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Abstract

Available nitrogen was determined using 11 extractants on 29 soils covering a wide range of physical and chemical properties. Assessment of 2M KCl (pH 7.0), 1N NaCl, 1N NaCl (pH 1.0), 2N NaCl, 1N Na_2SO_4 (pH 1.0), 0.5N $NaHCO_3$ (pH 8.5), Morgan's reagent, 0.1N $CaCl_2$, 0.5N HCl, 0.7N HCl and 0.5N H_2SO_4 extractable nitrogen showed that the best efficiency was obtained by 1N NaCl. IN NaCl and 2M KCl extractable nitrogen bear significant relationship with soil organic matter and total nitrogen were found to be dependent on the type of soil. Correlation study with nitrogen uptake by BR-4 rice reveals that 2M KCl is superior to 1N NaCl and closely followed by IN NaCl. Compared to these two extractants both aerobic and anaerobic incubation methods produced less satisfactory results.

Introduction

Information obtained from both greenhouse and field experiments showed that the efficient use of N-fertilizer results in greater crop yield. Excessive and indiscriminate application of N creates ill effects other than those reflected in profits, and often do, impair yield and quality (Bartholomew, 1972). The scarcity of N-fertilizer, however, is probably the most important factor limiting food production (Thomas, 1978). Besides, the N-fertilizers, commonly used urea and ammonium nitrate, are beyond the capacity of general farmers in developing countries because of their high production cost (Sahrawat and Ponnamperuma, 1978). This is true for this continent and in particular for Bangladesh where the soils are in general deficient in organic matter and subsequently in total nitrogen. Thus, an extensive research effort to utilize soil and fertilizer-N efficiently is very well justified (Sahrawat and Ponnamperuma, 1978). For optimization of fertilizer application, it is of great significance to know the level of available N already present in the soil.

Thus, an attempt was made to find out a suitable method for determining available N from 29 soils of Bangladesh by chemical extraction, short-term incubation and plant uptake in the greenhouse.

Materials and Method

Twenty nine soil samples (0-15 cm) under 13 General Soil Types representing different soil series were collected from various localities of Bangladesh. The soil samples were processed and analysed in the laboratory for their physical and chemical characteristics (Table 1).

Determinations were made of particles-size distribution by hydrometer method, pH with a combined glass/calomel electrode (soil: water, 1: 2.5), total N by Kjeldahl method, organic C by wet oxidation method (Walkley and Black, 1934) and CEC by normal ammonium acetate (pH 7.0).

Available N was determined following micro-Kjeldahl's distillation procedure. Eleven extractants covering various acids, bases and buffered solutions have been used to test for N availablity. The soil: extractant ratio was 1:10 and the extraction period was 30 minutes. Only for 2M KCl extractant the extraction time was 6o minutes. Extractants used were 2M KCl (Olsen, 1929); 1N NaCl (Hissink, 1923); 1N NaCl (pH 1.0) (Olsen, 1929); 2N NaCl (Bremner and Shaw, 1955) ; 1N Na_2SO_4 (pH 1.0); 0.5M $NaHCO_3$ (pH 8.5) (Olsen *et al.*, 1954); Morgan's reagent (10% CH_3COOH, pH 4.8) (Morgan, 1937); neutral 0.01m $CaCl_2$ (Lathwell *et al.*, 1972); 0.5N HCl (Peterson *et al.*, 1960); 0.7N HCl (Peterson *et al.* 1960) ; 0.5N H_2SO_4. (Tyurin, 1934; Tyurin and Kononova, 1934), Dil HCl was used to adjust the pH of 1N NaCl and 1N Na_2S0_4 solution.

Each sample was measured in duplicate but only the mean results were quoted (Tables 1&2).

