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Evaluation of acid permanganate extraction as an index of soil nitrogen availability

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Summary A chemical measure of soil nitrogen (N) availability has been evaluated. The method involved the estimation of initial mineral N, plus mineralizable N released with 0.05 *N* $KMnO_4$ in 1 *N* H_2SO_4. The results obtained correlated highly significantly with the N uptake by wheat plants ($r = 0.72, P < 0.01$).

Introduction

The assessment of potentially available soil N by the biological methods involving soil incubation under controlled laboratory conditions have been reported to be the most satisfactory methods[1]. Although these methods are quite reliable they are time consuming. Therefore, research efforts have been made to find out a rapid chemical method that could provide reliable index of soil N availability. A review by Dahnke and Vasey[5] mentioned 17 chemical methods that have been used for testing soils for available N. According to Fox and Piekielek[6], out of these 17 methods, only initial NO_3-N and soil organic matter are used by a few soil testing laboratories to predict the N supplying capacity of soils. Some of the recent studies indicated that NH_4-N released from soil organic matter with alkaline or acid permanganate could be used as an index of soil nitrogen availability[9,10,12]. Work carried out in this laboratory[7] has also indicated acid permanganate extraction to be a simple and rapid measure of available N in soils. This index has been proposed on the basis of results for only a few soils. In the present studies, therefore, 35 soils from a number of field locations of the Punjab province, were included to test this approach. Evaluation of the index has been made by comparing it with the performance of incubation test and various conventional chemical methods in relation to yield and N uptake by wheat plants.

Materials and methods

Soils

Surface soil samples (0–15 cm) used in this study were air dried soon after collection from the field. After passing through a 2-mm sieve, the soils were then analysed for some of their

physio-chemical properties. The pH of the soils ranged from 7.4–7.9, total N 0.033–0.099 per cent, organic matter 0.49–1.57 per cent and clay 12.0–37.4 per cent. pH of the soil paste was measured by glass electrode, organic matter was determined by dichromate oxidation[13] and total N by salicylic acid method[2].

Soil extraction procedure

i) *Extraction with 2 N KCl.* Five-g soil samples (in triplicate) were shaken with 2 *N* KCl for 1 h and the soil extracts were then analysed for NO_3-N by steam distillation with Devarda's alloy and MgO[3].

ii) *Extraction with different concentrations of $KMnO_4$ in 1 N H_2SO_4 following pre-extraction with 1 N H_2SO_4.* The extraction procedure was almost the same as proposed by Stanford and Smith[12] but the extracts recovered by centrifugation after the initial shaking of the soil samples with 1 *N* H_2SO_4, were also retained for their NH_4-N analysis. Acid permanganate extracting solutions were prepared on the day of extraction by dissolving appropriate amounts of $KMnO_4$ in 1 *N* H_2SO_4 to get the final $KMnO_4$ normality of 0.05, 0.1 and 0.2. The extraction procedure was as follows:

Two-g soil samples (in triplicate) taken in centrifuge tubes were shaken with 50 ml of 1 *N* H_2SO_4 for 1 h at room temperature. After centrifugation the supernatants were analysed for NH_4-N by steam distillation using NaOH as the alkalizer[2]. The soil residues were then shaken with 50 ml of acid $KMnO_4$ solution for 1 h at room temperature and then centrifuged. The supernatants collected were analysed for NH_4-N as described before.

Nitrate-N extracted by 2 *N* KCl and NH_4-N extracted by 1 *N* H_2SO_4 will be collectively designated as "mineral N" unless otherwise mentioned. Ammonium-N released owing to the oxidation of soil organic matter by acid permanganate solution will be referred as "mineralizable N" and the concentrations of $KMnO_4$ in the extractant will be specified.

