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Studies on K release capacity of Aridisols of Rajasthan

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Abstract
A greenhouse experiment was conducted on eight established Aridisols of Rajasthan to assess the release of non-exchangeable K of soils by seven successive crops of maize, soybean and dhaman grass. The relative efficiency of K releasing extractants were in order : 1 N HNO_3 > 10.28 N H_2SO_4 > 0.01 N HCl > 0.3 N NaTPB >1.38 N H_2SO_4. The K extracting capacity of these extractions were correlated with each other and significantly related with some properties of soils such as sand, silt, clay and $CaCO_3$. Dry matter yield of all three crops decreased after second cropping whereas a decreasing trend was observed from first cropping in case of potassium content, potassium uptake and exchangeable K. The values of 'minimal' exchangeable K varied from 0.079 to 0.397 cmol (p+) kg^{-1} soil for different soils and crops.

Additional keywords : Successive cropping, 'minimal' exchangeable K.

Introduction

Several studies have indicated that non-exchangeable K, which is initially unavailable to growing crops makes substantial contribution to plant requirements of K (Yadav and Swami 1984; Pal and Mukhopadhyay, 1992; Patra and Debnath 1996). Soils differ remarkably in their K releasing power and there is no agreed standard method for assessing non-exchangeable K and very few methods are available to farmers for routine determination of non-exchangeable K (Goulding 1987). In view of this, the information on appropriate method for estimating K releasing power of soils is imperative to correlate the need of crop for K nutrition. With these considerations, a greenhouse experiment was conducted to assess the release of non-exchangeable K in some soils of Aridisols of Rajasthan using maize, soybean and dhaman grass as test crops.

Materials and methods

The representative surface soil samples (0–15 cm) in bulk from eight established Aridisol soil series namely Chandwal, Chirai, Dhaber, Jadan, Jaitaran, Kolu, Pal and Pipar were collected from predetermined locations on the basis of information (Lal *et al.* 1994). The samples were air dried, gently crushed and passed through 2 mm sieve. Three kilogram air dried soil was filled in pots. A uniform dose of nitrogen @120 kg N ha^{-1} and phosphorus @60 kg P_2O_5 ha^{-1} was applied through urea and single superphosphate. The maize, soybean and Dhaman grass were allowed to grow (separately) in pots for a period of forty five days. Seven successive croppings of maize, soybean and dhaman grass were raised in the similar manner. Soil and plant samples were drawn from each pot after every successive crop. Initial soil samples were analysed for physical and chemical characteristics following standard procedures. Selected physical and chemical properties of these soils ranged as pH

7.9–8.4, EC 0.08–0.78 dS m^{-1}, organic carbon 0.08-0.49 per cent, $CaCO_3$ 0-1.80 per cent, cation exchange capacity 6.24–16.90 cmol (p+) kg^{-1}, sand 69.80-89.30 per cent, silt 4.90–21.20 per cent and clay 5.80–24.50 per cent. The soils were analysed for K releasing parameter by using five methods i.e. 1.38*N* H_2SO_4 (Hunter and Pratt 1957), 10.28 *N* H_2SO_4 (Hunter and Pratt, 1957), 1 *N* HNO_3 (Wood and DeTurk 1941), 0.3*N* NaTPB (Schulte and Corey 1965) and 0.01 *N* HCl (originally given by Garman, 1957, later modified by Pal and Mukhopadhyay (1992). The plant samples were oven dried and ground and analysed for K content. The soil samples drawn after each successive crop were analysed for exchangeable K (Knudsen *et al.* 1982). Potassium in soil and plant extracts was determined by flame photometry.

Results and discussion

K release as affected by different methods : Soils differ widely in their K releasing power (Table 1) which can be attributed to variation in their physical, chemical properties and degree of weathering. Ramanathan and Krishnamoorthy (1982) pointed out that the variation in K releasing power is attributed to the status of K content, water retention and amounts of clay in the soil. Among the five chemical methods, 1*N* HNO_3 method released maximum amount of potassium. This can be ascribed to dissolution of the more mineral K by the reagent (1 *N* HNO_3) as compared to others. Similar results were also obtained by Srinivasa Rao and Takkar (1997). The reagent 10.28 *N* H_2SO_4 extracted more K as compared to 1.38 N H_2SO_4 due to the higher concentration of sulphuric acid.

