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COMPARISON OF METHODS TO EVALUATE K AVAILABILITY IN RICE SOILS

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SUMMARY

Eleven extractants covering acids, bases and buffer solutions have been used to evaluate K availability from 29 rice soils. Of the methods, boiling 1N HNO_3 extracted the highest amount of available K. The methods may be arranged as boiling 1N HNO_3 > hot 1.4N H_2SO_4 > 1N Na_2SO_4 (pH 1) > modified 1N NaCl (pH 1) > 0.7N HCl > 0.5N HCl > Morgan's reagent > 0.5M $NaHCO_3$ (pH 8.5) > 1N NaCl > 1N NH_4OAc > water according to their relative efficiency. Extractants having acidic character were found to be superior over other methods. pH fluctuations possibly accentuated K release from the soils. All the methods correlated significantly with 60 days plant K. Highly significant correlation at 0.1% level was revealed by boiling 1 N HNO_3, hot 1.4N H_2SO_4, 1N NaCl (pH 1) and 0.5M $NaHCO_3$ (pH 8.5) with plant K. Only 1N NaCl (pH 1) extractable K showed significant correlation with 90 days plant K.

INTRODUCTION

K exists in soil in a number of forms and its availability to plants depends on the amount and relative mobility of different forms (Reitemeir, 1951). In addition, several other physical, chemical and biological factors govern the mobility of K to plants, which vary much from soil to soil. This has made the situation difficult to identify any single measurement of available K that is consistently superior to varying conditions.

The conventional extractants are water, salts and both weak and strong acids. Water-soluble K has not been recommended as a reliable measure of available K as plants take up more K than is present in the water-soluble form. K^+ ions held on the surface of soil minerals plus those which are parts of certain organic compounds can be reversely replaced by the salt solution viz. 1N NaCl, neutral 1N NH_4OAc, Morgan's solution, 1N NaCl (pH 1), 1N Na_2SO_4 (pH 1) etc. Mineral acids are effective in displacing K from exchange sites. Heat is usually given as on additional energy to enhanced the break down of minerals and release of K therefrom. The reagents in this group are: HCl of different strengths, 1.4N H_2SO_4, boiling 1N HNO_3 etc.

All these methods have been tried and recommended for soils of temperate zones other than humid tropical regions. Thus, in the present study, several extractants have been employed in view of predicting the best method that can assess the K availability status of some representative soils of Bangladesh.

MATERIALS AND METHODS

Materials: Surface soils (0-15 cm) from 29 soil series were collected, air dried, ground and passed through 2 mm sieve for mechanical and 0.5 mm sieve for chemical analyses.

Laboratory Analyses: Eleven extractants covering various acids, bases and buffered solutions were used to test for K availability (Table 1). Total K was extracted by HF-$HClO_4$ digestion method as outlined by Pratt (1965).

Green House Experiment: A pot experiment was conducted with air-dried sample from each soil (1 kg/pot, 12cm x 15cm size). Polythylene film was used between soil and pot to avoid contamination from the earthen wire pots. Soils in each pot was kept submerged for 3 days for wetting. Four weeks old healthy rice seedlings (Oryza sativa cv. BR-4) were transplanted (4 seedlings/ pot). About 2-3 cm level of standing water was maintained throughout the whole experimental period. The experiment was attanged in a completely randomized block design with three replications.

Plant sampling was carried at 60 and 90 days after transplanting, dried for 16 hours at 65°C (1°C) and ground to 1 mm size in a micro-grinder.

Analytical Techniques: Particle-size distribution was
determined by hydrometer method (Table 2). pH was measured with
a combined glass/colomel electrode and that of organic C by wet
oxidation method (Walkely and Black, 1934). CEG was estimated
from N NH$_4$OAc (pH 7.0) extract. Potassium in soil and plant
extracts was measured by flame photometer.