Greenhouse experiment : 3 kg air dry soil (2 mm) was taken in eaeh earthenware pot (18 cm × 22 cm). Polyethelene film was used between soil and pot to avoid contamination from the earthenware pots. Soils in each pot was kept submerged for three days for complete wetting. Four week old healthy rice (*Oryza sativa* cv. BR-4) seedlings of uniform size was transplanted (four seedlings/pot) at a regular distance. About 2 - 3 cm level of standing water was maintained throughout the whole experimental period. The experiment was arranged in randomized block design with three replications.

One plant sample was collected randomly from each pot by cutting 8 cm above the soil surface after 30, 60 and 90 days of transplantation. The plant samples were then washed with distilled water followed by oven drying for 16 hours at 65 ±1C and ground to 1 mm size in a microgrinder.

Incubation experiment : 20 g air-dried sample (2 mm) from each soil was weighed into 100 ml conical flask. Water was added in each conical flask

Table 1. Physical and chemical characteristics of the soil samples examined.

Soil series	Textural class	pH	CEC meq/kg	Organic C %	Total N %	C/N ratio	General soil type
Dhalla	SL	7.0	199.3	0.52	0.03	17	NCA
Dhaleshwari	SL	7.5	139.1	0.37	0.03	12	NCA
Karatoya	S	5.2	116.6	0.16	0.02	8	NCA
Hatiya	SiCL	7.1	244.4	0.60	0.04	15	CA
Ramgati	SiCL	7.8	210.6	0.46	0.04	12	CA
Sabhar Bazar	SiL	5.3	247.1	0.83	0.07	12	GFS
Shilmondi	SiCL	6.5	174.8	0.58	0.06	10	GFS
Sonatola	SiL	5.3	173.0	0.57	0.05	11	GFS
Jamun	L	5.1	71.4	0.74	0.04	19	GFS
Jhalakathi	SiL	7.7	134.0	0.32	0.03	11	GFS
Pahartali	L	6.0	167.3	0.80	0.07	11	GPS
Chakla	C	5.5	107.9	0.56	0.07	8	ABC
Naraibag	C	5.5	151.4	0.50	0.06	8	NCDGFS
Jalkundi	SiL	5.8	184.0	0.83	0.07	12	NCDGFS
Ghatail	SiCL	6.3	235.0	0.84	0.06	14	NCDGFS
Sara	SiC	7.1	320.9	0.79	0.05	16	CBFS
Pirgachha	L	5.1	133.5	0.59	0.05	12	NCBFS
Atwari	SCL	4.9	255.8	0.85	0.08	11	BTS
Pachagarh	SCL	5.4	73.1	0.39	0.03	13	BTS
Ruhea	SL	4.9	216.2	0.58	0.04	15	BTS
Gerua	SiCL	4.5	193.6	0.70	0.06	12	SRBTS
Salna	SiL	5.0	141.0	0.59	0.03	20	SRBTS
Tejgaon	L	5.4	122.2	0.76	0.05	15	DRBTS
Kashimpur	L	6.0	118.4	0.84	0.06	14	DRBTS
Noadda	CL	5.1	146.6	0.75	0.05	15	BMTS
Chiatta	SiCL	5.2	105.3	0.50	0.03	17	GTS
Chandra	CL	4.8	99.6	0.63	0.03	21	GTS
Kalma	SiCL	4.7	99.2	0.77	0.05	15	GTS
Unnamed	L	6.0	161.7	0.68	0.04	17	

Clay (C), Clay loam (CL), Loam (L), Sand (S), Sandy clay loam (SCL), Silty clay (SiC), Silty clay loam (SiCL), Silty loam (SiL), Sandy loam (SL).

