EVALUATION OF CHEMICAL METHODS FOR OBTAINING AN INDEX OF NITROGEN AVAILABILITY IN UPLAND SOILS

F. Hussain and K. A. Malik*

ABSTRACT

Various chemical methods for obtaining an index of soil nitrogen (N) availability were compared with biological methods involving soil incubation and plant uptake. A preliminary study with 10 soils indicated that the ammonium-N released from soil organic matter by oxidation with acid permanganate correlated with N uptake by wheat plants and mineral N produced during an incubation test.

A later study with 35 soils showed that among the chemical methods tried, the one that involved estimation of mineral N plus mineralizable N released by oxidation of soil organic matter with alkaline permanganate correlated well with the results of incubation test and N uptake by wheat plants.

The results revealed that the modified alkaline permanganate method deserves consideration as a routine test for obtaining an index of soil N availability in upland soils.

INTRODUCTION

Scientists have long searched for a chemical method that could provide a reliable index of soil nitrogen (N) availability. Numerous methods for estimating plant available N in soil have been reported during the last several years (Bremner, 1965a; Dahnke and Vasey, 1973; Robinson, 1975). Among these biological methods those involving soil incubation are generally accepted as the most reliable methods (Bremner, 1965a). However, these biological methods are time-consuming. Chemical methods like total-N and organic matter have been found to be of little value (Bremner, 1965a). Some of the recent studies (Stanford, 1978; Stanford and Smith, 1978; Sahrawat and Burford, 1982) have indicated that NH_4-N released from soil organic matter with acid or alkaline permanganate could be used as an index of soil N availabiity. However, acid permanganate method is more precise and reliable than alkaline permanganate method and its modifications (Stanford and Smith 1978). Therefore, this study was carried out to evaluate acid and alkaline permanganate methods as indices of N availability for soils collected from different districts of Punjab.

MATERIALS AND METHODS

Surface soils (0-15 cm) were collected from farmer's fields in Punjab. Soil samples were air dried, ground and sieved with a 2-mm screen. The preliminary and detailed studies included 10 (Expt.1) and 35 (Expt.2) soils, respectively. pH of the soil paste was measured by a glass electrode and electrical conductivity by a conductivity meter.

Soil organic matter was determined by dichromate oxidation method (Walkley and Black, 1934). Salicylic acid-thiosulphate modification of the Kjeldahl method (Bremner, 1965b) was used to measure total N. Sodium bicarbonate extractable P was measured as reported by Watanabe and Olsen (1965) and CaCO3 as by Puri (1931) and Allison and Moodie (1965). Percent clay in soils was determined by a Bouyoucos hydrometer (Bouyoucos, 1962). The ranges of properties of the soils used are given in Table 1.

*Nuclear Inst. for Agriculture and Biology, Faisalabad.

Table 1. **Range of Physico-chemical properties of the soils**

Soil property	Ranges	
	10 soils study	35 soils study
pH (paste)	7.2 - 8.0	7.4 - 7.9
ECe (ms cm -1)	0.87 - 4.8	0.42 - 10.0
Clay %	15.9 - 51.3	12.0 - 37.4
CaCO3 (%)	1.4 - 4.5	1.8 - 9.7
Organic matter	0.96 - 2.47	0.49 - 1.57
Total N (%)	0.059 - 0.125	0.033 - 0.099
Mineral N (mg kg-1)	7.7 - 36.9	2.8 - 62.3
NaHCO3 - extractable P (mg kg-1)	3.7 - 27.1	2.8 - 62.3

Soil nitrogen estimation

1. Mineral N: It was estimated by the method of Bremner and Keeney (1965)

2. Mineralizable N:

2.1 The soils were extracted with solutions containing different concentrations of potassium permanganate in 1 $\underline{N}$ H_2SO_4 (Stanford and Smith, 1978). Ammonium-N in the extracts was determined by steam distillation using NaOH as an alkalizer (Bremner, 1965b).