Incubation method

Portions of 50 g of soils were taken in flat bottomed plastic vessels with lids having a central hole to provide gaseous exchange. Soil samples in triplicate were brought to their respective 75 per cent field capacities by the addition of distilled water and incubated at 30 ± 1°C for 4 weeks. Soil moisture was maintained at 75 per cent field capacity by weighing the bottles and adding distilled water subsequently, at frequent intervals during the course of the experiment. At the end of the incubation period, the soils in the plastic vessels were thoroughly mixed and subsamples were extracted with 2 *N* KCl. Mineral N of incubation test was determined by steam distillation of the soil extract with Davarda's alloy and MgO[3].

Pot culture

Triplicate 1.5 kg subsamples of each soil were filled in polythene lined plastic pots and then brought to their respective field capacities by the addition of distilled water. Nine seeds of wheat (*Triticum aestivum* L.; cv. Sandal) were sown in each pot and the stand thinned to 5 seedlings thereafter. Soil moisture was maintained at field capacities of the soils by daily addition of distilled water throughout the plant growth period. The plants were harvested 40 days after germination and rinsed thoroughly in distilled water. Plant tops were oven dried at 70°C for 48 h and total N in the ground plant material was determined by Kjeldahl method.

Results and discussion

A comparison of different N availability indexes as estimated by biological and chemical methods and their relation to dry matter yield and N uptake by wheat plants is given in Table 1.

Table 1. Correlation coefficients of different N availability indexes vs. dry matter yield and N uptake by wheat (n = 35)

Measure of available N	Correlation coefficient (r)	
	Dry matter	N uptake
1. Soil incubation	0.44^{**}	0.82^{**}
2. Mineral N (by 2 *N* KCl and 1 *N* H_2SO_4), plus mineralizable *N extracted by acidic:*		
i) 0.05 *N* $KMnO_4$	0.53^{**}	0.72^{**}
ii) 0.1 *N* $KMnO_4$	0.49^{**}	0.68^{**}
iii) 0.2 *N* $KMnO_4$	0.52^{**}	0.66^{**}
3. Mineral N (2 *N* KCl)	0.13^{ns}	0.62^{**}
4. Total soil N	0.38^{*}	0.38^{*}
5. Organic matter	0.46^{**}	0.38^{*}

*Significant at *P* 0.05, **Significant at *P* 0.01, ns Non-significant

Incubation method

Mineral N after 4 weeks of soil incubation ranged from 18 to 77 mg/kg of soil. The correlation between mineral N of incubation test and N uptake by wheat plants has been shown in Fig. 1 which is quite high ($r = 0.82$, $P < 0.01$). This high association clearly indicates soil incubation method to be a reliable index of soil N availability. This has already been confirmed[1].

Chemical methods

Mineralizable N released by 0.05 *N* $KMnO_4$ in 1 *N* H_2SO_4 did not correlate well with the yield and N uptake by the plants. Mineralizable N extracted with higher concentrations of acid $KMnO_4$ solution correlated significantly ($P < 0.05$ in most of the cases) with both the plant yield and N uptake but the correlation in either case was relatively poor. From these results it appears that the determination of soil mineralizable N by acid permanganate extraction does not provide a good index of available N. The results of Castellanos and Pratt[4] also demonstrated that the amounts of N released by $KMnO_4$ were not significantly correlated with available N of the manures estimated as their original mineral N plus net N mineralized during a 10-month period of green house cropping. In the present studies when the values of mineral N were included with those of mineralizable N (released by different concentrations of acid $KMnO_4$ solution), the correlation with the plant yield and N uptake values was much improved (Table 1). The improved relationship could be explained on the basis that the initial mineral N content of the soils contributes in meeting the N requirements of plants.

