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Correlations between indexes of soil nitrogen availability and nitrogen percent in plant, nitrogen uptake, and dry-matter yield of rice grown in the greenhouse

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Summary Relationships between available nitrogen determined by two anaerobic incubation methods (30°C for 2 weeks; 40°C for 1 week) and seven chemical indexes (Organic C, total N, ammonium released by acid dichromate, acid permanganate, alkaline permanganate, hydrogen peroxide and dilute sulfuric acid) and nitrogen percent in rice plant, nitrogen uptake and dry-matter yield of IR 26 rice grown under submerged conditions in pots were investigated using 39 Philippine wetland rice soils differing markedly in their capacities to supply nitrogen. It was found that all the availability indexes were best correlated with nitrogen uptake of rice followed by N% in rice plants at 55 days after seeding. Dry-matter yield of rice was also significantly correlated with the available nitrogen status but the correlation coefficients were the lowest. It is concluded that for unfertilized soils, nitrogen uptake provides a better criterion for evaluating the performance of nitrogen availability indexes for wetland rice.

Introduction

Earlier work investigated relationships between nitrogen availability indexes and nitrogen uptake by rice plants at maximum tillering stage (55 days after seeding) grown under submerged conditions in the green house[5,6]. It was also found that the available nitrogen determined by anaerobic incubation methods and chemical methods generally showed better correlations with nitrogen uptake than with the dry-matter yield of rice[6].

The aim of the work reported here was to examine correlations between available nitrogen status determined by two anaerobic incubation and seven chemical methods with nitrogen per cent in rice plant at 55 days after planting and to compare these correlations with those obtained between nitrogen availability indexes and nitrogen uptake and dry-matter yield of rice. Such relationships have not been reported for rice though they can undoubtedly be useful for evaluating the laboratory indexes for predicting crop performance in greenhouse and field studies.

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It is generally believed that nitrogen uptake by plant is a better criterion for soil nitrogen availability than dry-matter yield, because plant growth is not only governed by nitrogen availability but also by several other nutrients. However, in situations where other nutrients are not influencing plant growth, nitrogen uptake and N% in plants at critical stages of growth should be correlated to drymatter production and soil nitrogen availability. In the present study soils used were carefully selected so as to exclude those which had severe nutrient disorders. Additionally, all other nutrients such as phosphorus, potassium and zinc were uniformly applied to all soils so that the results obtained can be largely ascribed to the nitrogen supplying capacity of soils.

Materials and methods

Soils

Soils used in the study were 39 surface (0–15 cm) samples collected from different rice growing parts of the Philippines shortly before the study. Important properties of the soils and methods of analysis were described earlier[6]. Briefly, the soils used had a wide range in texture (sandy loam to clay), pH (4.3 to 7.9), organic C (0.63 to 5.46%), total N (0.06 to 0.60%), cation exchange capacity (70 to 513 m.mol/kg of soil) and C/N ratio (7.9 to 15.9).

Nitrogen availability indexes

The methods used for determining soil available nitrogen status were described earlier[6,7]. To recapitulate them briefly:

Anaerobic incubation methods

1. Anaerobic incubation of soil samples under waterlogged conditions at 30°C for 2 weeks[12].
2. Anaerobic incubation of soil samples under waterlogged conditions at 40°C for 1 week[6,7].

The anaerobic incubation method[12] was modified in that the ammonium released during anaerobic incubation was measured by extracting the soil samples with 2 *M* KCl as suggested by Sahrawat and Ponnamperuma[8] and described earlier[6].

Chemical indexes

The details of the methods used for measuring soil available nitrogen are in earlier papers[6,7]. They are described briefly here.

1. Organic carbon: Organic C content of soils was estimated by the method of Walkley and Black[11].
2. Total nitrogen: It was determined by the semi-micro Kjeldahl method described by Bremner[1].
3. Alkaline permanganate digestion method: The method described by Subbiah and Asija[10] was followed with minor modifications[6].
4. Acid permanganate extraction method: The method of Stanford and Smith[9] as described earlier[6,7] was followed. Soil samples were first extracted with 0.5 $M H_2SO_4$ and the extract discarded. Soil residues left after acid extraction were extracted with acid permanganate (0.02 M $KMnO_4$ in 0.5 M H_2SO_4) and the ammonium released was measured by distilling with alkali[6,7].
5. Acid dichromate extraction: The ammonium released from soil samples by the oxidative action of acid dichromate (0.02 M $K_2Cr_2O_7$ in 0.5 M H_2SO_4) was measured as described by Sahrawat[6].
6. Hydrogen peroxide (H_2O_2) oxidation method: The method described earlier was used to measure the ammonium released from soils by H_2O_2 oxidation[6].
7. Dilute sulfuric (0.5 M H_2SO_4) extraction method: It involved extraction of the soil samples (1 g) with 25 ml of 0.5 M H_2SO_4 by shaking for one h on a horizontal shaker and the ammonium released was distilled with 50% NaOH solution and determined as described earlier[6].

Greenhouse procedure

The details of the greenhouse procedure are the same as described in an earlier paper[6]. In short, two plants of IR 26 rice per pot (containing 4 kg of soil) were grown under submerged conditions up to 55 days after seeding. There were three replications of each soil and a total of 117 pots for the 39 soils used. The soils were fertilized with triple superphosphate to give 50 mg P/kg of soil, muriate of potash to give 50 mg K/kg of soil and zinc oxide to give 10 mg Zn/kg of soil before planting them to rice.

The plants were harvested at 55 days after seeding and dried in an oven at 60°C. Dry matter weights were noted. Total N in the ground rice tops was determined[2] separately for each replication.

