Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences
Volume 1 Number 1, 7-11, 2002

Comparative Efficiency of Various Potassium Extraction Procedures

S. M. Mehdi, M. Sarfraz, M. Sadiq and G. Hassan
Soil Salinity Research Institute, Pindi Bhattian, Hafizabad, Pakistan

Abstract: A green house study was undertaken to see the comparative efficiency of various potassium extraction procedures in three soil series of Pakistan i.e., the Shahdara, the Sultanpur and the Lyallpur. The data showed that number of tillers plant^{-1}, grain and straw yield of wheat was increased by the application of N and P fertilizers. Potassium concentration in grain and straw was decreased while its uptake increased with the application of N and P. Potassium release from the native reserves increased with the application of N and P. The amount of K extracted by HNO_3 was maximum followed by NH_4OAC, MgOAC, $CaCl_2$ and water in the descending order. Ammonium acetate gave best correlation between K uptake by wheat plants and K extracted by various chemical extractant when no fertilizer was applied while $CaCl_2$ proved best extractant when N and P fertilizers were applied. Quantity factor gave best correlation with K uptake at all levels of N and P fertilizers application rates when Quantity, Intensity and Quantity/Intensity relations were studied. In case of Electroultrafiltration (EUF) determination, the values of correlation coefficient (r) were significantly high when K was determined for 35 minutes EUF at control while, 10 minutes EUF at all N and P application rates. In over all comparison of various procedures like water soluble, NH_4OAC, MgOAC, $CaCl_2$, HNO_3, EUF, Q, I and Q/I relations for determining the soil K status and its uptake by wheat plant showed that NH_4OAc gave the best correlation at zero application of N and P fertilizers, water soluble and $CaCl_2$ were found best when N_{150} and P_{100} dose was applied while EUF 10 minutes and $CaCl_2$ were good when N_{200} and P_{150} were applied. The activity ratio (Q/I) did not prove good parameters to measure the K availability status of the soils. Though the chemical extractant gave comparatively better correlation with K uptake but EUF method is a rapid and easy. So it should be used for routine work to get accurate and rapid results.

Key words: K extraction, wheat crop, correlations

Introduction

The supply of potassium from soil depends on the quantities and forms present and the rate at which the exchangeable potassium is replenished from non-exchangeable sites. Mostly the amount of water soluble, exchangeable and non-exchangeable forms of K are used to evaluate the K supplying power of the soil. The amount of potassium released to the plants and by various extracting solutions differ greatly. Amounts of potassium removed by NH_4OAc, HNO_3, HCl and $NaBPh_4$ from soil prior to cropping generally correlate better with its uptake by plants, than did amounts of K removed by other extractant (Conyers and McLean, 1969). While Grimme and Nemeth (1976) noted that K extracted by 0.025 N $CaCl_2$ was closely correlated with potassium concentration and they further emphasized on the advantage of EUF method that enable direct measurement of desorption and solubility rates.

There are many other soil testing methods and a great deal of work has been expanded in the search for the "best" method. The various soil testing methods can be classified according to the fractions of soil K, which are recovered. Different forms of K are

(I) Water soluble K (II) exchangeable K (III) Plant available K (IV) Non-exchangeable K (V) Fixed K (VI) Released K. The ratio of K to $(Ca+Mg)^{½}$ in the soil solution has been used by several workers to measure K availability in the soils. The quantity (K) and the intensity factor (AR^K) proposed by Beckett (1964 a) gave a better picture of the K supplying power of the soil than available K or the ionic activity ratio of K. The potential buffering capacity (PBC) combines in one parameter the quantity and intensity factor (Beckett, (1964ab). Soils having high PBC^K and low K and AR^K values are not responsive. The EUF method not only allows in the determination of intensity, quantity and buffering capacity (Nemeth, 1976 and Grimme, 1980) but also allows as assessment of the changes of mobile soil K with time. While Purwanto and Sri Adiningsih (1980) reported that over fairly wide range of soils, not 1 HNO_3 had the highest correlation with rice yield and K uptake but also Morgan and Venema (10 % NaOAC+3% CH_3COOH) gave correlation almost as high. The practice of soil testing for K in Pakistan consists of extracting the soils with neutral normal NH_4OAC, designating them low, medium or high on the basis of test estimates given by Tamhane and Subbiah (1960) making fertilizers use recommendations in the light of available experimental data. The soils of Pakistan have still large capacity to provide K to crops under ordinary conditions but introduction of high yielding crop varieties and increased crop intensity have resulted in considerable drain of soil K reserves and need for K fertilization is becoming necessary (Malik *et al*., 1989). So there is a great need to determine total and available K in soil and its uptake by plants as influenced by various doses of N and P. Keeping this in view this study was conducted with the following objectives:

Comparison of different chemical extractant for potassium status in soil.

