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Potassium Fixation as Affected by Moisture Conditions in Some Soils of Azerbaijan

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ABSTRACT

Potassium is the third macronutrient provided in a complete fertilizer. Exhaustive cropping of potassium-demanding crops like potato, sunflower and sugar beet leads to depletion of soil non-exchangeable potassium and subsequent fixation of added potassium. In this study the effects of different soil moisture conditions on potassium fixation were investigated in some potassium-depleted soils of Azerbaijan province. For this purpose 6 soil samples were selected from among 17 locations where the amounts of boiling nitric acid extractable-K were considerably lower in cultivated soils compared to the adjacent non-cultivated soils. The amount of potassium added to the soils (250 mg K kg^{-1}) was equivalent to the amount of depleted K. Results showed that the amounts of K fixation were significantly ($P<0.001$) increased (14.5%) after air-drying. There was a significant ($P<0.01$) positive relationship between the amount of K fixation and clay content. Three soil samples with different amounts of K fixation were chosen from among six soil samples for subsequent studies. Early air-drying of the soils was significantly ($P<0.01$) caused more K fixation comparing to middle and late air-drying. According to the results obtained the effect of soil matric potential (-30, -100, -500 kPa) on K fixation was significant ($P<0.001$).The highest amount of K fixation was found for -100 kPa. Furthermore, K fixation during two months of incubation was significantly ($P<0.001$) elevated with the increase in the number of wetting-drying cycles (1, 5, 10 and 20 cycles). The amount of K fixation was increased by 23% with wetting-drying incubation (under 20 cycles) compared to constant field capacity incubation.

Key words: potassium fixation, wetting-drying cycles, soil matric potential

INTRODUCTION

Potassium (K) is the third macronutrient provided in a complete fertilizer. Exhaustive cropping of K-demanding crops like potato, sunflower and sugar beet leads to depletion of soil non-exchangeable K and subsequent fixation of added K. Potassium fixation influences the effectiveness of fertilization in soil-plant systems (Murashkina et al., 2007). Understanding the mechanisms responsible for K fixation is therefore fundamental for developing soil fertility management strategies (Olk et al., 1995). The expansible 2:1 layer silicates such as weathered micas, vermiculites, and smectites are the major clay minerals responsible for K fixation in soils. Weathered micas and vermiculites fix K under moist as well as dry conditions, whereas smectites fix K only under dry conditions. The amount of K fixation by smectites is very small unless their charge density is high. Some soil smectites have a higher charge density and likely have wedge sites near mica-like zones where K selectivity is high and K fixation can take place (Huang et al., 2005). The degree of K fixation in clays and soils depends on the type of clay mineral and its charge density, the degree of interlayering, the moisture content, the concentration of K^+ ions as well as the concentration of competing cations such as NH_4^+, and the pH of the ambient solution bathing the clay or soil (Sparks and Huang, 1985). Wetting and drying and freezing and thawing can significantly affect K fixation. The degree of K fixation or release on wetting or drying is dependent on the type of colloid present and the level of K^+ ions in the soil solution (Huang et al., 2005). Air drying generally causes significant fixation of recently added K (McLean and Watson, 1985). Without recent K addition, wetting-drying cycles can promote either fixation or release depending on the quantity of labile K (Tisdale et al., 1990). Two competing processes may occur during drying: fixation occurs in wedge zones while exfoliation of layers releases K. The net result could be K release or fixation, depending on the dominant process (Olk et al., 1995). In this study laboratory experiments were designed to determine the effects of air drying, time of air drying, soil moisture potential and wetting-drying cycles on potassium fixation in some K-depleted soils of Azerbaijan province.