RESULTS AND DISCUSSION

K extracted by different method showed a significant
variation among the soils (Table 3). The relative efficiency
of the methods to release K also varied significantly and could
be arranged in the following sequence.

Boiling 1N HNO$_3$ > Hot 1.4N H$_2$SO$_4$ > 1N Na$_2$SO$_4$ (pH 1) >
modified 1N NaCl > 0.7N HCl > 0.5N HCl > Morgan's reagent > 0.5M
NaHCO$_3$ (pH 8.5) > 1N NaCl > N H$_4$OAc > water.

The results showed that the concentrated acids viz.
boiling 1N HNO$_3$ and hot 1.4N H$_2$SO$_4$ extracted relatively high K
(Table 3). The reasons were well described by Hunter and Pratt
(1957). The acids extracted difficulty available K in addition
to the readily available K (Ekepete, 1972).

The concentration of acids and heat energy might be
considerable factors in releasing available K. Thus, 0.5N HCl
and 0.7N HCl extracted similar but lower amounts of available K
than boiling 1N HNO$_3$ and hot 1N H$_2$SO$_4$ and also acidified salt
solutions. The latter ones extracted higher amounts of K than
normal salts and buffer extractant. pH fluctuations might also
enhance the release of nutrients.

Correlation coefficients between pairs of methods were
calculated (Table 4). The result showed that 1N HNO$_3$ possessed
significant correlation with all the methods except 1N NH$_4$OAc
at 0.1% level. Significant correlation was also observed at
0.1% level between 0.5N NaHCO$_3$ and all the extractants except
1N NH$_4$OAc and 0.7N HCl. Only nonsignificant correlation was
recorded between 1.4N H$_2$SO$_4$ and water. The range of significance
of correlation coefficients varied from 0.1 to 10%. 1N NH$_4$OAc
and water showed lower degree of significance (2 to 10%) with
most of the extractants.

The findings of this investigation have a practical significance concerning the use of chemical method in determining available K for fertilizer recommendations. In the first place, if one method is used on a group of soils with the same K distribution pattern, the correlation between available K and crop response to fertilizer will be better than a group of soils with different K distribution patterns. Secondly, when correlation between crop response and available K determined by one method on a particular group of soils is established, other methods whose extractants have a similar effect on soil K can also be applied to this particular group of soils. Thirdly, in each soil, there may be two or more forms of K which are the main sources of supply of available K to crops. If the extractants used in chemical methods can dissolve these forms selectively, the available K determined by this method will best reveal the status of available K of the soil. For example, if exchangeable and water soluble K were the main sources of available K in a soil, the NH_4OAc extraction method might better reveal the status of the soils available K. If difficulty exchangeable K was the main source of K supply, the boiling HNO_3 method would give a better measure of available K status of the soils.

To substantiate this view, correlation coefficients were calculated between available K extracted by different methods and K content in plant (Table 5). K uptake is certainly a better indication than K content. All the chemical extraction methods correlated positively but at different significance levels (1-5%) with 60 days plant K (Table 6). Boiling 1N HNO_3, hot 1.4N H_2SO_4, 1N NaCl (pH 1.0) and 0.5M $NaHCO_3$ (pH 8.5) showed significant correlation with plant K at 0.1% level. The highest value of r (+0.6631) was recorded with boiling 1N HNO_3. Similar findings were reported by other workers (Leaf, 1958; Ekepete, 1972, Panaullah, 1974). Formation of grain and translocation of K in the grain from the shoot might be cause of nonsignificant relation with 90 days plant K except 1N NaCl (pH 1) extractable K.

Summarizing the results obtained so far, the modified boiling 1N HNO_3 method of Pratt (1951) was found to be the best of all the extractants. The measure of availability of a particular nutrient is best judged by the performance of crops under field experiments carried out under natural conditions. The laboratory index of availability, however, could be used as a prelude to field experiments and fertilizer trials since, "a chemical method can be taken to be a true index of the fertilizer

needs of the soil only when it is correlated with crop yields and plant growth responses to fertilizers" (Ghani and Islam, 1957).

