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POTASSIUM SUPPLYING CAPACITY OF FLUVISOLS AND VERTISOLS IN THE MIDDLE AWASH VALLEY OF ETHIOPIA

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ABSTRACT: An investigation was carried out to study release of exchangeable potassium, potassium-fixation, non-exchangeable potassium release and potassium supplying capacity under laboratory condition. The results showed that release of exchangeable K varied from 2.82 to 3.51 cmol kg^{-1} in Fluvisol and from 2.56 to 3.76 cmol kg^{-1} in Vertisol. Non-exchangeable K also varied from 6.73 to 8.54 cmol kg^{-1} in Fluvisol and from 6.43 to 8.98 cmol kg^{-1} in Vertisol. The highest fixation was observed in Vertisol. Potassium fixation was high under continuous wet moisture condition in both soils. The potassium buffering capacity was slightly high in Vertisol as compared to that of Fluvisol. The K quantity, by which the soil gains or loses potassium in reaching equilibrium, fell below zero point in the control treatment. Availability of K was slow in the Vertisol, though its K buffering capacity/supplying was higher than in the Fluvisol.

Key words/phrases: Available potassium, non-exchangeable potassium, Fluvisol, Middle Awash Valley

INTRODUCTION

Potassium can be available to plants in many forms. Potassium as a component of soil minerals is available only after weathering of the soil minerals, which is normally a very slow process (Muchena, 1975; Grimme, 1979; Singh and Goulding, 1983). Fixed or non-exchangeable K constitutes a reserve which can be made available to plants (Cox and Uribe, 1992a). It is, however, necessary

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to have knowledge of all forms of K for a critical appraisal of the K supplying power of a particular soil (Tekalign Mamo and Haque, 1988).

Exchangeable or available K extracted with ammonium acetate provides an easily accessible source of potassium for plants (Rodriguez, 1974). Water-soluble K is another form of available K that can be taken up by plant roots. The amount of potassium in the soil solution depends not only on the amount of readily exchangeable potassium, but on the amount of potassium in solution. This determines the soil potassium potential/supplying capacity for meeting immediate crop needs. The soil potassium potential and capacity together make up the soil potassium supplying power (Talibudeen and Dey, 1968a; 1968b; Addiscott, 1970a; 1970b; 1970c).

Potassium fertilizer studies on cotton and maize carried out for several years in the Middle Awash Valley of Ethiopia did not produce any significant results (Eticha, 1986). It is known that the potassium quantity/intensity (Q/I) relationships might supply more information than routine soil testing for available or exchangeable potassium (Talibudeen and Dey, 1968a; 1968b; Addiscott, 1970a). Hence, the aim of this work was to investigate the potassium supplying capacity of irrigated Fluvisol and Vertisol in the Middle Awash Valley of Ethiopia.

MATERIALS AND METHODS

The experiment was conducted at Melka Werer Research Centre under laboratory condition on two soil types of alluvial origin deposited by Awash River (Vertisol and Fluvisol). The Vertisols are silty clay to clay and dark brown (10YR 2/2) in colour. The Fluvisols are brown (10YR 5/3) and have sandy loam to silt loam texture. Soil samples were taken from 0-30 cm soil depth and, air dried and ground to pass a 2 mm sieve. Exchangeable K from the native soil was extracted with neutral ammonium acetate (NH_4OAc) following standard procedures while non-exchangeable potassium was extracted by boiling soil samples for one minute with 1N HNO_3 (Haylock, 1956).

Potassium fixation

About one kg of absolute air dry soil from both soil types was incubated at near field capacity. Another group of soils was incubated wet and wet-dry. Four levels of K fertilizers (0, 22.71, 44.55 and 89.99 kg K ha^{-1}) were applied as KCl. All incubation was carried out at room temperature or 25° C, *i.e.* during the coolest months (September to December) in the Awash Valley. After the incubation period, exchangeable NH_4OAc extracted K, Ca and Mg from the soils. Exchangeable K was determined by flame photometry while Ca and Mg were determined by titration method.The amount of K-fixed was calculated using the following equation (Martini and Suarez, 1977).

$$K = K2 - (Ko + K1) \quad (1)$$

Where: Ko = Native exchangeable K
K1 = Fertilizer K or applied K
K2 = Exchangeable K after incubation

Potassium supplying capacity

Maize was grown at laboratory condition in polyvinyl chloride pots containing one kg of soil. Five maize seeds were planted. The pots were kept where appropriate sun light was available for nearly ten hours during the day. Potassium was applied as KCl in various amounts (0, 22.71, 44.55 and 89.99 kg K ha^{-1}) N 46 N kg ha^{-1} (as uria); P 46 kg ha^{-1} (as Na_3PO_4) and S 46 kg ha^{-1} (as Na_2SO_4). The experimental design was random complete block design with four replications. Potassium in plant tissue was measured by flame photometry after digestion with $HClO_3$-HNO_3 (1:5) as proposed by Chapman and Pratt (1961).