Availability of K by applying activity parameters i.e., $\dfrac{aK}{a\,(Ca+Mg)^{½}}$

Potassium supplying power of the soils as determined by EUF.

Potassium supplying power of the soils to wheat fertilized with various doses of N and P.

Materials and Methods

A pot experiment was conducted to determine the K status of various soil series of Punjab and its availability to wheat crop by applying nitrogen and phosphorus fertilizers. Six soil samples of three soil series viz the Shahdara, the Nabipur and the Lyallpur were collected with the technical assistance of soil Survey of Pakistan, Lahore from appropriate sites from 0-15 cm and 15-45 cm depth. These soil samples were air dried ground, passed through a 2 mm sieve and thoroughly mixed. Three kg of each sample was added to plastic pots and following treatments were applied.

T_1 = Control $T_2 = N_{150}P_{100}$ kg ha^{-1} $T_3 = N_{200}P_{150}$ kg ha^{-1}.

Wheat variety LU 26 S was sown and the system of layout was CRD with three replications. In this way 54 pots were used in this study. Crop was harvested at maturity, tillers plant^{-1}, grain and straw yield data were recorded. Grain and straw samples were analyzed for K contents by using method given in Handbook No. 60 (U.S.Salinity Lab. Staff, 1954) and K uptake was calculated by using the formula:

$$\text{Potassium uptake mg kg}^{-1} = \frac{\text{Grain/Straw yield (g pot}^{-1}) \times \text{K in Grain/Straw (\%)}}{100 \times 3} \times 1000$$

The original soil samples prior to filling in pots were analyzed for physical and chemical characteristics (Table 1) according to the methods given in Handbook No. 60 (U.S.Salinity Lab. Staff, (1954) except texture by Moodie *et al.* (1959), total N in soil by Jackson (1962) and available P by Watanabe and Olsen (1965). Potassium was extracted by (I) Water (II) 1 N NH_4OAC (U.S.Salinity Lab. Staff, 1954)(III) 0.5 N MgOAc (Conyers and McLean, 1969) (IV) 0.025 N $CaCl_2$ (Grimme and Nemeth, 1976) (V) 1 N HNO_3 (Knudsen *et al.*, 1982) (VI) Quantity/Intensity relationships of exchangeable K/solution

$$K = \frac{aK \text{ (Beckett, 1964 a)}}{a\,(Ca+Mg)^{1/2}}$$

(VII) K determination by electroultrafiltration EUF (Nemeth, 1972).
EUF method is a combination of electro dialysis and ultra filtration of the cathode and anode dialyzate at chosen voltages and temperature. The middle cell apparatus is used in EUF. The middle cell containing the soil suspensions, soil: water (1:10) has a strainer and a water inflow. Each side of this middle cell is provided with micropore filter attached to the platinum electrode that separates the middle cell from the two out side compartments. Therefore, the hydroxides (NaOH, KOH, Ca (OH_2), NH_4OAC) accumulate at the cathode and the acids (HNO_3, H_2SO_4 etc.) accumulate at anode are washed away by continuous stream of water to the collecting tank. The fraction is collected at 5 minutes or other intervals upto 35 minutes. The fraction 0-10 minutes is intensity, 0-35 quantity and 30-35 minutes is reserve K while ratio of 5-10: 30-35 minutes is potential buffering capacity (PBC). After the harvest of crop, soil samples were again analyzed for K by using N NH_4OAC. Correlation was determined between K extracted by various procedures and K uptake by wheat plants (K uptake by grain + K uptake by straw) as described by Steel and Torrie (1980).

