Indian J. Agric. Res., 36 (4) : 282 - 285, 2002

CHANGES IN PHYSICO-CHEMICAL PROPERTIES AND NITROGEN TRANSFORMATION IN THE ROOT-ZONE SOIL OF DIFFERENT RICE CULTIVARS IN PROBLEM SOILS

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ABSTRACT

A pot culture experiment was conducted to study physico-chemical and chemical properties of soils as influenced by root system of two rice varieties in acid and alkali soils and also nutrient uptake by rice varieties. It was observed that the submergence increased the pH considerably in acid soils and marginally in alkali soils while EC increased in both the soils. But in root-zone soil, the pH increased in acid soil and decreased in alkali soil. Root-zone soils recorded high NH_4-N, low organic-N, available-N and total-N. The increase in NH_4-N content was more pronounced in alkali soil than in acid soil. But the uptake of rice varieties under acid soil was more than the varieties under alkali soil.

INTRODUCTION

The root-zone soil differs physico-chemically, chemically and biologically from bulk soil (Carson, 1974). These differences have direct effect on the available plant nutrients. Besides these, the oxygen diffusion through roots of rice under flooded conditions also alters the chemical nature of the root-soil interface. Both susceptible and resistant varieties to iron toxicity performed well in the two problem soils *viz.*, acid and alkali. However, mechanisms for the better establishment under the acid or alkali stress are not known. A through investigation on the physico-chemical, chemical and biological dynamics of the rice root-zone region will reveal the nature of such mechanisms. But only very few studies had been carried out on the root-zone soil. This paper reveals the changes in pH, EC, nitrogen transformation and the interrelationship between forms of nitrogen in the root-zone of different rice cultivars and unplanted soils.

MATERIAL AND METHODS

A pot culture experiment was conducted at the Agricultural College and Research Institute, Killikulam (TNAU) during 1995-96. Bulk samples of acid soil was collected from Rice Research Station, Ambasamudram and alkali soil was collected from the Agricultural College and Research Institute, Killikulam. These soils were classified as Typic Ustropepts and Typic Rhodustalfs.

The soil samples were processed and analyzed for pH and electrical conductivity (Jackson, 1973); CEC, ammoniacal nitrogen and total nitrogen (Piper, 1966); nitrate nitrogen (Bremner and Keeney, 1966); available nitrogen (Subbiah and Asija, 1956); organic carbon (Walkey and Black, 1934); available-P (Bray and Kurtz, 1945) and available-K (Stanford and English, 1949) by standard methods.

The acid soil had a pH of 5.21, EC of 0.10 dsm^{-1}, CEC of 4.20 $Cmol(p^+)kg^{-1}$, organic carbon of 0.94%, organic-N of 513ppm, NH_4-N of 28ppm, NO_3-N of 128ppm, available-N of 280.5 ppm, total-N of 570 ppm, available-P of 26.5 ppm and available-K of 111 ppm. The alkali soil had a pH of 8.52, EC of 0.18 dsm^{-1}, CEC of 10.0 $Cmol(p^+)kg^{-1}$, organic carbon of 0.87%, organic-N of 672 ppm, NH_4-N of 9.8 ppm, NO_3-N of 74 ppm, available-N of 214.5 ppm, total-N of 540 ppm, available-P of 8.5 ppm and available-K of 155 ppm.

Five kg of processed soil was transferred to specially design tubular pots of 30 cm height and 20 cm diameter. The soil

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was hand puddled and the water level was maintained at 5 cm level throughout the experiment period. Twenty-three days old seedlings of the rice varieties ASD-18 and IET-1444 were planted in pots at two population levels equivalent to 66 hills m^{-2} and 115 hills m^{-2}. Ten pots were maintained without any plant (unplanted soil) under above said similar conditions. In other pots gap filling was done after a week of transplanting to ensure uniform population levels. Fertilizer was applied at the rate of 100-50-50 NPK kg/ha. Half of the nitrogen, entire phosphorus and potassium were applied as basal. The other half of the nitrogen was applied in two splits; one at the maximum tillering and the other at flowering stage. Adequate plant protection measures were given. At the time of collecting the soil samples from pot, the flood water in the pots were drained, and the pots were gently turned upside down and the soil core was allowed to slide down on a polythene sheet spread on the table. The soil volume permeated by the root system (Rhizosphere soil) was collected and analyzed for pH, EC, and various forms of nitrogen. The bulk soil (unplanted soil) was also collected and analyzed for pH, EC, and nitrogen content.

The plant samples collected were powdered and used for analysis of nitrogen by Microkjeldahl method (Humphries, 1956). The data collected were analyzed in FRBD following the procedure given by Gomez and Gomez (1984)

RESULTS AND DISCUSSION

The pH of the acid and alkali dry soils was 5.21 and 8.52 respectively. In both the soil, the pH increased due to submergence. But in planted condition, both in acid and alkali soils, the changes were more towards the neutral condition and attained the value of 7.08 and 8.01 respectively.