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        ion method. Soil Sci. 37, 29-38.

Extractant	Authors	Soil: extractant	Extraction time (hour)
Water		1:10	1
1N NaCl	Hissinik (1923)	1:10	1
Neutral N NH_4OAc	Jackson (1962)	1:10	1
Modified Morgan's universal solution	Morgan (1937)	1:10	1
Modified 1N NaCl (pH 1)		1:10	1
1N Na_2SO_4 (pH 1)		1:10	1
0.5N HCl		1:10	1
Modified 0.7N HCl	(Baumgardner and Barber (1965)	1:10	1
Modified hot 1.4N H_2SO_4	Hunter and Pratt (1957)	1:10	1
Modified 1N HNO_3	Pratt (1951)	1:10	1
Modified 0.5N $NaHCO_3$ (pH 8.5)	Olsen et al (1954)	1:10	1

Table 2.   Physical and Chemical Properties of the Soil Samples.

Soil Series	Texture	pH	O.C.%	CEC me/ 100 g	K-Sat %
Dhalla	SiL	7.0	0.52	19.9	0.90
Dhaleshwari	SiL	7.5	0.37	13.9	0.83
Karatoya	S	5.2	0.16	10.2	1.43
Hatiya	SiCL	7.1	0.60	24.4	1.67
Ramagati	SiCL	7.8	0.46	22.1	1.74
Savar Bazar	SiC	5.3	1.02	20.6	0.76
Shilmindi	SiCL	6.5	0.58	15.0	0.68
Sonatala	SiL	5.3	0.57	15.5	0.40
Jamun	L	5.1	0.74	7.3	0.71
Jhalkathi	SiL	7.7	0.32	20.2	0.77
Pahartall	CL	6.0	0.80	10.6	1.04
Chakla	C	5.5	0.56	27.4	1.21
Naraibag	C	5.5	0.50	29.6	1.76
Jalkundi	SiL	5.8	0.82	23.1	0.63
Ghatall	SiCL	6.3	0.84	15.5	0.81
Sara	SiC	7.1	0.99	32.0	1.62
Pirgacha	SiL	5.1	0.59	14.3	0.43
Atwari	SCL	4.9	0.85	25.4	0.86
Panchagar	SCL	5.4	0.29	25.3	0.94
Ruhea	SL	4.9	0.58	8.2	0.75
Gerua	SiCL	4.5	0.70	16.3	0.77
Salna	SiCL	5.0	0.59	13.1	1.04
Tejgaon	L	5.4	0.76	12.2	1.19
Kashimpur	L	5.5	0.84	21.4	1.21
Noadda	CL	5.1	0.75	14.7	0.99
Chiatta	CiCL	5.2	0.50	10.5	1.19
Chandra	CL	4.8	0.62	13.9	0.70
Kalma	CiCL	4.7	1.07	25.7	1.30
Dhurong	CL	6.0	0.68	15.2	0.83

Table 3.   Available K (µg⁻¹) Contents of Soil Samples as Determined by 11 Different Methods.