NCA = Non-calcareous Alluvium, CA=Calcareous Alluvium, GFS=Grey Floodplain Soil, GPS = Grey Pidmont Soil, ABC = Acid Basin Clay, NCDGFS = Non-calcareous Dark-Grey Floodplain soil, CBFS = Calcareous Brown Floodplain Soil, NCBFS = Non-calcareous Brown Floodplain Soil, BTS= Black Terai Soil, SRBTS = Shallow Red Brown Terrace Soil, DRBTS=Deep Red-Brown Terrace Soil, BMTS=Brown Mottled Terrace Soil, GTS=Grey Terrace Soil.

to bring into 50% maximum water holding capacity and mixed thoroughly. The flasks were plugged with absorbent cotton and incubated at 30 ±0.5. The experiment was arranged in a randomized block design with two replications. Samples (5g) in duplicate were collected from each flask after 15 days of incubation to determine avilable nitrogen and moisture.

A similar experiment was carried out under anaerobic condition where the soil samples were kept submerged (2 - 3 cm standing water) during incubation period. The flasks were covered with polyethelene paper. Soil samples were analyzed for available nitrogen and moisture content after 28 days (Ponnamperuma, 1965) of incubation.

Analytical techniques : Available nitrogen was extracted by 1N NaCl. Plant samples were digested with conc. H_2SO_4 and mixture of conc. H_2SO_4. and $HClO_4$ (4: 1, v/v). Total nitrogen of soil and plant was determined by Kjeldahl method.

Results and Discussion

(*A*) *Available nitrogen content of soils* : Concentration of available nitrogen was determined from 29 soils by 11 extractants (Table 2).

The quantity of nitrogen extracted by different extractants have been found to differ widely. Content of nitrogen varied between 0.7 (Pirgachha) and 15.5 mg 100^{-1}g soil (Sonatala) irrespective of the methods of extraction. The data further revealed that none of the methods was suitable for all soil samples to bring maximum amount of nitrogen into solution. The efficiency of the methods may be arranged as follows:

1N NaCl (7.3) > 2N NaCl (7.2) > 0.5N HCl (6.9)> 0.7N HCl (6.3) > 2M KCl (6.1)> 1N NaCl (pH 1.3) (6.0)> 0.5N H_2SO_4 (5.5) > 0.5N $NaHCO_3$ (5.4) > 1N Na_2SO_4 (5.3) > Morgan's reagent (5.0)> 0.01M $CaCal_2$ (4.1).

The highest effiiency was recorded for 1N NaCl solution and that of lowest for 0.01M $CaCl_2$ solution. The variation might be due to variation in nature of extractants. Moreover, Na^+ ion was possibly more effective than K^+ ion to release NH_4^+–N from the clay (Barshad, 1948; Anam *et al.*, 1978). NaCl not only extracted NH_4^+–N but also some easily mineralizable nitrogen (Barshad, 1948).

(*B*) *Correlation studies* : The relationship of available nitrogen extracted by various methods with organic carbon and total nitrogen was evaluated. As an extractant, 1N NaCl showed the best significant relationship ($r = +0.7323$) ($P = 0.001$) with total nitrogen content of soils among the extractants followed

Table 2. Available N content of soil samples (mg/100 g soil) as estimated by various extractants.

