Research Note

Short-Term Incubation Method for Mineralizable Nitrogen

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Soil N supply plays an important role in the N nutrition of cereal crops under dryland agriculture conditions in the semiarid tropics, where the use of chemical fertilizers is low. Mineralizable N was determined in the profiles of a benchmark Vertisol and Alfisol in the semiarid zone of India using three versions of a water-logged incubation method: incubation at 30°C for 14 days, at 40°C for 7 days, and at 50°C for 2 days. Mineralized N decreased with depth in the profile and increased with increase in temperature from 30° to 50°C. The mineral N released in the soils at 40°C in 7 days and at 50°C in 2 days were significantly correlated with the mineral N released in 14 days at 30°C. The results indicate that short-term water-logged incubation test using incubation for 2 days at 50°C may be employed for assessing the potentially mineralizable N in these soils.

Keywords Alfisol, N mineralization, semiarid, temperature coefficient, Vertisol, waterlogged incubation

The low-N status of most semiarid tropical soils has been recognized, but fertilizer use in rain-fed agriculture across the Indian semiarid tropics is low except with irrigation (Burford et al., 1989; Tandon & Kanwar, 1984). The indigenous soil N supply plays an important role in the agriculture system where the mineral inputs of fertilizer N are minimal.

Vertisols and Alfisols are the two important soil orders in the Indian semiarid tropics. The soils are low in organic matter but moderate to rich in bases (El-Swaify et al., 1985). Cereal crops such as sorghum are grown on these soils with low inputs of fertilizer N. These crops are deep rooted, especially when grown under non-irrigated conditions, and explore water and nutrients from the entire soil profile. For example, sorghum crops were reported to extend roots deeper than 1 m, and the rooting depth was deeper under nonirrigated than irrigated conditions (Lee et al., 1996).

The N supplying capacity of the soil under rain-fed agriculture conditions is better evaluated on a profile basis. Information on the distribution of potentially mineralizable N in the semiarid tropical soils is scarce (Burford & Sahrawat, 1989) despite its importance in rain-fed agriculture. In view of the importance of the soil N supply, it was decided to study the distribution of potentially mineralizable N, as affected by temperature in the range relevant to the semiarid regions, in profiles of

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benchmark Vertisol and Alfisol soils in the Indian semiarid tropics. At the International Crops Research Institute for the Semiarid Tropics (ICRISAT) in Patancheru, temperature of the surface (0–5 cm) soil can be 55°c or higher during the summer months of April and May before the onset of rains by mid-June. The soil temperature may range from 20 to 35°C during the rainy season (mid-June to October) (Sahrawat, 1984).

Soil profiles from the Kasireddipalli Series (Vertisol) and Patancheru Series (Alfisol) were studied. Some characteristics of the soils in the two profiles are shown in Table 1 The Kasireddipalli Series is a Typic Pellustert developed on basaltic alluvium on the lower pediments and in depressions. The soil samples were collected from a profile at ICRISAT. The Patancheru Series, also located at ICRISAT, is in the clayey-skeletal mixed isohyperthermic family of Udic Rhodustalf developed on weathered granite (Sahrawat, 1995).

Soil samples were collected by horizon from the two profiles, air-dried, and ground to pass a 2-mm sieve before analysis (Table 1). For organic C and total N analysis the samples were ground to pass a 0.25-mm sieve.

For the soil analysis reported in Table 1, *p*H was measured in a soil to water ratio of 1:2. Organic C was determined by using the Walkley-Black method (Nelson & Sommers, 1982). Total N was determined by using a macroversion of the Kjeldahl method, modified to include nitrate and nitrite using thiosulfate (Dalal et al., 1984).

The waterlogged incubation method described by Waring and Bremner (1964) with the modification suggested by Sahrawat and Ponnamperuma (1978) was adopted for determining the mineralizable N in the soil samples at 30, 40, and 50°C. In the modified method used, instead of directly distilling the incubated soil samples with MgO, they were first extracted with 2 *M* KCl, and filtered extracts of soil

TABLE 1 Soil characteristics and mineralizable N in soil profiles

Horizon	Soil depth (cm)	*p*H	Organic C ($g\ 100 \times g^{-1}$)	Total N ($mg\ kg^{-1}$)	N mineralization rate ($mg\ N\ kg^{-1}$ soil d^{-1}) 30°C	40°C	50°C
			Alfisol (Udic Rhodustalf)				
Ap	0–10	6.3	0.62	530	1.4	4.6	7.5
B1	10–20	6.4	0.66	650	1.4	3.9	6.0
B21t	20–49	6.7	0.63	780	1.3	2.4	6.5
B22t	49–102	6.6	0.49	510	0.9	2.0	6.0
Bc	102–145	7.4	0.20	190	0.5	1.4	4.5
C	145–160	8.0	0.10	130	0.5	1.7	4.5
	0–160				6.0	16.0	35.0
			Vertisol (Typic Pellustert)				
Ap	0–15	8.3	0.66	600	1.9	5.3	14.5
A11	15–40	8.5	0.33	380	0.9	1.3	5.0
A12	40–90	8.9	0.37	330	0.9	1.7	5.0
A13	90–105	8.9	0.29	280	0.9	1.9	5.0
Ac	105–150	8.7	0.18	210	0.9	1.9	4.5
	0–150				5.5	12.1	34.0

samples were used for the determination of ammonium released. Three versions of the incubation test, involving incubation at 30°C for 14 days, incubation at 40°C for 7 days, and incubation at 50°C for 2 days, were employed for determining the potentially mineralizable N.