The amount of K supplied to the plant during the incubation period was calculated using the following equation (2).

$$K = (K1 + Kp) - Ko \quad (2)$$

Where: K = K potassium supplied to the plant
Ko = exchangeable K in the soil before cropping
K1 = exchangeable K in the soil after cropping, and
Kp = K in plant tissue.

The relationship between quantity and potential (Q/I) of soil K was measured by relating change in exchangeable K ($\pm\Delta K$) to change in K potential or AR^k (activity ratio for potassium).

Where: $\pm\Delta K$ = K1 - Ko
K1 = soil exchangeable K after cropping
Ko = initial exchangeable K before cropping or fertilizer application.
$\pm\Delta K$ = quantity by which the soil gains or loses potassium in reaching equilibrium or the quantity (Q) factor.

$$^{a}K/\sqrt{^{a}Ca + {^{a}Mg}} = I = AR^{k}$$

AR^k = activity ratio for potassium or the intensity factor (Addiscott, 1970a).

$$^{a}K/\sqrt{^{a}Ca + {^{a}Mg}} = {^{C}K}/\sqrt{^{C}Ca + {^{C}Mg}} = f^{+}/\sqrt{f^{2+}} = I$$

Where, f^+ and f^{2+} are the activity coefficients of monovalent and divalent cations f^+/f^{2+} was taken as 1.0 (Addiscott, 1970c).

RESULTS AND DISCUSSION

The release of exchangeable K varied from 2.82 to 3.51 cmol kg^{-1} in Fluvisol and from 2.56 to 3.76 cmol kg^{-1} in Vertisol (Table 1). Exchangeable K at 60 days of incubation was the highest in the control treatment. This confirms that the release of exchangeable K depends not only on the fertilizer rates but also on the K supplying capacity of the soil. Concentration of non-exchangeable K on both soils was not uniform through out the incubation period, which was mainly governed by release and fixation phenomenon (Table 2). As a result non-exchangeable K content in Vertisol was high compared to Fluvisol (Table 3). Tekalign Mamo and Haque (1988) reported also that the highest fixation was observed in Vertisol while K fixation occurred in all soil types. In addition there was significant correlation between non-exchangeable and plant available K in both soils. This indicates that non-exchangeable K could be available gradually to the plants.

Table 1. Influence of increasing potassium level [cmol K(kg)$^{-1}$] and incubation periods on release of soil exchangeable potassium.

K levels [kg(ha)$^{-1}$]	Incubation Periods (days)		
	30	60	90
		Fluvisol	
0	2.94	3.48*	2.82
22.71	3.51	3.00	3.04
44.55	3.31	3.18	2.99
89.99	3.49	2.95	3.18*
		Vertisol	
0	2.62	2.70*	2.82
22.71	3.08	3.76	3.28
44.55	3.55	3.39	2.56
89.99	3.44	3.29	3.19

* Significant at $P \leq 0.05$.

Table 2. Influence of increasing potassium level [cmol K(kg)$^{-1}$] and incubation periods on the amount of non-exchangeable potassium.

K levels [kg(ha)$^{-1}$]	Incubation Periods (days)		
	30	60	90
		Fluvisol	
0	6.97	7.25	6.73
22.71	8.25	7.76**	8.54
44.55	7.47	7.11	6.93
89.99	8.44	7.25	8.44
		Vertisol	
0	6.85	6.71	6.98*
22.71	6.43	8.98**	7.60
44.55	7.54	7.60	8.08
89.99	8.32	7.72	8.08

* and **, significant at $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

Table 3. Influence of increasing potassium level [cmol $K(kg)^{-1}$] and incubation periods on fixed potassium.

K levels [$kg(ha)^{-1}$]	Incubation Periods (days)		
	30	60	90
		Fluvisol	
0	0.470**	1.010*	0.350*
22.71	1.014	0.054	0.570
44.55	0.789	0.659	0.520
89.99	0.917	0.377	0.607
		Vertisol	
0	0.100*	0.180*	0.300
22.71	0.534	1.214	0.734
44.55	0.979	0.819	-0.011
89.99	0.817	0.667	0.567

* and **, significant at $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

Soil under continuous wet moisture condition favoured more K fixation than under wet-dry soil moisture cycles (Table 4). Similar results were obtained by Martin and Suarez (1977). The K supplied to the plant in Fluvisol was slightly higher than that of the Vertisol, which resulted, in vigorous plant development and more maize dry matter yield in Fluvisol (Table 5). These differences suggest that availability of K to the plant in light textured soil was better than clay soil during critical plant growth stage (Rodriguez, 1974; Cox and Uribe, 1992a, 1992b). However, there was significant correlation between non-exchangeable K and dry matter yield of maize in both soils.