MATERIALS and METHODS

To investigate the effects of moisture conditions on K fixation in some soils of Azerbaijan province, seventeen points spread throughout the area were collected randomly. Each point was located at the common border of a cultivated soil (under cultivation of potato, sunflower and sugar beet for several decades) and a virgin soil. Composite soil samples were analyzed and their texture, pH, EC, calcium carbonate equivalent and organic carbon determined. Chemical extraction procedures [1 M ammonium acetate (AEK) and 1 M boiling nitric acid (NEK)] were evaluated for measuring the changes in soil K as a consequence of exhaustive cropping (Knudsen et al., 1982). Six soil samples were selected from among 17 locations where the amounts of boiling nitric acid extractable-K were considerably lower in cultivated soils compared to the adjacent non-cultivated soils. These soils (in three replications) received 0 and 250 mg K kg^{-1} (equivalent to the amount of depleted K) as a solution of KCl with sufficient volume to achieve field capacity (33 kPa) condition. The samples were incubated at constant temperature ($20\pm1^{\circ}$) for two days. The amounts of NH_4COONH_4-extractable K (labile K) were determined by Olk et al.(1995) procedure before and after air-drying of the soils. Solution K was measured by flame emission using flame photometer. Added K that was not recovered by NH_4^+ was considered to be fixed. Three soil samples with different amounts of K fixation were chosen from among six soil samples for subsequent studies. To determine the effect of the time of air-drying during the incubation period on potassium fixation, air-dying was done in three different times: 1) early days of incubation period (2 days after the beginning of incubation), 2) middle of incubation period (14 days after the beginning of incubation) and 3) near the end of incubation period (28 days after the beginning of incubation). K fixation was determined at the end of one month incubation period. To investigate the effect of soil matric potential on potassium fixation an experiment was carried out as follows: 10 g of air-dried soils were packed into small plastic barrels (one centimeter in height). Barrels were allowed to soak in solutions containing different concentrations of KCl (to add 0, 100, 200 and 400 mg K kg^{-1}) and small amounts of thymol in a desicator for 8 hours. Barrels were then equilibrated at either -30, -100 and -500 kPa in a pressure plate apparatus. After equilibration, the soils were covered with several layers of parafilm and incubated at 20±1° for three months. The magnitude of fixed K was determined after the end of incubation time. To specify the effect of wetting-drying cycles on K fixation, zero and 200 mg K kg^{-1} were added to the soils. The samples were incubated at the above conditions for two months. Zero, 1, 5, 10 and 20 cycles of wetting and drying were done during the incubation period. K fixation was determined at the end of incubation time. Analysis of variance and comparison of means (using Dunan`s test,$P<0.01$) were performed with SPSS.

RESULTS and DISCUSSION

Selected physical and chemical properties of the soils investigated are given in table 1.

Table 1. Some physical and chemical properties of the soils

No.	Texture	$pH_{1:1}$	$EC_{1:1}$ (dS m^{-1})	CCE (g kg^{-1})	OC (g kg^{-1})	AEK (mg kg^{-1})	NEK(mg kg^{-1})
1	S.C.L	7.9	2.1	91	10.1	145	420
2	S.L	7.0	1.1	169	2.1	240	272
3	L	8.8	1.9	190	5.8	390	746
4	L	8.2	0.97	101	5.1	350	1137
5	C.L	8.3	0.50	127	9.4	360	894
6	L	8.1	1.4	94	11.4	230	925

Effect of Moisture Condition before Extraction on K Fixation:

Potassium fixation occurred in all soils. The amounts of K fixed were from 37.5 to 97.5 mg kg^{-1} (67.9 mg kg^{-1} (27.2%), on average) and from 60 to 147.5 mg kg^{-1} (104.2 mg kg^{-1} (41.7%), on average) for moist and air-dry conditions, respectively (Fig. 1). Therefore, the magnitude of K fixation was significantly ($P<0.001$) increased (14.5%) after air-drying as reported by other workers (Foth and Ellis, 1988). As soil dries, labile K becomes more concentrated in a small volume of soil solution which increases the concentration gradient and subsequent potassium fixation.