Portions of soil (10 g) were placed in test tubes containing 20 mL of distilled water to give a standing water layer of 2–3 cm. The soil samples were slowly transferred to the test tubes containing water to minimize trapping of air. The test tubes were covered with aluminum foil and incubated at 30°C for 14 days, at 40°C for 7 days, and at 50°C for 2 days.

All determinations were made in two replicates, and the results were expressed on an oven-dry weight basis. The values of mineralized N reported are the net values of ammonium N released during the incubation period.

The soils were low in organic matter, as measured by organic C and total N, which is the source of potentially mineralizable N. The organic C content in the Alfisol (Patancheru) profile ranged from 0.10 to 0.62%, and in the Vertisol (Kasireddipalli) profile, it ranged from 0.18 to 0.66%. Organic C decreased with depth in the two profiles (Table 1). Total N content in the two profiles also was low and ranged from 130 to 780 mg N kg^{-1} soil.

The production of mineral N in the two profiles decreased with depth and increased with an increase in the incubation temperature from 30 to 50°C (Table 1). The rate of mineral N released from the soil organic N was highest in the Ap horizons of the two soils. The mineral N release rates in the lower horizons of the Vertisol profile were similar and showed little variability. On the other hand, the rates of soil N mineralization decreased gradually with depth in the Alfisol profile. The low variability in soil N mineralization rates in the Vertisol profile can be caused by the pedoturbation process due to shrinking and swelling of clays, which leads to mixing of soil materials from different horizons (e.g., Gehring et al., 1997). The mixing of soil materials from different horizons may lessen the soil variability in the profile. The pedoturbation effects are highly pronounced in the semiarid zones of India, for example, in the Vertisols located at ICRISAT.

The mineral N release rates at 30°C ranged from 0.5 to 1.4 mg N kg^{-2} soil d^{-1} in the Alfisol profile and from 0.9 to 1.9 mg N kg^{-1} soil d^{-1} in the Vertisol profile. The cumulative mineral N release rates in the Alfisol and Vertisol profiles were 6.0 and 5.5 mg N Kg^{-1} soil d^{-1}, respectively (Table 1). The results suggested that the potentially mineralizable N in the two soils was rather similar.

On average, with the increase in temperature from 30 to 40°C, the soil N mineralization rate increased by 2.7 times in the case of the Alfisol profile and 2.2 times in the case of Vertisol. With increase in temperature from 40 to 50°C, the temperature coefficient or Q_{10} for soil N mineralization was 2.2 for the Alfisol profile and 2.8 for the Vertisol profile (Table 2). The average Q_{10} value for soil N mineralization in the two soil profiles was similar for the 30–40 and 40–50°C temperature ranges. This indicates that the mineralization of soil N in the temperature range examined is similarly affected for the two soils.

Soil N mineralized at 40°C in 7 days and 50°C in 2 days was significantly correlated to the N mineralized at 30°C in 14 days. The regression equations describing the relationships are as follows:

$$\text{Soil N mineralized (mg kg}^{-1}\text{) at 40°C in 7 days} = -3.84 + 1.45\,(\text{N mineralized at 30°C in 14 days}) \qquad r^2 = 0.803\ (n = 11) \quad (1)$$

TABLE 2 Temperature coefficients or Q_{10} values for soil N mineralization in two soils

Soil	Q_{10} value at specified temperature	
	30–40°C	40–50°C
Alfisol (Udic Rhodustalf)	2.7	2.2
Vertisol (Typic Pellustert)	2.2	2.8
Mean	2.45	2.50

Data are averaged over soil depths for a temperature.

$$\text{Soil N mineralized at 50°C in 2 days} = 0.66 + 0.78 \text{ (N mineralized at 30°C in 14 days)} \quad r^2 = 0.615 \ (n = 11) \quad (2)$$

These results indicate that the short-term waterlogged incubation test, involving incubation of soil samples at 40°C for 7 days, but more importantly, the method involving incubation of soils at 50°C for 2 days, may be employed for determining the potentially mineralizable N in the soils of the semiarid tropical zones. The proposed short-term incubation method thus merits further evaluation for assessing potentially mineralizable N. It has been recognized that this was a preliminary study where the results obtained were based on two replicate tubes by using two sets. For proper evaluation of results obtained by this method, a minimum of three replicate tubes in three separate sets should be used for each value reported.

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