Simple correlations between nitrogen availability indexes and nitrogen per cent in rice tops, nitrogen uptake and dry-matter weights of rice were worked out.

Results and discussion

The soils provided a wide range in nitrogen-supplying capacity (Table 1) which was reflected in a broad range in dry-matter yield, nitrogen percent in rice tops and nitrogen uptake values (Table 2).

It was found that the nitrogen availability indexes were best correlated with nitrogen uptake, followed by nitrogen percent in rice tops harvested at 55 days

Table 1. Range and mean values of available nitrogen in 39 soils determined by different methods

	Available N (mg/kg of soil)	
Method	Range	Mean
Anaerobic incubation, 30°C (2 weeks)	17–428	78
Anaerobic incubation, 40°C (1 week)	13–522	98
Alkaline permanganate digestion	111–397	193
Acid permanganate extraction	42–139	80
Acid dichromate extraction	11–110	40
Hydrogen peroxide oxidation	26–1093	238
Dilute sulfuric acid extraction	7–77	37

Table 2. Range and mean values of drymatter yield, nitrogen percent in rice plants, and nitrogen uptake of IR 26 rice grown for 55 days on 39 soils

Parameter	Range	Mean
Dry-matter yield (g/pot)	3.9–29.6	13.7
Nitrogen percent in rice plants	0.82–3.34	1.67
Nitrogen uptake (mg/pot)	57–610	229

after seeding. In general dry-matter yield of rice showed the lowest correlations with the available nitrogen determined by different methods (Table 3).

While nitrogen uptake of rice was best predicted by organic C, total N and anaerobic incubation methods, on the other hand alkaline permanganate and acid permanganate methods proved better for predicting nitrogen percent in rice tops though the correlation coefficients were lower in the latter case. Ammonium nitrogen extracted by dilute sulfuric acid gave the highest correlation with nitrogen per cent (r=0.55**) in rice tops, followed by nitrogen uptake (r=0.42**) and the lowest (r=0.10 ns) with dry-matter yield of rice. The correlation coefficients, however, were the lowest with dilute sulfuric acid extraction considering all the three parameters used for evaluating the nitrogen availability indexes (Table 3).

It would appear from simple correlations that the performance of nitrogen availability indexes for wetland rice with unfertilized soils will be best predicted by nitrogen uptake. Dry-matter yield of rice provided the poorest criterion for evaluating nitrogen availability indexes. As noted under Introduction, growth of a plant is not solely governed by nitrogen supply, and uptake of nitrogen by the plant does not necessarily result in increased dry-matter production.

Chalk and Waring[3] grew wheat in pot culture on a large number of diverse Australian wheat soils and found that nitrogen uptake and dry-matter yield of wheat were better correlated with the available soil nitrogen as estimated by four tests. On the other hand, nitrogen percent in wheat tops was not significantly

Table 3. Simple correlations between nitrogen availability indexes and nitrogen uptake, nitrogen percent in rice plant, and dry-matter yield of rice (n = 39)

	Correlation coefficient (r) with		
N availability index	N uptake	N% in rice plant	Dry-matter wt.
Organic C	0.82**	0.66**	0.45**
Total N	0.84**	0.68**	0.46**
Anaerobic incubation, 30°C	0.84**	0.66**	0.40*
Anaerobic incubation, 40°C	0.82**	0.62**	0.46**
Alkaline $KMnO_4$	0.81**	0.71**	0.40*
Acid $KMnO_4$	0.75**	0.69**	0.39*
Acid $K_2Cr_2O_7$	0.74**	0.62**	0.39*
H_2O_2	0.82**	0.59**	0.46**
H_2SO_4	0.42**	0.55**	0.10^{ns}

** = Significant at 1% level
* = Significant at 5% level
ns = Not significant at 5% level

correlated with the available-nitrogen status. These authors suggested that dry-matter yield or nitrogen uptake would be the most useful plant indexes for evaluating soil tests for availability of soil nitrogen. Though equally effective, Chalk and Waring[3] preferred nitrogen uptake over dry-matter yield in subsequent studies because the former better reflected the nitrogen available to the wheat plant during a particular growing period.

Similarly, from a glasshouse study with 15 British soils having a range in texture, organic C and total N, Gasser and Kalembasa[4] reported that nitrogen uptake by ryegrass from soils without application of fertilizer nitrogen correlated better with nitrogen availability indexes than did dry-matter yield. It was also found that with added fertilizer N, dry-matter weights of ryegreas at the first cut correlated better with available nitrogen as compared to nitrogen uptake. But the total dry matter for the three cuts of ryegreas showed the lowest correlations with the available nitrogen values. Results of my study with rice are in agreement with those reported for wheat[3] and ryegrass[4] in that for unfertilized soils, nitrogen uptake is the best plant index for evaluating indexes of soil nitrogen availability.

In an earlier paper I reported that organic C, total N and available soil nitrogen determined by hydrogen peroxide oxidation and anaerobic incubation methods in general were better correlated with nitrogen uptake of rice than with the dry-matter harvested in six consecutive croppings of 8 unfertilized soils with IR 32 rice grown in pots under submerged conditions in the greenhouse[5].

The results of this study with 39 diverse soils support the conclusion that for soils without fertilizer nitrogen application, the evaluation of nitrogen availability indexes is best predicted by nitrogen uptake in rice plants harvested at about maximum tillering stage. The prediction of soil nitrogen availability to wetland rice by the nitrogen availability indexes tested decreased in the order: nitrogen uptake > nitrogen % in rice plant > dry-matter yield.

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