Soil series	2M KCl	1N NaCl	1N NaCl (pH 1.0	2N NaCl	1N Na_2SO_4	0.5 M $NaHCO_3$
Dhalla	1.9	5.3	6.5	9.9	7.7	4.3
Dhaleshwari	5.6	3.5	5.2	6.7	4.7	5.5
Karatoya	1.6	8.6	6.2	6.5	2.0	10.0
Hatiya	3.4	7.4	4.0	6.9	2.3	1.4
Ramgati	5.7	5,1	5.2	5.1	3.1	5.3
Sabhar Bazar	5.6	11.0	12.1	5.2	7.1	4.9
Shilmandi	2.8	9.1	6.9	1.2	7.2	6.4
Sonatola	9.1	15.5	2.5	8.5	9.4	12.8
Jamun	10.0	10.2	4.0	3.7	4.4	5.5
Jhalakathi	4.0	2.6	5.6	10.3	4.8	3.1
Pahartali	8.9	5.7	6.7	5.7	0.8	5.9
Chakla	6.4	11.3	4.7	2.9	2.5	7.7
Naraibag	6.4	6.6	7.6	9.5	1.4	1.4
Jalkundi	6.4	2.3	2.8	8.5	6.8	0.7
Ghatail	4.2	1.5	6.0	7.1	4.5	6.9
Sara	6.0	2.1	14.0	4.4	5.7	3.3
Pirgachha	5.9	3.7	5.5	3.1	0.7	3.5
Atwari	13.1	7.4	11.8	8.5	6.5	14.7
Pachagar	7.6	4.7	5.4	6.5	6.5	11.7
Ruhea	7.6	3.9	5.0	2.5	3.2	4.4
Gerua	2.6	7.6	7.1	8.1	10.1	1.5
Salna	9.0	9.4	4.8	11.3	10.4	3.3
Tejgaon	5.8	7.6	1.5	6.3	8.7	1.9
Kashimpur	5.8	9.8	6.9	8.5	4.1	2.3
Noadda	8.0	15.0	1.7	11.0	4.9	1.1
Chiatta	4.7	10.9	5.1	9.2	7.7	1.3
Chandra	5.2	9.5	5.6	8.5	12.2	8.7
Kalma	4.5	12.0	8.9	10.8	1.7	8.4
Unnamed	8.1	4.3	5.1	11.4	2.8	4.3
Maximum	13.1	15.5	14.0	11.4	12.2	14.7
Minimum	1.6	1.5	1.5	1.2	0.7	0.7
Mean	6.1	7.3	6.0	7.2	5.3	5.4
LSD at 5% level	10.52	0.95	1.20	0.34	0.63	0.74

(Table 2 contd.)

Soil series	Morgan's reagent	0.01 M $CaCl_2$	0.5N HCl	0.7N HCl	0.5N H_2SO_4
Dhalla	15.3	3.4	6.8	9.1	5.3
Dhaleshwari	5.2	9.4	8.5	5.3	6.9
Karatoya	1.4	7.6	7.5	4.5	2.2
Hatiya	5.9	8.6	8.7	4.9	8.9
Ramgati	1.6	4.8	3.2	7.7	6.1
Sabhar Baxar	1.2	5.2	6.7	11.2	4.6
Shilmandi	5.9	8.1	8.0	2.5	5.0
Sonatola	4,4	4.3	9.3	3.5	5.2
Jamun	1.0	2.2	7.2	1.5	4.0
Jhalakathi	4.9	1.1	7.0	5.5	6.3
Pahartoli	3.3	4.7	5.5	4.8	5.1
Chakla	4.5	4.6	6.4	9.9	4.6
Naraibag	8.1	2.0	9.4	11.8	9.5
Jalkundi	6.8	4.6	5.9	5.7	10.5
Ghatail	2.3	5.1	5.3	10.0	4.8
Sara	5.0	4.7	5.0	10.0	5.0
Pirgachha	3.7	1.5	3.5	3.1	4.2
Atwari	9.5	2.1	13.5	8.2	6.6
Pachagar	6.5	1.8	3.3	10.7	4.8
Ruhea	2.3	1.8	9.5	4.4	5.7
Gerua	12.4	3.5	3.9	6.9	6.0
Salna	4.7	3.2	9.7	4.1	6.0
Tejgaon	5.6	4.3	9.6	3.6	3.8
Kashimpur	5.2	1.8	7.3	1.3	5.3
Noadda	0.8	3.4	6.9	7.1	4.3
Chiatta	9.3	4.7	6.4	8.3	4.3
Chandra	3.1	4.4	4.8	4.7	4,8
Kalma	2.3	1.7	5.0	7.2	3.3
Unnamed	4.1	3.8	7.3	4.7	5.5
Maximum	15.3	9.4	13.5	11.8	10.5
Minimum	0.8	1.1	3.2	1.3	2.2
Mean	5.4	4.1	6.9	6.3	5.5
L S D at 5% level	1.4	0.38	1.67	0.86	0.56

by 2M KCl (pH 7.0) (r=+0.3939) (P=0.05). Barshad (1948) observed that Na^+ was better than K^+ for the extraction of exchangeable NH_4^+–N from the clay lattice. However, contrary to this, Bremner (1965) subsequently found that 2M KCl to be the best general extractant. Only 2M KCl (pH 7.0) (r=+0.3702) (P=0.05) and 1N NaCl (pH 1.0) (r=+0.889) (P=0.001) extractable nitrogen showed significant bearing with organic matter. However, most of the methods showed insignificant relationship with both the soil variables.