Results and Discussion

The data showed that all the soil series used were medium to fine in texture, non-saline, alkaline in reaction, low in total N and available P (Table 1) to supply adequate nutrient requirements of high yielding crops. The number of tillers plant^{-1}, grain and straw yield were maximum in Sultanpur sub soil while minimum in Lyallpur sub soil (Fig. 1, 2 and 3). As for as treatments are concerned, these parameters increased with increasing levels of N and P application in all the soils. A number of workers have also noted similar observations (Hayee and Aman Ullah, 1972 and Barheris, 1983). The K concentration in grain and straw was noted maximum in Sultanpur sub soil and minimum in Shahdara sub soil (Fig. 4 and 5). As for as treatments are concerned, K concentration decreased with the increasing rates of N and P fertilizers. The reason for decrease of K concentration might be dilutions effect i.e., the grain and straw yield was increased by adding N and P fertilizers resulting in decrease of K contents. Donohue and Brann (1984) also reported similar results.
Potassium uptake by wheat plants increased in all the soil series in surface and sub soils except Sultanpur sub soil where it decreased then increased with the application of N and P fertilizers (Fig. 6). Although the K percentage in the plant material was less in N and P fertilized pots yet the total K uptake was higher which might be due to dilution effect by relatively more yield of dry matter (grain and straw). Potassium uptake by the plants was somewhat proportional to the amount of this element in the soil. Similar findings were depicted by Al-Ravi and Al-Mohammidi (1979) and Mengel (1982). It can further be seen that K uptake in all the treatment was more from surface than that from sub soil except in the Shahdara surface soil in (T_1) and Sultanpur sub soil in all the treatments. The reason might be that soil sample of Sultanpur series was taken from the paddy area where most of the K was leached down from surface to sub soil, so its extractable contents were more in sub soil than that in surface layer. Release of potassium from non-exchangeable K by applying N and P was considerable (Table 2) in spite of the fact that initial K status of all the soil samples ranged between satisfactory to adequate. More K was absorbed by plants from those pots to which N and P were applied. Post harvest analysis of the soils indicated that NH_4OAc extractable K decreased in all the soils except Sultanpur surface where it increased in T_2 but not in T_1 and T_3.It can very safely be concluded that if we increase the application of N and P, then uptake of K is increased and more K will come from native to exchange sites or to soil solution form. Grimme (1974) found that in many cases yields are reduced, if a large proportion of the K requirement has to be covered by non-exchangeable K, because the release rate may be too low to meet the K demand of vigorously growing crops. Similar results were reported by McLean (1978) and Sekhon (1983).
Potassium was extracted by using five chemical extractant. The data showed that water extractable K was low as compared with other extractant (Table 3). The amount of K extracted by NH_4OAC was more than MgOAc, $CaCl_2$ because NH_4^+ ion has almost the same sized that of K, so it enters into clay holes and extracts K while Ca^{++} and Mg^{++} have large size and cannot replace K from internal sites of 2:1 clay minerals. So, less quantity is extracted by these extractant. All these three extracts water soluble + exchangeable K. Therefore amounts of K extracted by these extractant is greater than only K extracted by water. The amounts of K determined by boiling 1 N HNO_3 are very high because it determines the non-exchangeable fraction of soil K. Conyers and McLean (1969) reported HNO_3 treatments had major expansion and dissolution effect on vermiculite and a component of an illite but had relatively small effects on Kaolinite, montmorillonite and a Brooksten soil clay.
Quantity (Q) and intensity (I) values were determined from primary data to see the K potential buffering capacity (PBC) of all these soil series. The maximum value of Q (me 100 g^{-1}), I [AR $(MI)^{1/2}$] and Q/I (PBC) was in Sultanpur sub soil (Table 4) while minimum Q and I was in Shahdara surface and Q/I in Sultanpur surface soil. According to Beckett (1964 b) the factor Q and I gave a better picture of the K supplying power of a soil. The potassium was also determined by EUF which indicated that K desorption rate were similar in both surface and sub surface of the Shahdara series (Table 5, Fig. 7 and Fig. 8). The amounts of soil solution K (0-10 minutes) and exchangeable K (0-35 minutes) were adequate to supply K to wheat plants. The portion 30-35 minutes indicate that release of K from reserve was enough to supply K through out the growing period. The ratio between 5-10 and 30-35 minutes indicate the K released which was high and show a high K fixation capacity of these soils. In case of the Sultanpur soil series, the EUF fractions of K were different in surface and sub soil (Table 5, Fig. 9 and 10). In case of surface soil the supply would be constant through out the growing period and the reserve quantity and fixation capacity were high. In case of sub soil, the EUF curves indicate that the initial K status was very high but with the passage of time, the supply would decrease. This soil was also found to supply enough reserve K in very low amounts in comparison to exchangeable K (0-35 minutes). In case of the Lyallpur series, the EUF fractions of absorbed K were also different for surface and sub surface soil (Table 5, Fig. 11 and 12). The results indicated that the solution K was less while exchangeable K was more and its release rate was constant in surface layer. The ratio between 5-10 and 30-35 minutes indicates that K released which was very wide showing low K fixation capacity of this soil. In sub soil the K availability 1st increased then decreased indicating the need of K fertilizer application for greater and constant supply of K. This soil also has low K fixation capacity. Similar explanation for these data was given by Grimme (1980). Potassium extracted by all the five chemical extractant was positively correlated with the K uptake by wheat plants in all the treatments (Table 6). The maximum correlation coefficient value was 0.98 and minimum 0.026. Among all the extractant. K extracted by N NH_4OAC was highly correlated ($r=0.98$) with K uptake by wheat in T_1 followed by MgOAc ($r=0.97$), HNO_3 ($r=0.83$) and water ($r=0.026$) while at the T_2 water was highly correlated ($r=0.84$) followed by $CaCl_2$ ($r=0.68$), MgOAc ($r=0.67$), NH_4OAc ($r=0.62$) and HNO_3 ($r=0.45$). At T_3 $CaCl_2$ gave maximum correlation value ($r=0.82$) followed by MgOAc ($r=0.81$), NH_4OAc ($r=0.74$), water ($r=0.67$) and HNO_3 ($r=0.49$). These results are line with those of Grimme and Nemeth

