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9. ABSTRACT

A property important in the transformation of native nitrogen in soil is the ratio of carbon to nitrogen. This study analyzed the effect on native N transformation in some Hawaiian soils of adding sugar cane bagasse (the crush stalk) and sucrose. The mineralization of native N was curtailed by adding carbon sources in all soils tested. A readily available energy source, sucrose, accelerated and increased the immobilization of native as well as added N more than a slowly available energy source, sugar cane bagasse. The addition of N as ammonium sulfate increased CO_2 production in only one out of five soils when no energy source was added. When an energy source was added, the N addition enhanced CO_2 production in most soils. Without any treatment, the immobilization of added N was related to the soil's ratio of carbon to nitrogen. Maximum immobilization occurred in the soil with the widest C:N ratio.

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DIFFERENTIAL EFFECT OF CARBON SOURCES ON NITROGEN TRANSFORMATION IN HAWAIIAN SOILS

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SUMMARY

Mineralization of native N was curtailed by addition of carbon sources in all soils tested. A readily available energy source, sucrose, accelerated and increased the immobilization of native as well as added N more than a slowly available energy source, sugar cane bagasse. Addition of N as ammonium sulfate increased CO_2 production in only one out of five soils when no energy source was added. With energy source addition, N addition enhanced CO_2 production in most soils. Without any treatment, the immobilization of added N was related to the C:N ratio of the soil; maximum immobilization occurred in the soil with the widest C:N ratio.

INTRODUCTION

Immobilization-mineralization relationships are affected by soil properties and its environment. A property important in this respect is the C:N ratio. Jensen[8] studied ammonium and nitrate production in soils in the presence of organic substances varying in C:N ratios from 10 to 85. In acid soils mineralization took place at ratios of 13.3 or below; in alkaline soils the limiting ratio was 26. However, it is reported that the effect of C:N ratio is modified by the type of organic compound added[10]. It is well established that a substantial amount of fertilizer or soil mineral N is immobilized as organic N during the decomposition of carbonaceous material, and becomes temporarily unavailable to growing plants. In this regard, additions of organic matter, such as straw[3,6], sawdust[2,4], and pine

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needle [9], has been reported to lower the inorganic N content of soils, at least initially. This is a study on the effect of sugar cane bagasse* and sucrose additions on native N transformation, and on added N immobilization in some Hawaiian soils. The production of CO_2 as influenced by these energy sources was also determined.

MATERIALS AND METHODS

Five Hawaiian soils, Wahiawa silty clay (Tropeptic Euthrorthox), Paaloa silty clay (Humoxic Tropohumult), Koko silty clay loam (Ustollic Eutrandept), Lualualei clay (Typic Chromustert), and Akaka silty clay (Typic Hydrandept), were used in this study. Their site of collection and properties are described in an earlier paper (11); however, some of the relevant properties are included in Table 1. Surface samples of these soils were collected and passed through an 8-mesh sieve, except the Akaka which was screened through a 6 mesh sieve because of its high moisture content.

Effect of energy sources on immobilization mineralization of N in the aforementioned soils was studied by adding sugar cane bagasse or sucrose (reagent grade). Evidently, bagasse is a slowly-available and sucrose a readily-available energy source. The bagasse (obtained from the Oahu Sugar Co. Mill, Island of Oahu) contained 0.25% total N and 37.21% organic C (on oven-dry weight basis). Fifty g soil samples were placed in 500 ml Erlenmeyer flasks. Ground bagasse (20-mesh) and sucrose, where needed, were added to give a 1% (by weight) rate. Ammonium sulfate was added at a rate of 200 ppm N. Sucrose and ammonium sulfate additions were made in solution form (5 ml per 50 g soil). Soil moisture was adjusted to approximate moisture equivalent of the soil. Where bagasse was added, an additional 1 ml water was added for each gram of material. The following set of experiments were performed.

TABLE 1

Properties of the experimental soils

Soil	Moisture equivalent %	pH	Total N* %	Organic C* %	C:N
Wahiawa silty clay	30	4.9	0.174	1.44	8.2
Paaloa silty clay	30	3.7	0.252	3.26	12.9
Koko silty clay loam	33	7.2	0.288	3.12	10.8
Lualualei clay	43	7.6	0.099	1.06	10.7
Akaka silty clay	176	4.4	0.812	14.60	18.0

* Values expressed on oven-dry weight basis.

* Bagasse is the remains of the sugar cane stalk after it is crushed for its juice.