Potassium fixation in air-dry condition correlated with clay content (r=0.965*). This is in disagreement with the finding of Murashkina et al. (2007). According to this result, as clay content increases 10 percent, potassium fixation increases 17 percent. This strong correlation may be attributed to little variation in clay mineral composition between the soils. Nevertheless, the regression between K fixation and clay content for moist condition was not significant. This lack of correlation could be explained by the presence of vermiculites which fix potassium in moist condition, but do not be limited to clay particles (Fig. 2).

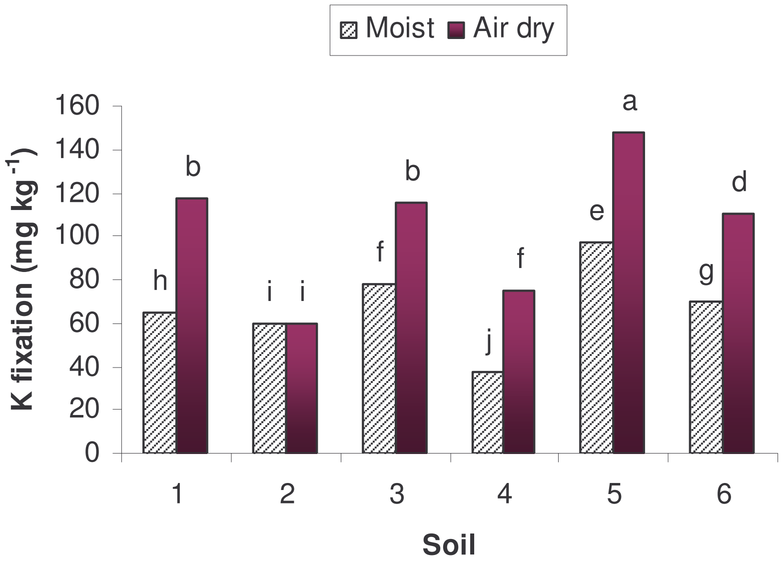

Fig. 1-Mean values of K fixation for moist and air dry conditions (P<0.01).

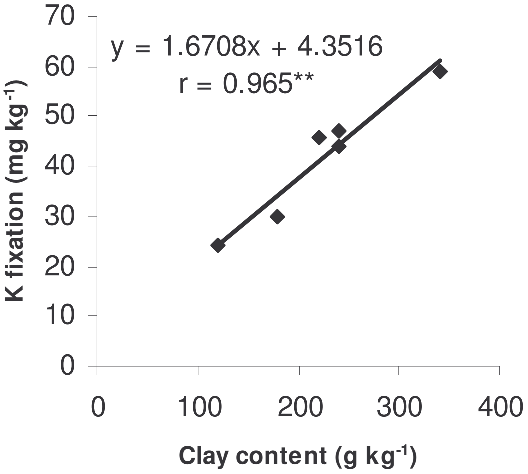

Fig. 2- Relation between K fixation and clay content.

Effect of the Time of Air Drying on K Fixation:

The amounts of K fixed after 2, 14 and 28 days of the beginning of incubation period were 10, 6.2 and 31.2 mg kg^{-1} (15.8 mg kg^{-1} on average) for soil 2; 57.5, 26.2 and 18.7 mg kg^{-1} (34.1 mg kg^{-1} on average) for soil 3; and 75.2, 72.1 and 53.5 mg kg^{-1}(66.9 mg kg^{-1} on average) for soil 5, respectively. In all soils, the magnitude of K fixation for three different times of air drying was in an order of (Fig. 3): early days of incubation (47.6 mg kg^{-1}) > middle of incubation (34.8 mg kg^{-1}) =near the end of incubation (34.5 mg kg^{-1}). Based on the above order, the magnitude of K fixation was greater when air drying was done in early days of incubation period. However, there was no difference between two other times of air drying (*P*<0.01). As noted before, two processes may occur during drying:1)K fixation in wedge zones and 2)K release while exfoliation of layers. It seems that the former mainly occurs in the first days of incubation and the latter mainly occurs in middle and near the end of incubation period.