Table 1: Physical and Chemical Characteristics of the Soils

Soil Series	Depth	Texture	pHs	EC_e (d S m^{-1})	Total N (%)	Available P (mg kg^{-1})	Extractable K (mg $k^{-}g^{-1}$)
Shahdra(S_1)	0-15	Clay loam	8.05	3.50	0.028	5.4	62.50
Shahdra(S_2)	15-45	Sandy clay loam	8.02	1.20	0.020	7.0	60.00
Sultanpur(S_3)	10-15	Loamy clay	7.93	1.60	0.040	6.50	81.25
Sultanpur(S_4)	15-45	Loamy clay	8.12	1.90	0.036	7.40	205.00
Lyallpur(S_5)	0-15	Silty clay loam	7.60	0.86	0.024	6.0	106.25
Lyallpur(S_6)	15-45	Silty clay loam	8.10	1.30	0.038	8.0	75.00

Table 2: Release of Potassium

									Post Harvest				
Series	Depth (cm)	Treatment	W.Soluble K	Exch. K	Ext.able K	Non-exch K	Total Capacity K	W.Sol. K	Exch K	Straw K	Grain K	Total K	Release K
											mg kg^{-1}		
Shahdra	0-15	T_1	25.47	37.03	62.5	803.90	866.40	16.21	72.13	19.430	4.46	122.22	49.720
Shahdra	15-45	T_1	3.85	56.15	60.00	748.00	808.00	7.15	60.77	24.734	3.40	96.054	36.054
Sultanpur	0-15	T_1	8.69	72.56	81.25	830.75	912.00	9.70	83.22	31.214	6.13	130.264	49.014
Sultanpur	15-45	T_1	14.14	190.86	205.00	1147.00	1352.00	19.21	118.29	57.52	9.91	204.93	-0.07
Lyallpur	0-15	T_1	5.38	100.87	106.25	1223.75	1330.00	5.54	96.55	34.464	6.25	142.804	36.554
Lyallpur	15-45	T_1	2.96	72.04	75.00	805.00	880.00	6.39	69.02	24.020	4.78	104.22	29.22
Shahdra	0-15	T_2	25.47	37.03	62.5	803.90	866.40	12.70	45.30	49.766	10.69	115.466	52.956
Shahdra	15-45	T_2	3.85	56.15	60.00	748.00	808.00	4.57	50.43	37.234	10.44	102.664	42.674
Sultanpur	0-15	T_2	8.69	72.56	81.25	830.75	912.00	7.98	72.02	39.958	13.34	133.298	52.048
Sultanpur	15-45	T_2	14.14	190.86	205.00	1147.00	1352.00	20.33	132.27	52.100	10.20	214.800	9.80
Lyallpur	0-15	T_2	5.38	100.87	106.25	1223.75	1330.00	5.128	6.96	41.360	10.94	144.390	38.14
Lyallpur	15-45	T_2	2.96	72.04	75.00	805.00	880.00	5.79	51.71	40.634	9.16	107.294	32.294
Shahdra	0-15	T_3	25.47	37.03	62.5	803.90	866.40	9.37	30.63	67.24	12.86	120.104	57.604
Shahdra	15-45	T_3	3.85	56.15	60.00	748.00	808.00	6.57	37.18	50.884	10.66	105.294	45.294
Sultanpur	0-15	T_3	8.69	72.56	81.25	830.75	912.00	5.50	42.0	45.350	10.59	103.440	22.190
Sultanpur	15-45	T_3	14.14	190.86	205.00	1147.00	1352.00	20.49	112.85	80.104	17.33	230.754	25.754
Lyallpur	0-15	T_3	5.38	100.87	106.25	1223.75	1330.00	7.47	87.53	51.024	10.00	158.024	49.774
Lyallpur	15-45	T_3	2.96	72.04	75.00	805.00	880.00	5.19	57.73	48.848	8.56	120.328	45.328