Soil Series	1N NH₄OAc	1N NaCl	1N NaCl	1N Na₂SO₄ (pH 1.5)	Morgan's solution	0.5N HCl	0.7N HCl	1.4N H₂SO₄	1N HNO₃	0.5N NaHCO₃ (pH 8.5)	Water
Dhalla	70.0	182.4	583.8	697.3	494.6	316.2	279.7	1216.2	2529.6	166.2	28.4
Dbaleshwari	45.0	101.2	1238.9	1700.5	247.0	251.0	259.1	2050.2	2137.7	133.6	23.8
Harichoya	57.0	165.8	752.2	679.4	190.1	234.6	210.3	1504.3	1989.7	149.6	14.2
Batiya	160.0	153.9	1239.6	1355.6	352.5	518.5	534.8	972.3	2625.1	239.0	93.2
Rangati	150.0	194.3	1214.5	1554.6	364.4	510.1	534.4	895.8	2326.2	218.6	70.9
Savar Bazar	61.0	101.3	802.4	285.9	145.9	141.9	125.7	1459.1	1750.9	77.0	7.1
Shillmondi	40.0	44.5	226.5	904.4	93.0	85.0	90.0	401.2	517.8	52.6	10.6
Sonatala	24.0	93.0	97.1	244.3	74.8	52.0	56.6	331.7	582.4	38.4	8.6
Jamur	20.8	32.4	97.0	202.2	60.7	48.5	48.5	182.0	194.1	28.3	12.1
Jhalkathi	61.0	162.2	984.6	608.1	239.2	948.6	921.1	2197.2	1799.9	174.3	10.1
Pahartali	43.0	60.7	101.2	157.9	101.2	85.0	89.0	194.3	234.8	52.6	24.3
Chakia	129.0	80.9	117.3	129.4	108.2	161.7	258.8	970.4	420.5	64.7	21.2
Naraibag	203.0	129.6	1409.6	271.4	198.5	210.8	186.3	1263.8	1263.8	113.4	56.7
Jalhundi	57.0	77.1	99.4	240.1	144.0	125.7	137.9	632.8	494.9	98.4	32.5
Gnatali	49.0	60.7	198.4	631.5	109.3	113.4	121.5	242.9	542.5	64.8	24.8
Sara	203.0	93.2	202.7	705.3	137.8	300.0	243.2	2008.9	2042.9	101.3	14.2
Pirgacha	24.0	40.5	170.0	348.0	78.9	60.8	64.8	222.6	615.2	44.5	9.1
Atwari	85.0	129.6	163.3	137.7	101.2	105.3	105.3	898.8	485.8	40.5	7.1
Panchagar	93.0	52.7	243.2	154.0	109.5	60.8	81.1	1021.6	518.9	52.7	5.1
Rubes	24.0	24.3	137.7	259.4	81.0	60.0	56.7	166.1	275.4	44.6	14.2
Gorua	49.0	48.5	66.7	97.4	95.0	72.8	84.9	192.4	266.9	50.6	6.1
Salna	53.0	56.6	80.8	87.3	93.0	90.0	129.4	242.6	66.7	66.7	22.2
Tejgaon	57.0	46.5	56.6	91.4	78.9	72.8	72.8	202.2	299.2	48.5	13.2
Kashiapur	101.0	93.0	109.2	160.1	155.6	157.7	145.5	295.1	517.4	135.4	34.4
Noadda	57.0	80.9	84.9	152.1	151.7	101.1	101.1	230.5	307.4	86.7	22.2
Chatta	49.0	60.8	60.8	87.5	97.3	89.0	85.1	121.6	259.4	64.9	9.6
Chandra	38.0	40.4	46.5	91.4	62.7	56.6	72.8	214.3	157.7	46.5	6.6
Islam	130.0	56.7	60.7	79.9	68.8	81.0	80.5	186.3	330.7	40.5	28.4
Dhurong	49.0	56.6	133.7	234.6	93.0	80.9	89.9	113.2	493.4	56.6	20.2
Mean	75.2	86.9	375.1	342.6	149.1	179.3	180.0	699.2	911.1	87.3	22.5
Highest	203.0	194.3	1409.6	1700.5	494.6	948.6	921.1	2806.9	2625.1	239.0	93.2
Lowest	—	—	46.5	79.9	60.7	48.5	48.52	113.2	66.7	28.3	5.1

Table 4. Coefficient of Correlation Calculated Between Available K as Determined by Two Methods.