Table 1. Amount of K released by different methods (mg kg^{-1} soil)

S.No.	Methods/soil series	Chandwal	Chirai	Dhaber	Jadan	Jaitaran	Kolu	Pal	Pipar
1.	1.38*N* H_2SO_4	0.47	0.25	0.41	0.53	0.27	0.28	0.26	0.51
2.	10.28*N* H_2SO_4	1.60	1.13	1.89	2.23	1.58	1.65	1.38	2.07
3.	1*N* HNO_3	1.73	1.21	2.05	2.41	1.71	1.84	1.42	2.21
4.	0.3*N* NaTPB*								
	– 15 min.	0.32	0.22	0.30	0.41	0.28	0.29	0.24	0.38
	– 1 hour	0.36	0.24	0.34	0.47	0.33	0.31	0.27	0.46
	– 4 hours	0.49	0.27	0.37	0.54	0.35	0.39	0.31	0.52
	– 16 hours	0.52	0.33	0.43	0.66	0.39	0.42	0.35	0.62
5.	0.01*N* HCl**								
	– CKR1	0.34	0.20	0.25	0.36	0.24	0.25	0.22	0.35
	– CKR5	0.51	0.27	0.37	0.58	0.34	0.36	0.29	0.49
	– CKR10	0.56	0.32	0.43	0.64	0.36	0.43	0.35	0.62
	– CKR15	0.66	0.35	0.47	0.72	0.43	0.45	0.38	0.69

* NaTPB = Sodium tetraphenyl boron at different periods; **CKR = Cumulative potassium release at different extractions.

All the K extractants were positively correlated with each other, which indicate that total amount of extracted K were comparable (Table 2). Yadav and Swami (1984) also reported that potassium extracted with 1.38 *N* H_2SO_4, 10.28 *N* H_2SO_4, 0.01*N* HCl and 1*N* HNO_3 method were significantly correlated to each other in red soils of Dungarpur district of Rajasthan. Clay showed significant relationship with 10.28*N* H_2SO_4 (r=0.76*), 1*N* HNO_3

(r=0.76*), NaTPB-15 min. (r=0.72*) and NaTPB-1 hour (0.71*). Silt and sand fractions showed significant correlation only with 10.28*N* H_2SO_4 (r=–0.73* and -0.78*) and 1*N* HNO_3 (r=0.73* and -0.78*), respectively (Table 3). Pratt (1951) pointed out that the most important factors controlling the release of K from micas is particle size and clay fraction. $CaCO_3$ content showed significant relationship with 10.28*N* H_2SO_4 (r=0.91**), 1*N* HNO_3 (r=0.91**), NaTPB-15 min. (r=0.82**), NaTPB-1 hour (r=0.81*) and NaTPB-16 hour (r=0.71*). Powell and Hutscheson (1965) pointed out possibility that Ca^{2+} ions slip between the individual units at the edges of potential K fixing clay minerals, thereby exerting a 'propping' action which would tend to prevent entrapment of K^+ ions and result in release of previously 'trapped' or lattice K.