1. Native N transformation as influenced by energy sources.
2. Carbon mineralization as influenced by energy sources in the presence and absence of added N, and
3. Immobilization of added N as influenced by energy sources.

In all experiments, samples were incubated up to 23 days and available N and C were determined at periodic intervals. The determination of NH_4- and NO_3-N was done by the extraction-distillation procedure of Bremner [5] and CO_2 by the method described in an earlier paper [1].

RESULTS AND DISCUSSION

Mineralization and immobilization of native soil nitrogen

The data on the effect of carbon sources on native N transformation are given in Table 2. Without any added carbon, there was mineralization of native N in all soils, and the magnitude increased with the length of incubation. But the addition of carbon sources decreased the mineral N in the soils. Sucrose was more effective than bagasse. The latter rendered gradual reduction in mineral N, and it took about 14 days in the Wahiawa and 5 to 8 days in the Lualualei to immobilize all the inorganic N present. In the Paaloa and Koko soils, the reduction was progressive but complete immobilization failed to occur even after the 23-day incubation period. Evidently, addition of bagasse did not make an appreciable difference in the Akaka soil.

Sucrose caused complete immobilization of mineral N in the Koko and Lualualei soils in one day. However, mineralization of immobilized N commenced quite early, *i.e.*, at the 4-day period, in the Koko, and rather late, 23 days, in the Lualualei. Mineral N was completely immobilized in the Wahiawa soil within two days. Like bagasse, sucrose did not immobilize the low mineral N in the Akaka soil. In general, less N was tied up by soils treated with the slowly-available energy material, bagasse, than the readily available source, sucrose.

The mineralization of native N is apparently related to total N and organic C contents of the experimental soils (Table 1). The Koko and Paaloa soils, which contain relatively high total N and C, showed higher mineralization than the Lualualei and Wahiawa soils, which contain low contents of these two elements. On the other hand, the Akaka with the highest total N content showed the least mineralization of organic N. It is highly probable that N in this soil is tied up

TABLE 2

Influence of carbon sources on the available nitrogen status (ppm N) in experimental soils.

Soil	Carbon source	Days of incubation						
		0	1	2	4	8	14	23
Wahiawa	None	38	39	35	45	49	48	49
	Bagasse	—	42	36	31	14	1	0
	Sucrose	—	30	0	0	1	0	0
Paaloa	None	136	137	131	133	151	141	156
	Bagasse	—	132	130	131	135	124	118
	Sucrose	—	126	97	79	42	23	42
Koko	None	82	83	81	99	108	116	107
	Bagasse	—	72	70	75	55	32	17
	Sucrose	—	0	0	1	14	28	44
Lualualei	None	34	34	33	38	40	42	48
	Bagasse	—	30	12	6	0	0	0
	Sucrose	—	0	0	0	0	0	6
Akaka	None	5	5	3	2	13	4	11
	Bagasse	—	2	2	2	2	4	9
	Sucrose	—	2	4	1	4	4	2

in a highly resistant organo-inorganic complex. The retarding influence of allophane in release of N from soil organic matter in the presence of decomposing residues, as reported by Broadbent *et al.*[7], further substantiates this behavior of the Akaka soil. Tamura *et al.*[12] have reported as high as 23 per cent allophane in the clay fraction of this soil.

Mineralization of carbon

The data in Table 3 indicate that the cumulative CO_2 production in all soils for the 23-day period was highest in soils treated with sucrose, followed by those with bagasse, and lastly by those with no carbon source (control). Without an added carbon source, N addition increased CO_2 production only in the Akaka soil. With the addition of bagasse, N addition resulted in a greater production of CO_2 in the Wahiawa, Lualualei and Akaka soils, beginning with the eighth day of incubation. With sucrose addition, N influence on greater CO_2 production was evident with the Wahiawa, Koko, Lualualei and Akaka soils. This influence was not evident at the first day of incu-

TABLE 3

Cumulative carbon dioxide production (mg C/50 g soil) in soils receiving carbon sources with or without 200 ppm NH_4-N.