Table 3: Potassium Extracted by Different Extractant (ppm)

Soils	Water soluble	1 N NH_4OAC	0.5 N MgOAC	0.025 N $CaCl_2$	1 N HNO_3,
(S_1)	25.47	62.50	55.00	50.00	866.40
(S_2)	3.85	60.00	50.00	45.00	808.00
(S_3)	8.69	81.25	58.25	56.25	912.00
(S_4)	14.14	205.00	187.50	180.00	1352.00
(S_5)	5.38	106.25	87.50	75.00	1330.00
(S_6)	2.96	75.00	50.00	43.75	880.00

Table 4: Quantity (Exchangeable potassium), Intensity (activity ratio) and Quantity/Intensity (Potential buffering capacity)

Soils	Q (K me/100 mg)	I [AR (M/l) ^{½}]	Q/I (PBC)
(S_1)	0.0947	7.846×10^{-4}	120.70
(S_2)	0.1441	1.00×10^{-3}	144.10
(S_3)	0.1857	1.962×10^{-3}	94.65
(S_4)	0.4897	3.786×10^{-3}	129.35
(S_5)	0.2582	2.272×10^{-3}	113.64
(S_6)	0.1844	1.707×10^{-3}	108.03

Table 5: K Determined by EUF (ppm)

Series	Depth (cm)	10 min.	35 min.	31-35 min.
Shahdra	0-15	12.5	37.6	4.2
Shahdra	15-45	12.5	37.6	4.2
Sultanpur	0-15	12.5	49.9	4.2
Sultanpur	15-45	74.7	182.7	33.2
Lyallpur	0-15	24.9	54.1	4.2
Lyallpur	15-45	8.4	37.6	8.3

Table 6: Correlation coefficients of K uptake by wheat crop and K Removed by Various K extractant from soils in all treatments

Treatment	Water soluble	NH_4OAC	MgOAC	$CaCl_2$	HNO_3
T_1	0.026 ^{NS}	0.98 *	0.97 *	0.97 *	0.83 *
T_2	0.84 *	0.62 ^{NS}	0.67 ^{NS}	0.68 ^{NS}	0.45 ^{NS}
T_3	0.67 ^{NS}	0.74 ^{NS}	0.81 *	0.82 *	0.49 ^{NS}

T_1 (r= 0.98) T_2 (r= 0.84) T_2 (r= 0.68) T_3 (r= 0.82) Y = 29.58 +0.85 X Y = 145.63 + 1.72 X Y = 154.72 + 0.23 X Y = 148.77 + 0.77 X

* = Significant at 5 % level of probability. N.S. = Non-significant

Table 7: Correlation coefficients of K uptake by wheat crop versus Q, I and Q/I in soils in all the treatments

Treatment	Q (K me/100mg)	I (AR (M/l) ^{½}	Q/I (PBC)
T_1	0.99 *	0.97 *	0.10 ^{NS}
T_2	0.49 ^{NS}	0.46 ^{NS}	0.02 ^{NS}
T_3	0.64 ^{NS}	0.52 ^{NS}	0.43 ^{NS}

T_1 (r = 0.99) Y = 37.57 + 334.29 X

T_2 (r = 0.49) Y = 149.05 + 61.61 X

T_2 (r = 0.64) Y = 155.50 + 226.66 X

* = Significant at 5 % level of probability N.S. = Non-significant

Table 8: Correlation coefficients of K determined by EUF and K uptake by wheat plants

Treatment	10 min.	35 min.	31-35 min.
T_1	0.958 *	0.959 *	0.897 *
T_2	0.660 ^{NS}	0.665 ^{NS}	0.627 ^{NS}
T_3	0.826 *	0.815 *	0.815 *

T_1 (r = 0.959) Y = 59.89 + 0.8 X

T_2 (r = 0.665) Y = 149.65 + 0.2 X

T_2 (r = 0.660) Y = 151.82 + 0.46 X

T_3 (r = 0.826) Y = 167.68 + 1.61 X

* = Significant at 5 % level of probability N.S. = Non-significant

(1976), Al-Ravi and Al=Mohammidi (1979) and Purwanto and Sri Adiningsih (1980). With the help of regression equations (1, 2, 3, 4) developed for maximum (r) value at each treatment, it is possible to tell how much will be the K uptake (y) by wheat if K extracted (x) by NH_4OAC when no fertilizer is to be applied, water and $CaCl_2$ extractable K (x) when N_{150} P_{100} are to be applied and $CaCl_2$