Table 2. Correlation coefficients among K releasing methods

K releasing methods	10.28*N* H_2SO_4	1 *N* HNO_3	NaTPB (15 min)	NaTPB (1 hour)	NaTPB (4 hour)	NaTPB (16 hour)	CKR1	CKR5	CKR10	CKR15
1.38*N* H_2SO_4	0.84**	0.82*	0.91**	0.91**	0.93**	0.94**	0.95**	0.94**	0.96**	0.96**
10.28*N* H_2SO_4	-	0.99**	0.94**	0.94**	0.84**	0.88**	0.81*	0.82*	0.85**	0.81*
1N HNO_3	-	-	0.94**	0.93**	0.84**	0.87**	0.80*	0.82*	0.84**	0.80*
+NaTPB (15 min)	-	-	-	0.99**	0.95**	0.98**	0.94**	0.94**	0.96**	0.94**
NaTPB (1 hour)	-	-	-	-	0.95**	0.97**	0.94**	0.92**	0.95**	0.94**
NaTPB (4 hour)	-	-	-	-	-	0.98**	0.99**	0.98**	0.99**	0.99**
NaTPB (16 hour)	-	-	-	-	-	-	0.98**	0.97**	0.99**	0.98**
+CKR1	-	-	-	-	-	-	-	0.99**	0.99**	0.99**
CKR5	-	-	-	-	-	-	-	-	0.98**	0.98**
CKR10	-	-	-	-	-	-	-	-	-	0.99*

* Significant at 5% level; ** Significant at 1% level; +NaTPB = Sodium tetraphenyl boron at different periods; + = Cumulative K release at different extractions.

Dry matter yield, potassium content and its uptake : Dry matter yield of maize, soybean and dhaman grass show a decreasing trend after second successive crop (Fig. 1). This might be due to the low temperature which influences the emergence of seedlings. There was a wide variation in dry matter yields of all three crops in different soils. This can be ascribed to the variation in K supplying power of soils and K exracting power of different crops. Nath and Dey (1982) also observed similar trends in the alluvial soils of Assam. Potassium content and its uptake varied with soils and crops and decreased with successive croppings (Figs. 2 and 3). This variation may be due to the difference in the K requirements of crops. Pal *et al.* (1997) reported a different K uptake for maize and groundnut crops in exhaustive cropping studies.

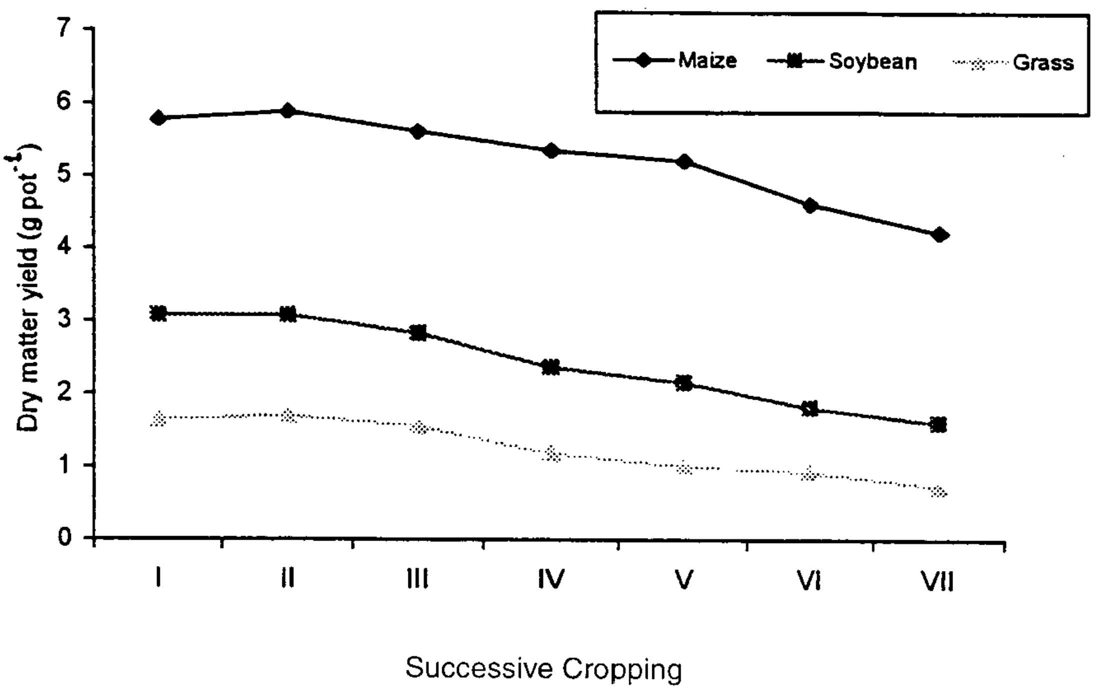

Fig. 1 : Mean dry matter yield in seven successive croppings of maize, soybean and dhaman grass