Soil and carbon source	Without NH_4-N				With NH_4-N			
	Days							
	1	8	14	23	1	8	14	23
Wahiawa								
None	1	3	4	5	0	3	4	5
Bagasse	1	7	24	35	1	22	41	60
Sucrose	2	102	126	141	4	135	146	153
Paaloa								
None	0	2	3	5	1	3	5	7
Bagasse	0	9	15	23	1	10	17	28
Sucrose	4	116	131	140	5	118	130	142
Koko								
None	7	22	28	36	7	23	30	38
Bagasse	7	60	79	102	7	63	87	107
Sucrose	46	121	138	160	73	139	153	169
Lualualei								
None	6	26	32	39	6	26	32	36
Bagasse	7	55	73	93	8	62	85	107
Sucrose	31	126	142	157	66	160	173	183
Akaka								
None	2	20	32	49	4	30	46	67
Bagasse	3	28	44	64	4	34	54	81
Sucrose	39	98	118	141	38	111	132	157

bation for the Wahiawa and Akaka soils (as contrasted to the Koko and Lualualei soils which showed increased CO_2 evolution at the first day) but was evident at the eighth day. Of added sucrose - C, 65, 64, 59, 56, and 44 per cent without N and 71, 64, 62, 70, and 43 per cent with N were mineralized, respectively, for the Wahiawa, Paaloa, Koko, Lualualei and Akaka soils. Of added bagasse - C, 16, 10, 35, 29 and 8 per cent without N and 30, 11, 37, 38 and 8 per cent with N were mineralized, respectively, for the same five soils. Whatever stimulation in CO_2 evolution upon the addition of N is undoubtedly due to the availability of more nutrients to microorganisms. Similar results were reported by Allison and Cover [2] for wood and straw with the addition of ammonium nitrate.

Immobilization of added nitrogen

Immobilization of added N at all periods and in all soils was greatest with sucrose, followed by bagasse and control in a decreasing order (Table 4). This is due to the fact that the energy is quickly available in sucrose and slowly in bagasse. It appears that in the presence of an energy source the influence of nitrogen on CO_2 production is relatively little (as shown by the data in Table 3) as compared to the big influence on N immobilization (Table 4). It can therefore be concluded that microorganisms use much N if available but are not very sensitive to N deficiency. Without an energy source, the immobilization of added N seems to be related to the C:N ratio of the soils. Maximum N was immobilized in the Akaka and least in the Wahiawa; C:N ratio is widest in the former and narrowest in the latter (Table 1). The Paaloa and Wahiawa soils appeared to be the lowest and slowest immobilizers, especially in the absence of sucrose. It should be noted that the CO_2 production (Table 3) in the Paaloa soil was also low, although organic C and the C:N ratio of this soil are high. Low biological activity because of extreme acidity and nutrient deficiencies may account for the low CO_2 production

TABLE 4

Influence of carbon sources on the immobilization (%) of 200 ppm NH_4-N in the soils.

Soil	Carbon source	Days 1	2	4	8	14	23
Wahiawa	None	6	3	8	10	9	6
	Bagasse	7	6	14	28	38	51
	Sucrose	31	74	86	95	99	93
Paaloa	None	5	3	6	6	5	14
	Bagasse	10	3	8	18	16	31
	Sucrose	17	12	51	59	66	63
Koko	None	15	12	17	26	31	24
	Bagasse	19	16	34	51	65	74
	Sucrose	100	100	100	100	100	100
Lualualei	None	14	11	16	19	23	26
	Bagasse	18	18	38	49	66	68
	Sucrose	100	100	100	100	100	100
Akaka	None	36	38	39	49	43	56
	Bagasse	40	39	40	45	50	66
	Sucrose	64	78	84	91	98	100

and N immobilization in this soil. Unlike the other three soils, the Lualualei and Koko soils tied up all the added N in one day, and kept it immobilized during the rest of the incubation period. Similar results were obtained with the immobilization of native N discussed previously.

Relationship between cumulative CO_2 production and added N immobilized in the presence of sucrose