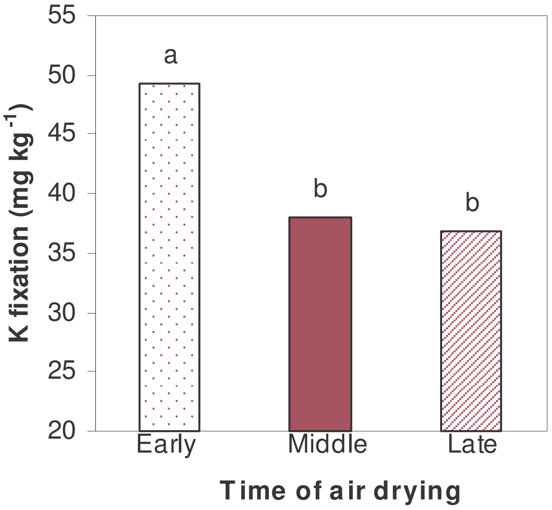

Fig. 3- Mean values of K fixation for three times of air drying (P<0.01).

Effect of Different Moisture Potentials on K Fixation:

As added K increases, K fixation increases linearly (Fig. 4). The data indicated that K fixation was greater at -100 kPa than at -30 and -500 kPa($P<0.001$). This may be explained as follows: lack of sufficient potassium concentration at -30 kPa causes low fixation. On the other hand, at -500 kPa, lack of sufficient moisture and presence of tortuous pathways retard K diffusion and subsequent K fixation (Fig. 5).

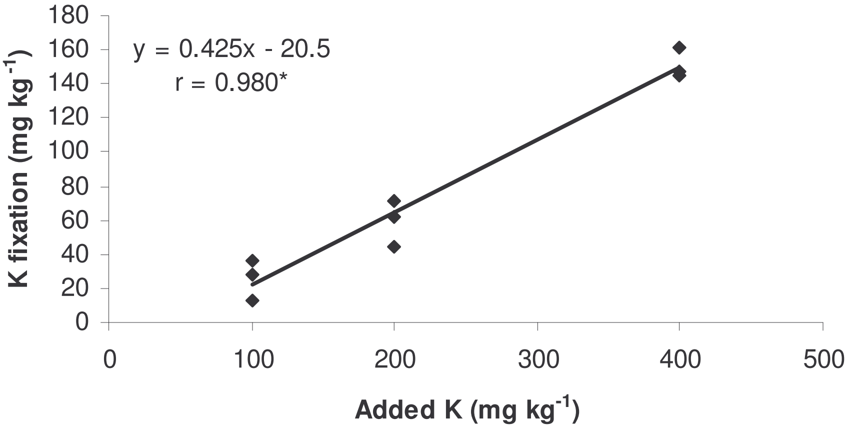

Fig. 4-Relation between K fixation and added K.

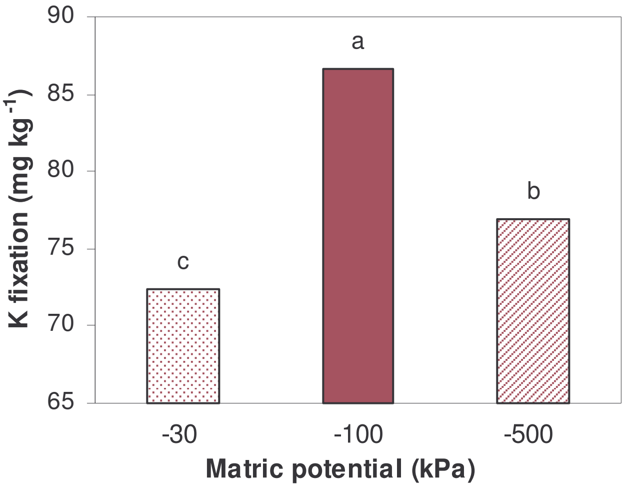

Fig. 5-Mean values of K fixation for different matric potentials (P<0.01).