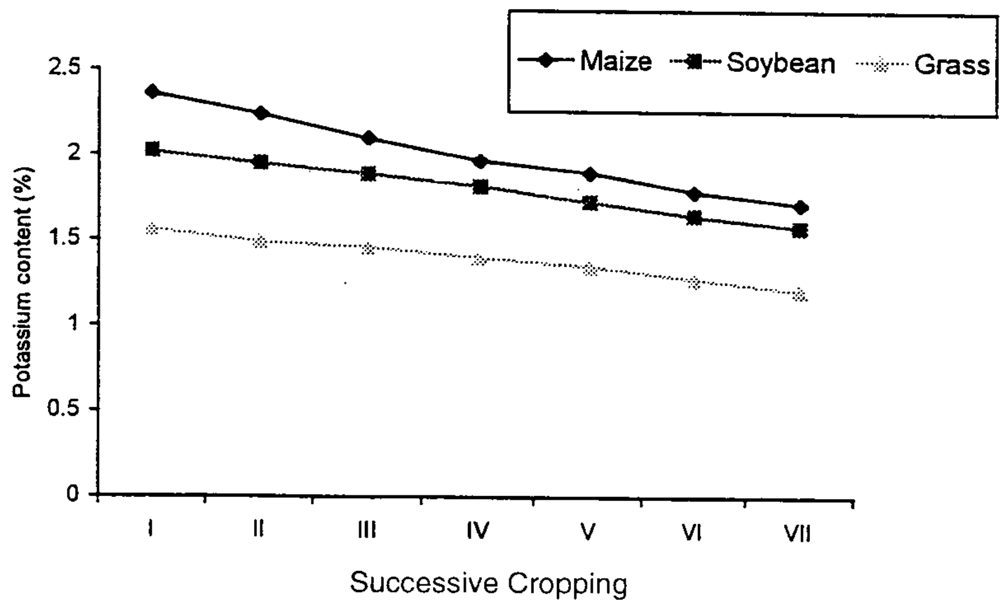

Fig. 2 : Mean K content in seven successive croppings of maize, soybean and dhaman grass