In Figures 1 and 2 are given the cumulative CO_2 production, with

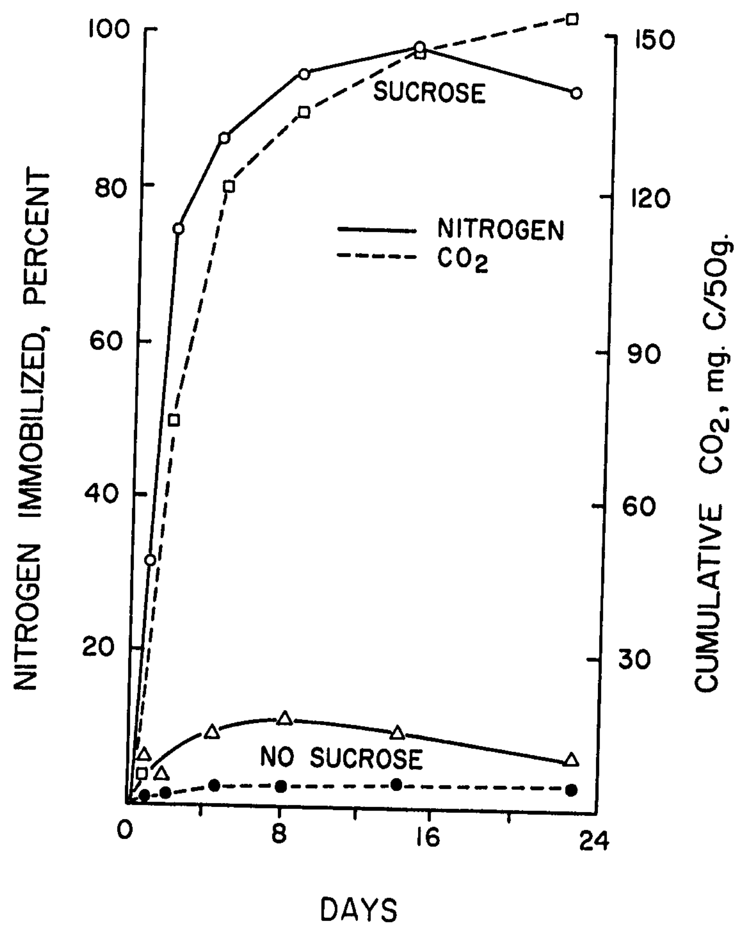

Fig. 1. The immobilization of nitrogen and the cumulative CO_2 production in Wahiawa soil receiving sucrose and NH_4-N.

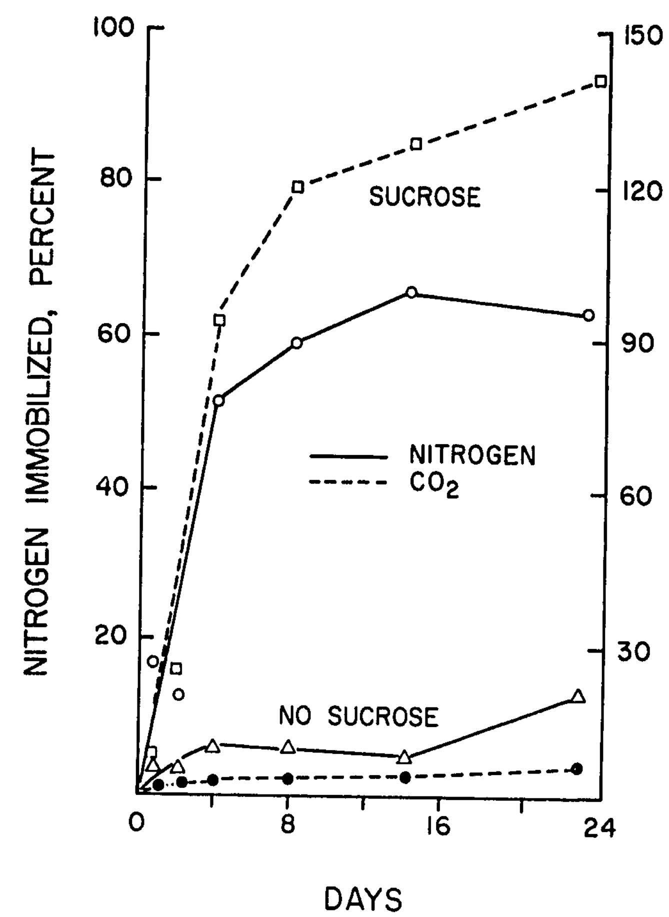

Fig. 2. The immobilization of nitrogen and the cumulative CO_2 production in Paaloa soil receiving sucrose and NH_4-N.

and without the addition of sucrose, and concurrent addition of N. Together with CO_2 production, corresponding immobilized N values under similar conditions are plotted. In the Wahiawa soil (Fig. 1) nitrogen immobilization preceded CO_2 production in both sucrose-treated and no sucrose samples. This trend was also found for the Koko, Lualualei and Akaka soils (no figures are presented for these latter three soils because of this similar pattern). In all of these four soils there was a rapid tie-up of added N initially in sucrose-treated samples. This was accompanied by a high rate of CO_2 production in these samples. Evidently the organisms involved in N immobilization were very active in these soils. In the Paaloa soil (Fig. 2), however, the trend was not the same. CO_2 production preceded N immobilization in the sucrose-treated samples while N immobilization preceded CO_2 production in the no sucrose samples. As earlier pointed out, the Paaloa soil is low in biological activity because of extreme acidity and nutrient deficiency and this is believed to account for low N immobilization, even in the presence of an added energy source.

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