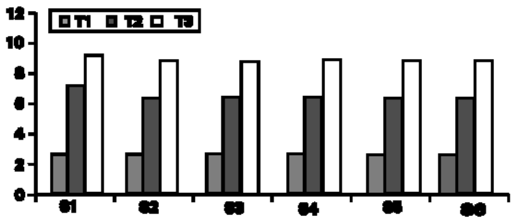

Fig.1: Number of Tillers plant^{-1}

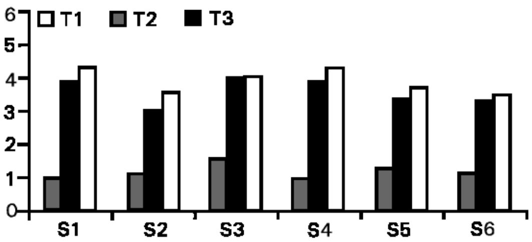

Fig. 2: Grain yield (g pot^{-1})

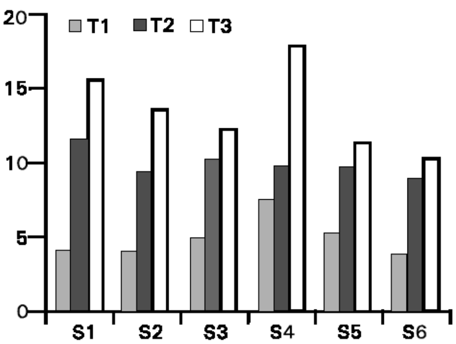

Fig. 3: Straw yield (g pot^{-1})

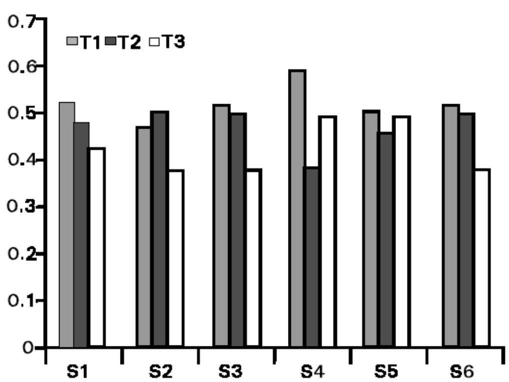

Fig. 4: Potassium in grains (%)

extractable K (x) if N_{200} P_{100} are to be applied. The correlation data between Q, I, Q/I and K uptake by wheat plants (Table 7) showed that Q gave maximum correlation With K uptake by wheat plant followed by I and least by Q/I. The correlation coefficient (r) between Q, I and K uptake by wheat was Positive and significant at T_1 while at T_2, T_3, Q, I and PBC have non- significant positive correlation. Similar results were noted by MacLean (1961) and Munn and McLean (1975). Regression equations were also computed for Q

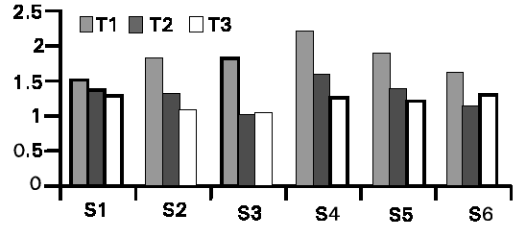

Fig. 5: Potassium in straw (%)

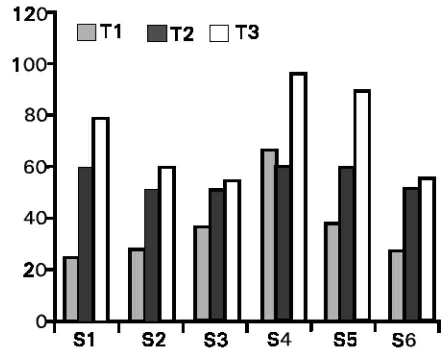

Fig. 6: Potassium Uptake (mg/kg)

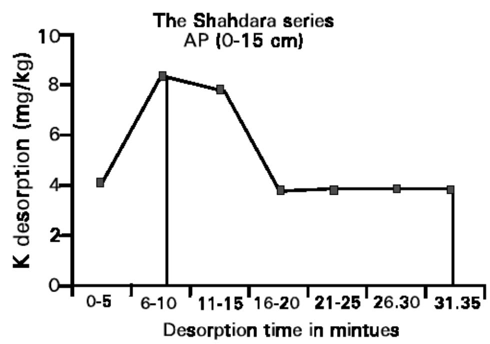

Fig. 7: K Determined by EUF (ppm)