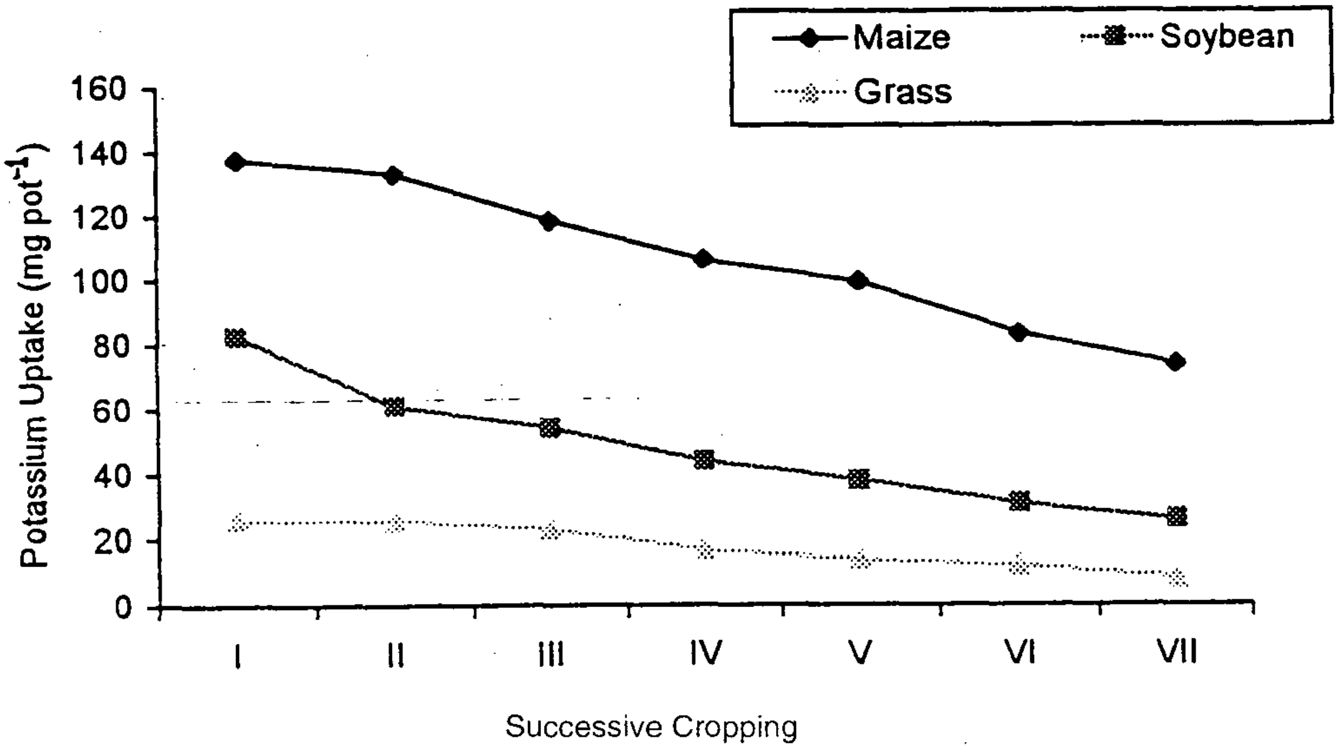

Fig. 3 : Mean K uptake in seven successive croppings of maize, soybean and dhaman grass

Table 3. Correlation coefficient between K releasing methods and some soil properties

K releasing method	Soil characteristics Sand (%)	Silt (%)	Clay (%)	CEC cmol (p+) kg^{-1}	O.C.(%)	pH (1:2.5)	EC dS m^{-1}	$CaCO_3$ (%)
1.38*N* H2SO4	-0.54	0.25	0.65	0.42	0.52	-0.14	0.10	0.68
10.28*N* H2SO4	-0.78*	0.73*	0.76*	0.57	0.62	-0.04	0.19	0.91**
1*N* HNO3	-0.78*	0.73*	0.76*	0.53	0.60	-0.06	0.20	0.91**
+NaTPB								
15 min.	-0.69	0.59	0.72*	0.52	0.58	0.05	-0.06	0.82*
1 hour	-0.69	0.60	0.71*	0.57	0.60	0.08	-0.05	0.81*
4 hour	-0.53	0.42	0.57	0.39	0.45	0.06	-0.16	0.61
16 hour	-0.59	0.45	0.64	0.44	0.50	0.03	-0.16	0.72*
0.01*N* HCl								
CKR1	-0.52	0.38	0.59	0.42	0.48	0.08	-0.16	0.59
CKR5	-0.60	0.44	0.68	0.45	0.54	0.10	-0.09	0.63
CKR10	-0.52	0.38	0.60	0.38	0.44	-0.01	0.12	0.65
CKR15	-0.52	0.37	0.59	0.42	0.48	0.06	0.15	0.61

* Significant at 5% level; ** significant at 1% level; +NaTPB = Sodium tetraphenyl boron at different periods; CKR = Cumulative K release at different extractions.

Table 4. Correlation coefficient and regression equations between minimal exchangeable K and soil properties