Mineralizable N has been reported to be good index of soil N availability[1]. However, this index is open to many criticisms. One of them is

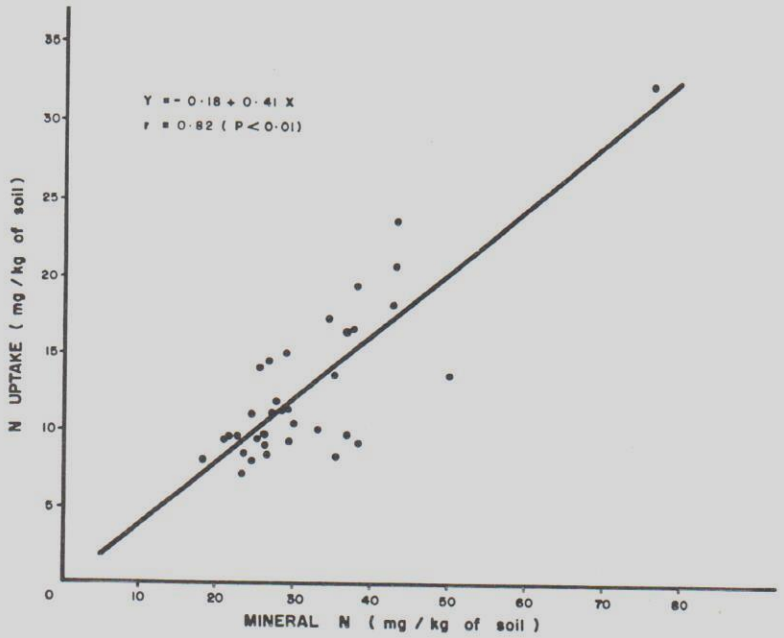

Fig. 1. Relationship between N uptake by wheat and mineral N produced by aerobic incubation of soils at 30 ± 1°C for 4 weeks.

that mineralizable N does not provide an estimate of the amount of mineral N present in the sample before incubation and takes no account of mineral N which has accumulated during fallow or from fertilizer applications[1]. The results of the present study also emphasise that the initial mineral N (2 *N* KC1) content of soils are also worthy of consideration while devising some method for obtaining N availability index. Certain other investigators have interpreted similar findings indicating that initial mineral N should not be overlooked[11]. They suggested that if an appreciable amount is present in the root zone at the beginning of a cropping season, its potential contribution, as well as that of the organic soil N must be considered in making a valid prediction of N fertilizer needs. For crops like winter wheat, potatoes and sugar beet, soil analysis for mineral N has been experimentally demonstrated to be a means of better assessing optimum fertilizer N requirements[8]. Sahrawat and Burford[9] also pointed out that nitrates are not included in the available N pool when the alkaline permanganate method is used for determination of available soil N. According to them this may not be of importance for wetland soil where nitrate is unlikely to be present. But nitrate may accumulate in appreciable amounts in upland soils, and it may contribute significantly to a soil pool of available N.

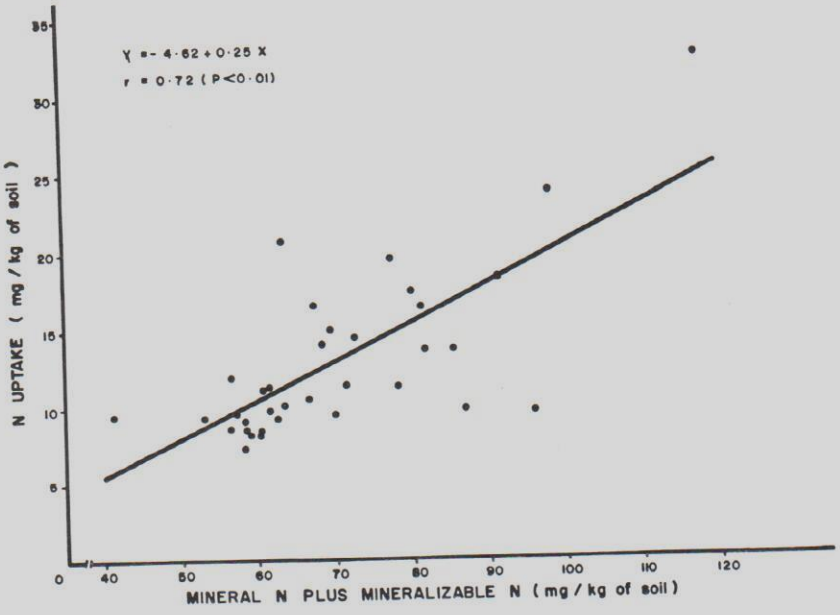

Fig. 2. Relationship between N uptake by wheat and soil available N values estimated as mineral N, plus mineralizable N by 0.05 *N* $KMnO_4$ in 1 *N* H_2SO_4.