2.2 The mineralizable N was also estimated by the standard alkaline permanganate method (Sahrawat and Burford, 1982).

3. Mineral plus mineralizable N:

Estimated by three methods:

3.1 The supernatants obtained while centrifuging the soil to estimate soil mineralizable N (Stanford and Smith, 1978) were retained and analysed for NH4-N. This NH4-N was summed up to the mineralizable N as determined in section 2.1 and to the NO_3-N determined by the method of Bremner and Keeney (1965)

3.2 The acid permanganate method of Stanford and Smith (1978) was modified to include mineral N as well. Instead of pre-extraction of the soil with 1$\underline{N}$ H_2SO_4, the acid permanganate solution was used to remove mineral-N from the soil. Ammonium-N in the extract (either released by oxidative action of acid permanganate or exchanged by H^+) was determined by steam distillation using NaOH as an alkalizer. Devarda's alloy was added to include NO_3 fraction of mineral N during steam distillation of the extract.

3.3 Mineral plus mineralizable N was also estimated by the modified alkaline permangfanate method proposed by Sahrawat and Burford (1982)

b All nitrogen estimations were performed on triplicate soil samples.

Soil incubation

Fifty gram soil samples taken in plastic bottles were incubated in triplicates under anaerobic conditions at 30±1oC and 75% field capacity moisture level. At the end of incubation, subsamples of thoroughly mixed soils were extracted with 2 N KCl. The extracts were analysed for

mineral-N by steam distillation with Devarda's alloy and MgO (Bremner and Keeney, 1965).

Pot culture studies

Wheat was grown in subsamples (1.5 kg) of all the soils. During the plant growth period moisture was maintained at respective field capacities of the soils by daily addition of deionized water. Plants were harvested 40 days after germination and dried at 70°C for 48 h. Total N in the ground plant material was determined by the Kjeldahl method.

RESULTS AND DISCUSSION

In the study with 10 soils, mineralizable N estimated by $KMnO_4$ in 1 N H_2SO_4 correlated with the mineral N of the incubation test and N uptake by wheat plants (Table 2). The results of this initial study encouraged to do further work on a large number of soils.

Table 2. Correlation between mineralizable N, and mineral N, dry matter yield and N uptake by wheat plants (Expt. 1)

Mineralizable N estimated by:	Correlation coefficient, r			
	Mineral N of incubation test		Plant yield and N uptake	
	4 weeks	8 weeks	Dry matter	N uptake
1) 0.05 N KMnO4 in 1 N H2SO4	0.60ns	0.38ns	0.04ns	0.39ns
2) 0.1 N KMnO4 in 1 N H2SO4	0.76*	0.82**	0.47ns	0.65*

* Significant at 5 per cent probability level
* Significant at 1 per cent probability level

** ns Nonsignificant.

Nitrogen released during soil incubation had significant correlation with the dry matter yield and N uptake by wheat plants (Table 3). This clearly indicates that soil incubation test is a good index of soil available N. The mineralizable N alone estimated by either different concentrations of $KMnO_4$ in 1 N H_2SO_4 or by standard alkaline permanganate method had no or poor correlation with the mineral N of incubation test, plant yield and N uptake by wheat plants. However, when mineral N of the soil was also included in the mineralizable N by modifying the acid-or alkaline permanganate method, the correlation with incubation method as well as with N uptake by plants was improved

Table 3. **Relationship of N availability indices, mineralizable N, dry matter yield and N uptake by wheat plants. (Expt. 2).**