Soil properties	Minimal exchangeable K					
	Maize		Soybean		Dhaman grass	
	Correlation coefficient	Regression equation	Correlation coefficient	Regression equation	Correlation coefficient	Regression equation
Sand (%)	-0.86**	Y=0.83+0.007 X	-0.85**	Y=0.87±0.008 X	-0.85**	Y=0.88±0.007 X
Silt (%)	0.84*	Y=0.09+0.014 X	0.84**	Y=0.09+0.015 X	0.82*	Y=0.11+0.015 X
Clay (%)	0.78*	Y=0.15+0.012 X	0.78*	Y=0.16+0.012 X	0.79*	Y=0.16+0.013 X
pH (1:2.5)	0.45	Y=-1.51+0.220 X	0.41	Y=-1.45+0.220 X	0.39	Y=-1.35+0.200 X
EC ($dS\ m^{-1}$)	0.07	Y=0.29±0.026 X	-0.05	Y=0.31±0.020 X	-0.03	Y=0.32±0.014 X
O.C. (%)	0.71*	Y=0.18+0.440 X	0.69	Y=0.19+0.450 X	0.69	Y=0.19+0.460 X
$CaCO_3$ (%)	0.70	Y=0.23+0.092 X	0.72*	Y=0.24+0.099 X	0.72*	Y=0.25+0.100 X
CEC $cmol(p+)kg^{-1}$	0.62	Y=0.11+0.015 X	0.59	Y=0.13+0.015 X	0.58	Y=0.14+0.015 X
Available P	0.68	Y=0.79+0.009 X	0.66	Y=0.11+0.009 X	0.64	Y=0.12+0.009X

* Significant at 5% level; ** significant at 1% level

All the methods showed significant positive correlation with cumulative dry matter yield as well as cumulative K uptake by successive croppings. The values of correlation coefficients with cumulative K uptake by soybean and dhaman grass were of higher order in comparison to cumulative dry matter yield (Table 5). Sodium tetraphenyl boron method (shaking for fifteen minutes) found to be the most appropriate for the prediction of cumulative dry matter yield and cumulative K uptake for all types of the crops (Table 5). This indicates that cumulative K uptake could be predicted with reasonably higher accuracy. This corroborates with the findings of Yadav and Swami (1984).

Table 5. Correlation coefficients between K releasing methods and cumulative dry matter yield and cumulative K uptake

K releasing method	Cumulative dry matter yield (gm)			Cumulative K uptake ($mg\ kg^{-1}$)		
	Maize	Soybean	Dhaman grass	Maize	Soybean	Dhaman grass
1.38*N* H_2SO_4	0.92**	0.71*	0.90*	0.90**	0.93**	0.88**
10.28*N* H_2SO_4	0.90**	0.73*	0.82*	0.93**	0.82*	0.97**
1*N* HNO_3	0.89**	0.73*	0.81*	0.91**	0.80*	0.96**
+NaTPB (15 min.)	0.93**	0.80*	0.92**	0.88**	0.88**	0.98**
NaTPB (1 hour)	0.93**	0.74*	0.92**	0.90**	0.86**	0.97**
NaTPB (4 hour)	0.88**	0.72*	0.89**	0.81*	0.89**	0.90**
NaTPB (16 hour)	0.90**	0.79*	0.91**	0.83*	0.89**	0.95**
++CKR1	0.88**	0.71*	0.90**	0.80*	0.91**	0.87**
CKR5	0.91**	0.81*	0.94**	0.81*	0.94**	0.90**
CKR10	0.87**	0.74*	0.88**	0.80*	0.90**	0.90**
CKR15	0.89**	0.73*	0.92**	0.81*	0.91**	0.88*

* Significant at 5% level; ** significant at 1% level; +NaTPB = Sodium tetraphenyl boron at different periods; ++CKR = Cumulative K release at different extractions.

Exchangeable K : The initial exchangeable K ranged between 0.18 to 0.49 cmol (p+) kg^{-1} of soil was decreased to 'minimal' exchangeable K levels after the harvest of seventh cropping (Fig. 4). A number of reports indicated decreasing trend in amount of exchangeable K due to successive croppings (Yadav and Swami 1984; Pal *et al.* 1997). 'Minimal' exchangeable K varied with type of soil and crop in the present investigation. Pal *et al.* (1997) reported that 'minimal' exchangeable K varied with soil type and its time of attainment depends on the cropping pattern. Thus, present results are in agreement of the above findings.