The present data also indicated that in case of the method involving estimation of mineral N plus mineralizable N, 0.05 *N* $KMnO_4$ concentration in 1 *N* H_2SO_4 was quite suitable for extracting mineralizable N of soils ($r = 0.72$, $P < 0.01$, Fig. 2). Using higher concentrations of $KMnO_4$ in the extraction solution could not further improve the correlation values (Table 1). Stanford and Smith[12] while presenting a new chemical index of soil N availability based on acid permanganate oxidation, proposed that either of the two concentrations of $KMnO_4$ in 1 *N* H_2SO_4 *i.e.* 0.05 *N* or 0.1 *N* could be used for extracting the soils.

The correlation coefficients of mineral N (2 *N* KCl), total soil N and organic matter *vs.* dry matter yield and N uptake by plants were found to be either nonsignificant or quite poor. The present studies revealed that after soil incubation the method involving the estimation of mineral N plus mineralizable N proved to be a useful index of available N. Since the chemical method proposed is less time consuming and when compared with other chemical methods gives good correlation with N uptake by wheat, it deserves consideration to be used as a routine test for assessing N availability in soils.

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References

1 Bremner J M 1965 Nitrogen availability indexes. *In* Methods of Soil Analysis, Part 2. Ed. C C A Black, Agronomy 9. Am. Soc. Agron., Madison, Wisconsin, pp 1324–1345.

2 Bremner J M 1965 Total nitrogen. *In* Methods of Soil Analysis, Part 2. Ed. C A Black, Agronomy 9. Am. Soc. Agron., Madison, Wisconsin. pp 1149–1178.

3 Bremner J M and Keeney D R 1965 Steam distillation methods for determination of ammonium, nitrate and nitrate. Anal. Chim. Acta 32, 485–495.

4 Castellanos J Z and Pratt P F 1981 Mineralization of manure nitrogen correlation with laboratory indexes. Soil Sci. Soc. Am. J. 45, 354–357.

5 Dahnke W C and Vasey R H 1973 Testing soils for nitrogen. *In* Soil Testing and Plant Analysis, Rev. Edn., Eds. L M Walsh and J D. Beaton, Soil Sci. Soc. Am. Madison, Wis.

6 Fox R H and Piekielek W P 1978 Field testing of several nitrogen availability indexes. Soil Sci. Soc. Am. J. 42, 747–750.

7 Hussain F and Malik K A 1983 Mineralizable nitrogen as an index of soil nitrogen availability. Pakistan J. Sci. Ind. Res. 26, 95–99.

8 Ris J, Smilde K W and Wijnen G 1981 Nitrogen fertilizer recommendations for arable crops as based on soil analysis. Fertil. Res. 2, 21–32.

9 Sahrawat K L and Burford J R 1982 Modification of the alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. Soil Sci. 133, 53–57.

10 Stanford G 1978 Evaluation of ammonium release by alkaline permanganate extraction as an index of soil nitrogen availability. Soil Sci. 126, 244–253.

11 Stanford G and Legg J O 1968 Correlation of nitrogen availability indexes with N uptake by plants. Soil Sci. 105, 320–326.

12 Stanford G and Smith S J 1978 Oxidative release of potentially mineralizable soil nitrogen by acid permanganate extraction. Soil Sci. 126, 210–218.

13 Walkley A and Black I A 1934 An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37, 29–38.