both levels of root application. This is shown for the fertilized treatments in Figure 3 which also depicts the greater degree of microbial activity occurring in the Clansthal sand compared with that in the other soils. N mineralization and immobilization rates calculated from the equations of Kirkham and Batholomew[8] confirm the greater activity in this soil, where at the 1.0% level of added root material during the first week of incubation, the rates of mineralization and immobilization were 22 ppm and 30 ppm per day respectively, while for the other soils they averaged only 14 ppm and 20 ppm respectively. Differences in soil pH may be partly responsible as demonstrated by Broadbent and Tyler[3], but rapid decomposition and cycling of N (see Table III) are also features of this particular soil series (Wood[11]).

Discussion

The results indicate that C/N ratios within the rhizosphere may strongly influence the nitrogen nutrition of crops, especially where an extensive root system is produced as is the case with grass leys and sugarcane. Differences in amounts of available N found in the soils at the end of the incubation period following the various treatments, can largely be attributed to the extent to which mineral N was immobilized by micro-organisms associated with the rhizosphere. In the field this mainly depends upon the degree to which such micro-organisms are able to utilize the carbonaceous energy coming from the root system either as exudates or from the dying back of roots which occurs continually under a growing crop.

Harmsen and Kolenbrander[5] state that the significance of immobilization of mineral N in the rhizosphere can be derived from the fact that recovery of applied N in the crop is always much lower than the decrease in amount of inorganic N in the soil during the growth of the crop. This has been confirmed by Goring and Clark[4], Broadbent and Nakashima[2] and others, who have shown that the growing plant is able to exert a depressing effect on net mineralization of soil organic N compared to that occurring in a fallow soil.

Those soils under established leys or sugarcane which are inherently N deficient or inadequately supplied with fertilizer N for maximum plant growth, will tend to produce roots of high C/N ratio and in this environment their exudates will also have a wide C/N ratio. Their decomposition will lead fairly quickly to the exhaustion of the N pool (fertilizer N + soil N), so that the only source of available N remaining will be that mineralized by the soil. Where insufficient mineralized soil N is available for rapid decomposition, which for example may frequently occur under ratoon cane on certain sugar belt soils (Wood[10]), net immobilization of N will result, so aggravating the existing deficiency and generally worsening the N nutrition of the crop. On the other hand, adequate amounts of fertilizer N will have the reverse effect lowering the C/N ratio of roots and exudates, and stimulating increased mineralization of soil derived nitrogen.

Acknowledgements

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Discussion

Mr. Wise: As Mr. Wood states that the nitrogen pool is quickly dissipated in T.M.S. soils should we not split our nitrogen dressings?

Mr. Wood: Not necessarily. If you do not apply enough nitrogen on these soils you will of course not get enough uptake by the plant. When you split dressings you tend to immobilise more nitrogen than you would by a single dressing.

Mr. Odendaal: Leaching of nitrogen has received a lot of attention in the past. Mr. Wood says that inorganic nitrogen is immobilised and becomes organic and therefore lasts longer and is available longer. Considering the losses in the fields through leaching the response to nitrogen under certain conditions is rather remarkable. Can Mr. Wood offer an explanation for this and is it not an indirect contradiction of losses expected from leaching. Mr. Wood's reply to Mr. Wise is in contrast to what we have been led to believe, namely that in a sandy soil a split application would be more efficient than a single application.

Mr. Wood: We have no evidence that splitting an application on sandy soil is beneficial. Most of our fertilizer is applied in the ammonium form which basically takes part in the process of immobilisation. Nitrate nitrogen also takes part but to a far lesser extent and therefore is more subject to leaching as it is not as bound up with the soil complex as ammonium nitrogen.

Mr. Cownie: Are the practical implications of this research that after cutting cane nitrogen should be applied as soon as possible to avoid complete immobilisation of soil nitrogen?

Mr. Wood: No, because the important point is to apply the nitrogen when the plant has developed sufficient roots to take it up. I think it would be preferable to apply nitrogen several weeks after cutting, unless optimum conditions for rapid growth are present.

Mr. Cownie: According to Mr. Glover there is some activity from the old roots and there is very rapid development of new roots, under irrigation conditions, so it would be better to apply the nitrogen straight away.

Mr. Wood: Although by applying fertiliser you will help the decaying material to break down more rapidly I still do not think this is sufficient reason for such an early application, though the period before application could probably be reduced.

Mr. Wilson: The growth analysis experiment at Chaka's Kraal indicated that the major part of a plant's nitrogen requirements was taken up early in its growth.

Mr. Wood: That is why application within the first few weeks of growth is generally most beneficial.

Mr. du Toit (in the chair): We apply nitrogen for the particular crop in question and feel that there is generally little or no carry over of the nitrogen response to subsequent crops. However, we have had experiments where a response has been observed in a subsequent crop after a heavy dose of nitrogen.

Mr. Wood: I do not think that there is any doubt that a residual effect is possible. It was recently shown in Hawaii using ^{15}N labelled fertilizer that under dry conditions a plant crop was not able to utilise much of the applied nitrogen but that the subsequent ratoon benefited considerably from the original fertilizer nitrogen.