	1 N NaCl	1N NaCl pH 1	1N Na_2SO_4	Morgan	0.5N HCl	0.7N HCl	1.4N HCl	1N HNO_3	Water	0.5N $NaHCO_3$
1N NH_4OAc	+0.463[3]	+0.450[3]	+0.324[5]	+0.371[5]	+0.366[5]	+0.364[5]	+0.565[2]	+0.462[3]	+0.612[1]	+0.477[3]
1N NaCl		+0.738[1]	+0.566[2]	+0.844[1]	+0.739[1]	+0.729[1]	+0.631[1]	+0.840[1]	+0.523[2]	+0.847[1]
1N NaCl			+0.734[1]	+0.713[1]	+0.679[1]	+0.670[1]	+0.535[2]	+0.825[1]	+0.612[1]	+0.784[1]
1N NaCl pH 1				+0.682[2]	+0.572	+0.577[2]	+0.373[5]	+0.780[1]	+0.589[2]	+0.745[1]
1N Na_2SO_4 pH 1					+0.669[1]	+0.656[1]	+0.457[3]	+0.856[1]	+0.622[1]	+0.880[1]
Morgan						+0.991[1]	+0.662[1]	+0.709[1]	+0.420[4]	+0.809[1]
0.5N HCl							+0.620[1]	+0.690[1]	+0.444[4]	+0.802[1]
0.7N HCl								+0.720[1]	+0.093ns	+0.499[2]
1.4N H_2SO_4									+0.500[2]	+0.863[1]
1N HNO_3										+0.718[1]
Water										

1, 2, 3, 4 and 5 denites level of significance at 0.1, 1, 2, 5 and 10% respectively.

Table 5.   K Content (%) of Rice Plant

Soil Series	60 Day	90 Day
Dhalla	1.57	1.40
Dgakesgwaru	1.60	1.28
Karatoya	1.44	1.10
Hatiya	1.54	1.08
Ramgati	1.70	1.43
Savar Bazar	1.40	1.07
Shilmondi	1.44	0.97
Sonatala	1.41	1.27
Jamun	1.18	1.33
Jhalkathi	1.68	1.31
Pahartali	1.20	0.89
Chakla	1.36	1.20
Naraibag	1.75	1.43
Jalkundi	1.37	1.33
Ghatail	1.41	1.18
Sara	1.75	1.26
Pirgacha	1.52	1.02
Atwari	1.24	1.84
Panchagar	1.42	1.20
Ruhea	1.38	1.12
Gerua	1.24	1.36
Saina	1.62	0.89
Tejgaon	1.46	1.25
Kashimpur	1.41	1.20
Noadda	1.23	1.02
Chilata	1.24	1.11
Chandra	1.30	1.55
Kalma	0.97	1.40
Dhurong	1.19	0.80
LSD at 5% level	0.03	0.02

Table 6.   Coefficients of Correlation Calculated Between
            Available K as Measured by Different Extractants
            and K content of Plant.

Methods	K (%) 60 day	K (%) 90 day
Boiling HNO_3	$+0.6631^{1}$	$+0.1200$ ns
Hot 1.4N H_2SO_4	$+0.6274^{1}$	$+0.2283$ ns
1N Na_2SO_4 pH 1	$+0.5488^{2}$	$+0.0077$ ns
1N NaCl pH 1	$+0.6410^{1}$	$+0.1415$ ns
0.7N HCl	$+0.5527^{2}$	$+0.1475$ ns
0.5N HCl	$+0.5798^{2}$	$+0.1483$ ns
Moragan's	$+0.5403^{2}$	$+0.1661$ ns
0.5M $NaHCO_3$ pH 8.5	$+0.6131^{1}$	$+0.0777$ ns
1N NaCl	$+0.5286^{2}$	$+0.36134^{4}$
1N NH_4OAc	$+0.4179^{3}$	$+0.3049$ ns
Water	$+0.3915^{3}$	$+0.0194$ ns

1,2,3 and 4 denotes level of significance at 0.1, 1, 5 and 10%
respectively.