(*C*) *Nitrogen content of rice plant* : Content of nitrogen in BR-4 grown on 29 soils showed a wide range of variation from 0.67 to 1.91, 0.62 to 0.99 and 0.25 to 0.61 per cent at 30, 60 and 90 days of growth after transplantation (Table 3). Per cent nitrogen in plant tissues vaired significantly in all the intervals of growth. This differentiation is due to variation in initial available nitrogen content of soils (Table 1). The results, furthermore, clearly demonstrate that concentration of nitrogen in plant body decreases as the plant attains to maturity.

The coefficients of correlation were calculated between the available nitrogen as measured by different methods and nitrogen content in rice plant at different intervals of growth (Table 4). Plant nitrogen showed good significant correlation with available nitrogen extracted by 1N NaCl and 2M KCl only in the earlier stages of growth. Between the two methods, the superiority of 2M KCl was observed to 1N NaCl in this respect. However, all other methods showed no such relation except in a few cases having a lower degree of significance.

(*D*) *Correlation between mineralized-N and plant–N* : The amount of nitrogen mineralized during aerobic (14 days) and anaerobic (28 days) incubation of soils was determined by 1N NaCl solution (Table 3). The results showed that amount of nitrogen mineralized significantly varied from soil to soil. Plant nitrogen showed significant relation with nitrogen made available during aerobic incubarion of soils for 30 (o=+0.4831) (P=0.02) and 60 (r=+0.4177) (P=0.35) days of growth. Nitrogen made available during anaerobic incubation of soils showed significant relationship (r=+0.3788) (P=0.1) only with 30 days plant nitrogen. However, the level of significance is far below than that obtained with 2M KCl. Therefore, 2M KCl method was considered to be the best method.

(*E*) *Nitrogen availability status of the general soil types* : 2M KCl and 1N NaCl extractable nitrogen was significantly correlated with plant nitrogen. Therefore, an attempt was made here to assess the available status of the soils on the basis of General Soil Types.

Table 3. Per cent nitrogen content of rice plant at different growth intervals and release of mineral nitrogen (NH_4^+—N+NO_3^-N, $\mu g\ g^{-1}$ soil) during incubation of soils.

Soil series	At days of transplantation			Incubation condition	
	30	60	90	Aerobic	Anaerobic
Dhalla	0.86	0.66	0.51	39.9	30.7
Dhaleshwari	1.25	0.88	0.60	58.0	49.0
Karatoya	1.02	0.72	0.46	47.3	42.3
Hatia	0.86	0.69	0.55	47.3	43.9
Ramgati	0.02	0.82	0.51	69.7	48.1
Sabhar Bazar	0.67	0.62	0.43	69.9	66.6
Shilmondi	1.14	0.79	0.25	79.6	66.3
Sonatola	1.20	0.84	0.48	72.1	64.7
Jamun	1.07	0.99	0.51	77.1	76.3
Jhalakathi	1.61	0.71	0.48	44.9	42.4
Pahartali	1.48	0.87	0.48	82.1	71.0
Chakla	0.89	0.71	0.42	64.7	55.4
Naraibag	1.11	0.75	0.61	44.8	33.2
Jalkundi	1.00	0.77	0.39	60.9	63.2
Ghatail	1.20	0.67	0.39	59.8	52.3
Sara	1.06	0.87	0.49	94.7	91.9
Pirgachha	1.16	0.73	0.43	62.2	55.6
Atwari	1.91	0.94	3.60	101.0	101.9
Panchagar	1.28	0.95	0.39	77.3	69.8
Ruhea	1.55	0.92	0.43	94.7	94.7
Gerua	0.84	0.67	0.42	74.6	65.5
Salna	1.07	0.96	0.31	69.7	59.7
Tejgaon	1.30	0.71	0.60	104.5	92.0
Kashimpur	1.39	0.75	0.49	101.9	91.3
Noadda	1.24	0.71	0.45	99.5	98.7
Chiatta	1.33	0.14	0.47	75.9	81.6
Chandra	1.02	0.75	0.37	101.9	87.7
Kalma	1.04	0.79	0.39	97.1	90.5
Unnamed	1.17	0.71	0.47	89.5	81.2
Maximum	1.91	0.99	0.61	104.5	131.9
Minimum	0.67	0.62	0.25	39.9	30.7
Mean	1.68	1.14	0.67	74.9	68.1
LSD at 5% level	0.11	0.18	0.06	3.53	4.74