Effect of Wetting-Drying Cycles on K Fixation:

Potassium fixation during two months of incubation was significantly (*P*<0.001) elevated with increasing the number of wetting-drying cycles (1, 5, 10 and 20 cycles). The amounts of K fixed by soils 2, 3 and 5 were 13, 20 and 35% (23% on average) more in the wetting-drying incubation (under 20 cycles) than in constant field capacity incubation, respectively (Fig. 6). Earlier reports propose that drying and rewetting cause a temporary exposure of new surfaces (Nevo and Hagin, 1966). Furthermore, air drying causes the movement of K ions from peripheral sites to deeper interlayer sites by an increased diffusion gradient (Sparks and Huang, 1985).

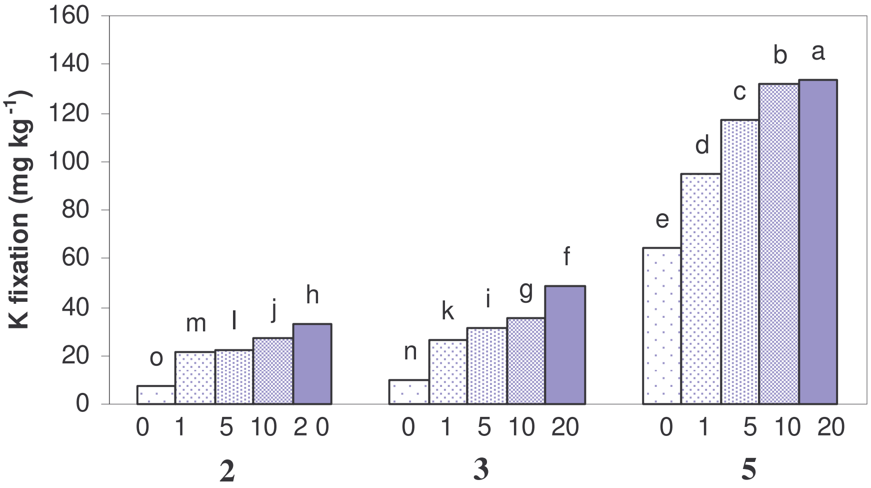

Fig. 6-Mean values of K fixation for different wetting-drying cycles (P<0.01).

Findings of this study reveal the significant effects of air drying, time of air drying, soil moisture potential and wetting-drying cycles on potassium fixation in some K-depleted soils of Azerbaijan province.

REFERENCES

Foth, H. D. and B. G. Ellis.1988. Soil Fertility. John Wiley. pp. 116-118.

Huang, P.M., J.M. Zhou, J.C. Xie, and M.K. Wang.2005. Potassium in Soils.*In*: Encyclopedia of Soils in the Environment (Ed.Daniel Hillel et al.). Academic Press, New York,USA. pp:303-314.

Knudsen, D., G.A. Peterson, and P.F.Pratt.1982.Litium, Sodium and Potassium. *In*: Methods of Soil Analysis. Part 2,Second edition(Ed. A.L.Page).SSSA.Madison,WI.pp.225-246.

Murashikina, M.A. , R.J.Southard and G.S. Pettygrove.2007.Potassium fixation in San Joaquin valley soils derived from granitic and nongranitic alluvium.Soil Sci.Soc.Am. J.71:125-132.

Nevo, Z. and J. Hagin.1966.changes occurring in soil samples during air dry storage. Soil Sci. 102:157-160.

Olk, D. C., K. G. Cassman and R. M. Carlos.1995. Kinetics of potassium fixation in vermiculitic soils under different moisture regimes. Soil Sci. Soc. Am. J. 59: 423-429.

Sparks, D.L.,and P.M. Huang.1985.Physical Chemistry of Soil Potassium.*In:* Potassium in Agriculture (Ed. R.D. Munson). SSSA, Madison, WI. pp.201-276.

Tisdale, S. L., W. L. Nelson, J. D. Beaton, and J. L. Havlin.2003. Soil Fertility and Fertilizers. Prentice – Hall of India. pp. 231-243.