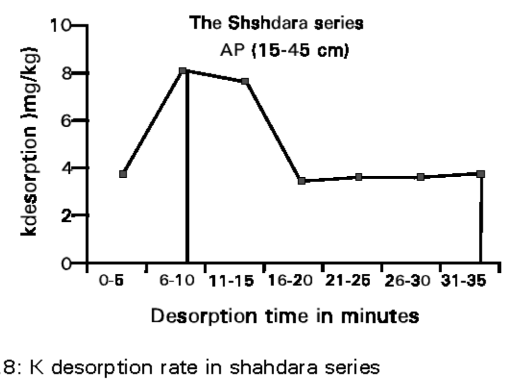

Fig.8: K desorption rate in shahdara series

to calculate K uptake if Q is determined. However under the conditions of this study the Q/I parameters of the soil seem to offer no advantage for predicting plant available K over the chemical extractant used. The correlation between K uptake and K concentration of soil solution determined by EUF was positive and significant (Table 8) at T_1 (r = 0.958) and T_3 (r = 0.826) but non-significant positive at T_2 (r = 0.660). Similarly

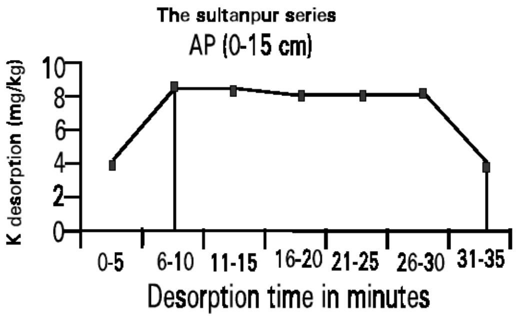

Fig. 9: K Desorption in sultanpur series

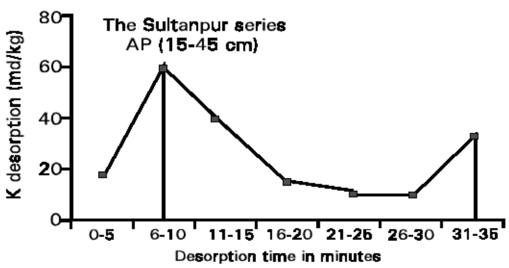

Fig.10: K Desorption in sultanpur series

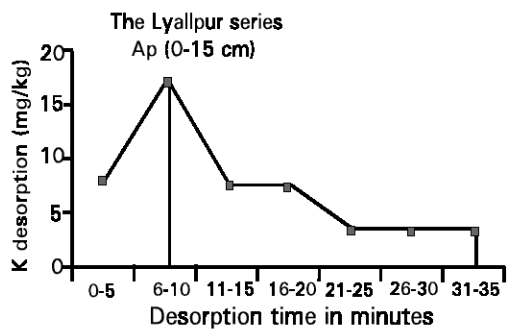

Fig.11: K Desorption in lyallpur series

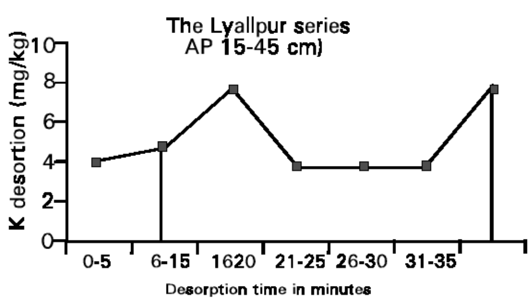

Fig.12: K Desorption in Lyallpur series

exchangeable K and K buffer capacity gave positive significant correlation at T_1 and T_3 and only positive at T_2. The EUF fractions of K gave similar correlations in the studies of Nemeth and Forster (1976) and Nair and Grimme (1979). Regression equations for calculation of K uptake by wheat were also computed for each treatment separately. In over all comparison of all the procedures tested like water, NH_4OAC, MgOAC, $CaCl_2$, HNO_3, EUF and activity ratio for determining the soil K status and its uptake by wheat plant showed that NH_4OAC is best when no fertilizer to be applied, $CaCl_2$ is best when N and P fertilizers to be applied. The activity ratio did not prove a good parameter to measure the K availability status of soil. Though the chemical extractant gave comparatively better correlation with K uptake but EUF method is rapid and easy. So it should be used for routine work to get accurate and rapid results.

References

Al-Ravi, A. A. H. and N. H. Al-Mohammidi, 1979. The potassium supplying power of some Iraqi Alluvial soils as related to mineralogical composition. 14th Coll. Int. Potash Inst., Bern, Switzerland, pp: 205-211.

Beckett, P. H. T., 1964a. Studies on soil potassium. Confirmation of the ratio law. J. Soil Sci., 15: 1-8.