(i) 2M KCl (pH 7.0) extraction: Black Terai Soils (9.4)>Grey Piedmont Soils (8.9)>Unnamed Soil (8.1)> Brown Mottled Terrace Soils (8.0)>Acid Basin Clay (6.4)>Grey Floodplain Soils (6.3)> Calcareous Brown Flooddlain Soils (6.0)> Non-calcareous Brown Floodplain Soils (5.9)>Deep Red-Brown Terrace Soils (5.8)>Shallw Red Brown Terrace Soils (5.8)> Non-calcareous Dark-Grey Floodplain Soils (5.4)>Calcareous Alluvium (4.6)>Grey Terrace Soils (4.o)>Non-calcareous Alluvium (3.0).

Table 4. Correlation coefficient between N content of rice plant at different growth intervals and available N content of soils as measured by various extraetion methods.

Extraction methods	Per cent N content		
	30 days	60 days	90 days
2M KCl (pH 7.0)	+0.5012[2]	+0.6437[1]	+0.2737 ns
1N NaCl	+0.3902[4]	+0.4145[3]	+0.0906 ns
1N NaCl (pH 1.0)	+0.0470 ns	−0.2512 ns	+0.0275 ns
2N NaCl	+0.0028 ns	−0.0843 ns	+0.1295 ns
1N Na_2SO_4 (pH 1.0)	−0.1052 ns	+0.0884 ns	−0.2964 ns
0.5N $NaHCO_3$ (pH 8.5)	+0.0147 ns	+0.3378[5]	−0.0246 ns
Mergan's reagent	+0.0221 ns	−0.1249 ns	−0.2187 ns
0.01M $CaCl_2$	−0.2699 ns	−0.1037 ns	+0.0096 ns
0.5N HCl	+0.4510[2]	+0.2824 ns	+0.3970[4]
0.7N HCl	−0.2146 ns	−0.2360 ns	+0.0940 ns
0.5N H_2SO_4	−0.0163 ns	−0.0422 ns	+0.2458 ns

1, 2, 3, 4, 5 represent significance level at 0.1, 1, 2, 5, 10%, respectevely.

(ii) IN NaCl extraction : Brown Mottled Terrace Soils (15.0)> Acid Basin Clay (11.3)> Grey Terrace Soils (10.5)> Grey Floodplain Soils (9.7)> Deep Red-Brown Terrace Soils (8.7)> Shallow Red-Brown Terrace Soils (8.5)> Calcareous Alluvium (6.2)> Non-calcareous Alluvium (5.8)> Grey Piedmont Soils (5.7) > Black Terai Soils (5.3)> Unnamed Soil (4.3)> Non-calcareous Brown Floodplain Soils (3.7)> Non-calcareous Dark-Grey Floodplain Soils (3.5) > Clacareous Brown Floodplain Soils (2.1).

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