Table 1. Mean values of changes in pH and EC in the root-zone and unplanted soils

Properties	Dry soil		Unplanted soil		Root-zone soil			
	Acid	Alkali	Acid	Alkali	Acid		Alkali	
					ASD 18	IET 1444	ASD 18	IET 1444
pH	5.21	8.52	8.05	8.83	7.17	6.99	7.97	8.04
EC	0.10	0.18	0.23	0.27	0.24	0.23	0.34	0.34

Normally submergence leads to gradual increase of pH in acid soils and decrease of pH in alkali soils (Ponnamperuma *et al.*, 1966; Mukherjee and Basu, 1971). However, this trend was observed only under planted condition in this study. Under unplanted condition because of the presence of $CaCO_3$ in alkali soils, the pH did not decrease to neutrality. The organic matter along with calcium carbonate would not have produced sufficient amount of CO_2 to lower the pH (Yamane, 1978). But in the presence of plants there seems to be a presence of regulatory mechanism by the root system on the root environment. So the root-zone soil reduces the pH to neutrality. Similar observation has been reported by Grinsted *et al.* (1982) and Leticia *et al.* (1989). The reason attributed for this is that the pH is regulated by hydration of CO_2 to carbonic acid (Brady, 1974), release of cellular organic acids (Carson, 1974; Leticia *et al.*, 1989) and the imbalance of cation and anion uptake and the associated release of protons (H+) or hydroxyl (OH-) or buffering effect of exuded organic compounds from roots.

The EC of both the soils increased both under planted and unplanted condition. This increase in the EC was more under planted soils than the unplanted soils indicating the influence of root effect on this electro-chemical property. The increase in the conductance of soil solution due to submergence have been attributed to the mobilization of Fe^{++}, Mn^{++}, NH_4^+, HCO_3^-, $RCOO^-$ and displacement of cations by soil colloids by Mn^{++}, Fe^{++}, etc. as reported by Ponnamperuma (1972; 1978), Patrick and Reddy (1978) and Yamane (1978).

This increased EC in the root-zone soil may be attributed to the following reasons. The increase in CO_2 concentration in the root-zone due to metabolic activities of roots and microorganisms, which in turn solubilized the $CaCO_3$ resulting in the contribution of Ca ions towards EC (Broadfield, 1941). Secondly, the organic acids diffused by rice roots and synthesized by microorganisms would have solubilized several insoluble compounds of soil resulting in cations and anions which could increase the EC and lastly, when mass flow supplied more nutrients to root-soil interface than the root can absorb, its concentration in root surface increases but decreases away from the root (Barber, 1984).

The water extractable and exchangeable NH_4-N content in dry soil was 18.9ppm. It was more in root-zone soil (44.25ppm) than unplanted puddled soil (30.68ppm). The increase in NH_4-N under planted condition was due to higher rate of mineralization of organic matter as evidenced by decrease of organic-N and total-N in planted soils.

The increase in NH_4-N was more pronounced in alkali soils (52.17ppm) than in acid soils (36.33ppm). This can again be attributed to higher mineralization rate of organic matter in root-zone alkali soil. Mengel (1985) reported NO_3-N does not accumulate during rice growth in soil and thereby provided indirect evidences for the accumulation of NH_4-N in the root-zone soil.

The available-N ($KMnO_4$ oxidisable N) was higher both in dry soil (247.5ppm) and unplanted soil (192.73ppm) than that of root-zone soil (126.92ppm). The decrease in available nitrogen was more pronounced in alkali soil (Table 2). The alkaline permanganate oxidisable nitrogen represents easily oxidisable organic-N. Such easily oxidisable organic-N compounds would have been more in alkali soil than in acid soil and the resulted NH_4-N could have been lost and leading to low available-N in the root-zone of alkali soils.

Table 2. Changes in NH_4-N, available-N, organic-N and total-N (ppm)

Forms of nitrogen	Dry soil		Unplanted soil		Root-zone soil	
	Acid	Alkali	Acid	Alkali	Acid	Alkali
NH_4-N	28.00	9.80	30.77	30.60	36.33	52.17
Available-N	280.50	214.50	194.25	191.21	141.58	112.26
Organic-N	513.00	672.00	496.70	427.00	476.88	411.91
Total-N	570.00	540.00	556.00	497.65	533.74	488.77

The organic-N and total-N contents were high in dry soil which was followed by unplanted soil and planted soil (Table 2). The mean organic-N content of acid and alkali soil decreased from 593ppm in dry soil to 461.8ppm in unplanted soil. Similarly the mean total-N content of acid and alkali soil decreased from 555ppm in dry soil to 526.8ppm in unplanted soil indicating the mineralization and subsequent loss of nitrogen due to submergence. In planted soil, the organic and total-N content loss was much more pronounced because of oxygen diffusion by rice roots leading to the favorable micro environment for the nitrification of organic nitrogen followed by diffusion of NO_3 ions into the anaerobic environment in which denitrification process takes place.

Table 3. Mean values of nitrogen content (%) in both plant and grain

	Acid soil	Alkali soil
Plant	0.44	0.34
Grain	0.67	0.35

The uptake of nitrogen (Table 3) by rice varieties grown under acid soil (0.44%) was higher than alkaline soil (0.34%). This was possible due to pH difference, mineralization and volatilization. In alkali soil, though there was higher mineralization of organic-N, it was not much used effectively by rice plants due to conducive environment for volatilization loss of NH_3 by high pH in flood water. But in acid soil, even though mineralization rate was lower due to low pH, rice plants effectively utilized the mineralized forms of nitrogen and also the ammonia under acidic condition was stable.

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