High K buffering capacity of finer textured soils could be a prevailing factor that favours K absorption by plants (Avellanda and Jauregui, 1995). In agreement with this potassium buffering capacity was high in Vertisol. The potassium buffering capacity (PBC^k) appeared to be slightly high in Vertisol as compared to that of the Fluvisol (Table 6). However, it did not give more distinctive advantage in plant uptake over Fluvisol, due to low K release and high fixation in Vertisol which was reflected in plant dry matter yield.

Table 4. Exchangeable potassium release [cmol K(kg)$^{-1}$] as influenced by wet-dry and wet soil moisture conditions.

K levels [kg(ha)$^{-1}$]	Incubation Periods (days)			
	30	60	30	60
	Wet-dry	wet	wet	wet-dry
		Fluvisol		
0	3.08	2.62	2.60	2.33
22.71	2.30	2.28	1.95**	2.31
44.55	2.70	2.60	2.79	2.32
89.99	2.79	2.65	2.75	2.41**
		Vertisol		
0	2.33*	2.27	2.37	2.32
22.71	2.21	2.16	1.41	2.46
44.55	2.05	2.26	2.44	2.37
89.99	2.15	2.16	2.33	2.51

* and **, significant at $P \leq 0.05$ and $P \leq 0.01$ levels, respectively.

Table 5. Potassium released or supplied (cmol kg^{-1}) to the plant on Fluvisol and Vertisol.

Levels (kg ha^{-1}).	Fluvisol				Vertisol			
	Kl	Kp*	Ko	K	Kl	Kp*	Ko	K
0	2.45	1006.9	3.20	1006.2	2.75	1002.4	2.99	1002.2
22.71	2.65	789.3*	3.20	788.8*	2.86	1139.2	2.99	1139.7
44.55	3.27	1185.1	3.20	1185.2	3.06	1109.2	2.99	1109.3
89.99	3.37	1179.6	3.20	1151.0	3.37*	914.30	2.99	914.7

* Significant at $P \leq 0.05$.

Talibuden and Day (1968a; 1968b) and Addiscott (1970a; 1970b; 1970c) showed that the potassium quantity/intensity (Q/I) relationships might supply more information than routine soil testing for available or exchangeable potassium. In Fluvisol ± ΔK was in equilibrium with Q/I in treatment 2 (Table 6). This could be described on the basis of potential buffering capacity, which was lower in Fluvisol than that of the Vertisol. In effect, K exhaustion on Fluvisol was faster than on Vertisol. In Vertisol the ±ΔK or quantity by which the soil gains or losses potassium in reaching equilibrium or the quantity (Q) factor fell below the zero value in the control treatment. In such cases K was available to the plant even from non-exchangeable and fixed potassium. The potassium supplying capacity of the soil is related to soil texture and mineralogy (Muchena, 1975; Grimme, 1979; Singh and Goulding, 1983). The higher the clay content of the soil, the higher is the supplying power. Also, the higher the mica content (or potassium rich 2:1 minerals) the higher is the potassium supplying power (James and Weaver, 1975; Muchena, 1975). Fluvisols are constituents of muscovite/illite clay minerals and Vertisol are dominated by illite/montmorillonite clay minerals. Thus the potassium in Fluvisol appeared more mobile for the plant during the critical growth stage than that in Vertisol while in Vertisol availability of K was slow.

Table 6. Change in soil exchangeable K (±ΔK) after cropping, quantity and potassium intensity relationships (Q/I) and potassium buffering capacity (PBC^k) or (± ΔK)/(± ΔAR^k).

K Levels (kg ha^{-1})	Fluvisol			Vertisol		
	±ΔK	Q/I	PBC^k	±ΔK	Q/I	PBC^k
0	0.56	1.33	-0.05	-0.31	-0.82	0.38
22.71	0.00	0.00	0.00	0.26	0.55	0.11
44.55	0.25	0.49	0.04	0.51	1.02	0.58
89.99	0.81	1.37	0.12	1.17	1.98	0.73

CONCLUSION

Laboratory studies were conducted to determine potassium-supplying capacity of irrigated soils, Fluvisol and Vertisol, of the Middle Awash Valley, Ethiopia. Results showed that these soils have adequate supply of potassium. Potassium-supplying capacity in Vertisol was much better in Fluvisol than in Vertisol. However, K availability to the plant at the early critical growth stage was better in Fluvisol than in Vertisol. Moreover K availability to the plant depended on soil moisture regimes. Very wet soil moisture condition inhibited potassium availability and increased potassium fixation. This indicates that over-irrigation or over-saturation of these soils might hamper availability of K to the plant. Application of K mineral fertilizer to these soils did not give any advantage over K reserve in the soil. In Vertisol the potassium supplying capacity extended to negative values without affecting plant growth and dry matter yield. This confirms that soils with high clay content have very high K supplying power than light textured soils, which gradually release K from their reserve pool under appropriate soil moisture regimes. The potassium quantity/intensity (Q/I) relationships supply more information than routine soil testing for available or exchangeable potassium.

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