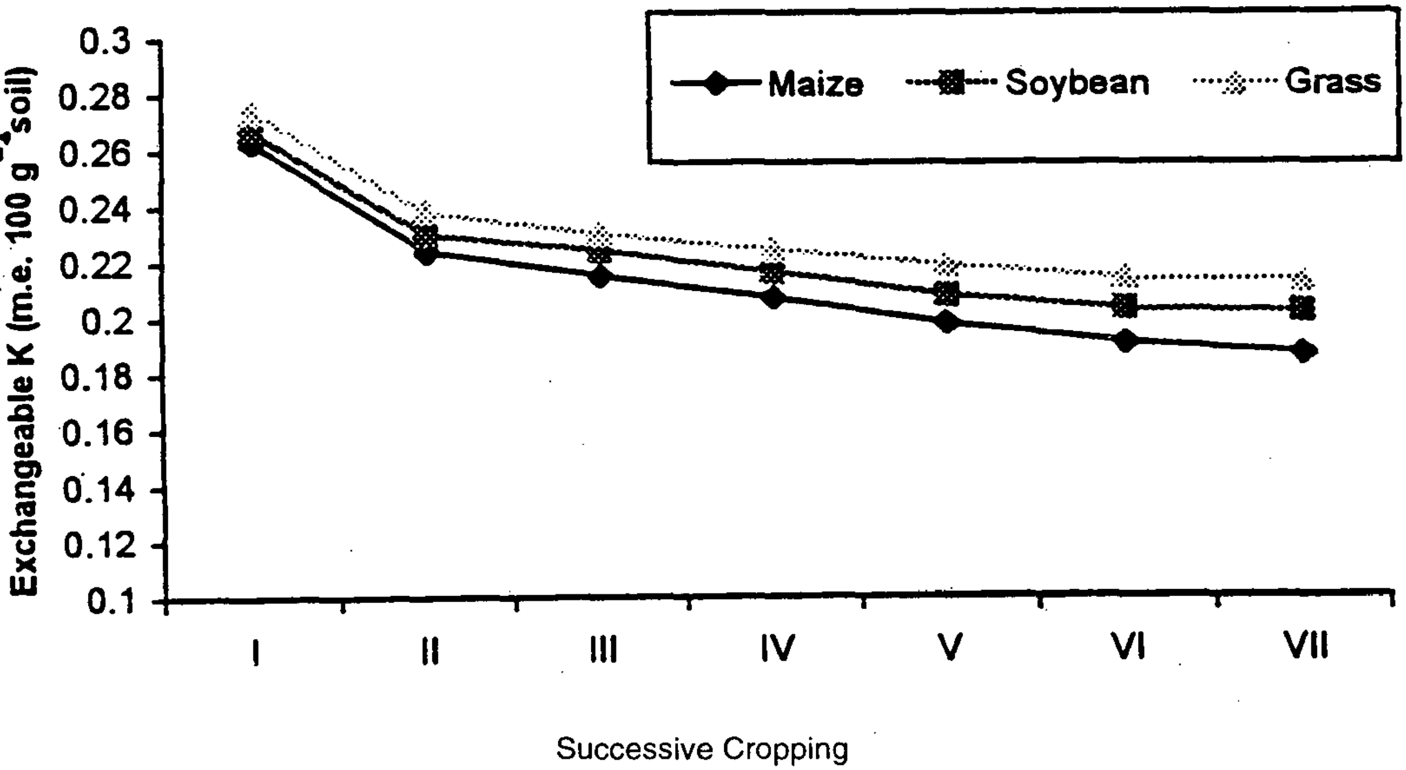

Fig. 4 : Mean exchangeable K after seven successive croppings of maize, soybean and grass in experimental soils.

Values of correlation coefficients and regression equations between 'minimal' exchangeable K and some physical and chemical properties of soil are given in table 4. The data indicates that 'minimal' exchangeable K was found significantly positive related to clay and silt, whereas it was found negatively related to sand. Pal *et al.* (1997) observed significant relationship between clay and 'minimal' exchangeable K. It can be further seen that organic carbon significantly related to 'minimal' exchangeable K in maize crop (r=0.71*). The minimal level of K was also related to $CaCO_3$ in soybean (r=0.72*) and dhaman grass (r=0.72*) cropping. Yadav and Swami (1984) reported a significant relationship between 'minimal' exchangeable K with clay and $CaCO_3$.

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