Index of available N	Correlation coefficient, r		
	Mineral N (4 weeks incubation)	Dry matter	N uptake
1. Mineral N of soil incubation (4 weeks)	-	0.44**	0.82**
2. Mineralizable N estimated by:			
1) 0.05 N KMno4 in 1 N H2SO4	0.22ns	0.56*	0.34*
2) 0.1 N KMno4 in 1N H2SO4	0.42*	0.42*	0.37*
3) 0.2 N KMno4 in 1 N H2SO4	0.38*	0.45**	0.39*
3. Mineralizable N (by 2 N KC1 and 1 N H2SO4) plus mineralizable N estimated by:			
1) 0.05 N KMn04 in 1 N H2SO4	0.68**	0.53**	0.72**
2) 0.1 N KMn04 in 1 N H2SO4	0.74**	0.49**	0.68**
3) 0.2 N KMn04 in 1 N H2SO4	0.68**	0.52**	0.66**
4. Mineral N plus mineralizable N estimated by modified acid permanganate method	0.80**	0.49**	0.69**
5. Mineralizable N estimated by standard alkaline permanganate method	0.36*	0.43*	0.37*
6. Mineral N plus mineralizable N estimated by modified alkaline permanganate method	0.84**	0.44**	0.76**
7. Mineral N (by 2 N KC1)	0.81**	0.13ns	0.62**
8. Total N	0.40*	0.38*	0.38
9. Organic matter	0.34*	0.46**	0.38*

*Significant at 5 and 1 per cent probability level,
** ns Nonsignificant

considerably. The results of the present study emphasized that the initial mineral N (NH_4+NO_3) of soils must also be considered while devising some method to estimate available soil N. Other workers (Stanford and Legg, 1968) have also suggested that if an appreciable amount of initial mineral N is present in the soil at the beginning of cropping season, its potential contribution should not be overlooked. Sahrawat and Burford (1982) also pointed out that considerable amounts of nitrate may accumulate in upland soils which could contribute significantly to a soil poor of available N. Mineral N of the soil alone did not correlate with the dry matter yield. However, it gave relatively higher correlation coefficient with the incubation test as well as plant N uptake. Poor correlation coefficients obtained in case of total-N or organic matter content of the soils indicated that these methods are of little value. Out of all the chemical indexes studied, the one that involved the estimation of mineral plus mineralizable N by alkaline permanganate method gave the highest correlation with the incubation test and plant N uptake (0.84** and 0.76**, respectively). Thus this method deserves consideration to be used for estimating plant available N in upland soils.

ACKNOWLEDGEMENTS

We are grateful to Ch. M. Rafiq, Director, Soil Survey of Pakistan, Lahore and Mr. Nazir A. Kasana of Soil Fertility Survey and Soil Testing
Institute, Faisalabad for providing assistance during soil sampling. Thanks are also due to Mr. G. R. Tahir, for statistical analysis of the data and Mr. Anwar-ul-Haq for assistance in the analytical work.

LITERATURE CITED

Allison, L. E. and C.D. Moodie. 1965. Carbonates. p. 1379-1396. In (C.A. Black (ed.) Methods of soil analysis, Part2. Agronomy 9. Am. Soc. Agron., Madison, Wisconsin.

Bremner, J.M. 1965a. Nitrogen availability indexes p. 1324-1345. In (C.A. Black (ed.) Methods of soil analysis, Part 2. Agronomy 9. Am. Soc. Agron., Madison, Wisconsin.

Bremner, J.M. 1965b. Total nitrogen. p. 1149-1178. In (C.A. Black ed.) Methods of soil analysis, Part 2. Agronomy 9. Am. Soc. Agron., Madison, Wisconsin.

Bremner, J.M. and D.R. Keeney. 1965. Steam distillation methods for determination of ammonium nitrate and nitrite. Analytical Chime. Acta 32: 485-495.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54: 464-465.

Dahnke, W.C. and R.H. Vasey. 1973. Testing soils for nitrogen. In Walsh and J.D. Beaton (eds.) Soil testing and plant analysis, L.M. Soil Sci. Soc. Am., Madison, Wisconsin.

Puri, A.N. 1931. A Simple method of estimating total exchangeable bases in soils. Soil Sci. 31; 275-279.

Robinson J.B.D. 1975. Special Bull. No.1, Commonwealth Bureau Soils, Harpenden, England.

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

Stanford, G. 1978. Evaluation of ammonium released by alkaline permanganate extraction as an index of soil nitrogen availability. Soil Sci. 126: 244-253.

Stanford G. and J.O. Legg. 1968. Correlation of nitrogen availability indexes with N uptake lby plants. Soil Sci. 105: 320-326.

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

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

Watanable, F.S., and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soils. Soil Sci. Soc. Am. Proc. 29: 677-678.