Beckett, P. H. T., 1964b. Studies on soil potassium 1. The immediate Q/I relations of labile potassium in the soil. J. Soil Sci., 15: 8-23.

Conyers, E. S. and E. O. McLean, 1969. Plant uptake and chemical extraction for evaluating potassium release characteristics of soils. Soil Sci. Amer. Proc., 33: 226-230.

Donohue, S. J. and D. E. Brann, 1984. Optimum N concentration in winter wheat grown in the coastal plain region of Virginia. Communications in Soil Science and Plant Analysis 15: 651-666. (En, 9 ref.) Deptt. Agron., Virginia Polytech. Instt. and State Univ., Blacksburg, V.A.24061, USA.

Grimme, H., 1974. Potassium release in relation to crop production. Proc. 10th Congr. Int. Potash Instt., Bern, Switzerland. pp: 131-136.

Grimme, H., 1980. The evaluation of soil K status by means of soil testing. K workshop, Ibadan, Nigeria, pp: 23-40.

Grimme, H and K. Nemeth, 1976. Bief et die $CaCl_2$. Methode Vorteile beider Bestimmung der K-Versorgung Von. Boden. Lardw. Forsch., 29: 1-12.

Hayee, M. A. and Aman Ullah, 1972. Effect of high levels of nitrogen and phosphorus on the yield of wheat. Pak. J. Agri. Sci., 9: 139-142.

Jackson, M. L., 1962. Soil Chemical Analysis. Constable and Co. Ltd., London, pp: 183-192.

Knudsen, D., G. A. Peterson and P. F. Pratt, 1982. Lithium, sodium and potassium in methods of soil analysis (A. C. Page, R. H. Miller and D. R. Keenery Eds.). American Society of Agron., Inc. Soil Sci. Soc. Amer. Inc., pp: 225-246.

MacLean, A. J., 1961. Potassium supplying power of some Canadian Soils. J. Soil Sci., 41: 196-206.

Malik, D. M., R. A. Chaudhry and G. Hassan, 1987. Crop response to K application in the Punjab. Potassium workshop. Islamabad, Pakistan., pp: 1-60.

McLean, E. O., 1978. Influence of clay content and clay composition on potassium availability. Proc. of Symposium, K in Soils and Crops. Vigyan Bharan, New Delhi, pp: 1-19.

Mengel, K., 1982. Factors and Processes affecting potassium requirements of crops. Potash Review. Sub. 16, 90th suite, 9: 1-12.

Moodie, C. D., H. W. Smith and P. R. McCreery, 1959. Laboratory Manual for Soil Fertility. State College of Washington. Mimeograph, Pullman, Washington, pp: 175.

Munn, D. A. and E. O. McLean, 1975. Soil potassium relationships as indicated by solution equilibration and plant uptake. Soil Sci. Soc. Amer. Proc., 39: 1072-1076.

Nair, P. K. R. and H. Grimme, 1979. Q/I relations and EUF of soils as measures of potassium availability to plants. Z. Pflanzenernahr. Bodenkd. 142: 87-94. Fed. Rep. Germany.

Nemeth, K., 1972. The determination of desorption and solubility rates of nutrients in the soil by means of EUF. Proc. Coll. Int. Potash Instt., 9: 171-180.

Nemeth, K., 1976. The determination of effective and potential availability of nutrients in the soil by EUF. App. Sci. Develop., 8: 89-111.

Nemeth, K. and H. Forster, 1976. Beziehung Zwischen Ertragxund K-Entzug Von Ackerbohnen sowie verschieden E-Fraktionen Von. Boden Die Bodenkultur, 27: 11-119.

Purwanto, S. and S. S. Adiningsih, 1980. Humbungan penye diaan K pada tanah dengan Produksi bahan kering dan serapan K. In. Pen. Tanah Proc., No.1, pp: 137-147. Bogor.

Sekhon, G. S., 1983. Potassium dynamics in the soil of semi arid and arid areas. Potash Rev. Int. Potash Instt., Bern, Switzerland, Sub. 6, 48th suite No.,7.

U. S. Salinity Laboratory Staff, 1954. Diagnosis and Improvement of Saline and Alkali Soils. U.S.D.A. Hand Book No. 60. pp: 160. Washington, D.C.

Watanabe, F. S and S. L. Olsen, 1965. Test of an ascorbic acid method for determining P in water and $NaHCO_3$ extract from soil. Soil Sci. Soc. Am. Proc., 29:577-578.

Steel, R. G. D. and G. H. Torrie, 1980. Principles and procedures of statistics. McGraw Hill Book Co. Inc., New York, USA.