K-Cycling under Maize Cultivation in Togo

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Introduction. In Southern Togo, continuous maize cropping following an extended fallow period shows a yield decline from 2 t ha^{-1} to 0.8 t ha^{-1} in a 5 year period of traditional management of residue removal without fertilizer addition. This decline is the result of a progressive deficiency in potassium attributed to leaching from the Ferralsols of the region (mean rainfall 1000 mm). This paper examines the losses by leaching as part of a detailed potassium budget under continuous maize cultivation with and without potassium fertilization. The budget was measured over two years and estimated over 10 years to account for the changed potassium status in the soil.

Materials and Methods. Two plots from a NPK factorial experiment ongoing since 1976 were studied. One plot (K0) had received no potassium, the other (K2) had been fertilized with 85 kgK ha^{-1} y^{-1}. Both plots had been cropped in maize twice a year. Crop residues were removed for the first five years and were retained later.

Drainage flux below the root zone (1.5 m) was evaluated in 1985 and 1986 from daily measurements of suction profiles and Darcy's law. Potassium in the soil solution was measured during the same period from fortnightly sampling of 8 ceramic cups in each plot. Potassium leaching was calculated from the drainage flux and the soil solution concentrations (4). A water balance model with daily rainfall input provided estimates of leaching for the period 1976-1986. Dry matter yields and crop removals (shoot and roots) were studied one year. A relationship was establish between the grain yield and the weight of crop residues to estimate the crop removals for the 1976-1986 period.

Potassium was measured in the soil from the surface to 1.6 m from representative samples taken at the beginning of 1987. Exchangeable K was extracted by ammonium acetate, total K by fluoro-perchloric acid digestion. The concentrations in the extracts were determined by flame spectrophotometry. Fixation and release of K from soil was studied with ^{42}K by isotopic exchange on 0-30 cm and 80-100 cm samples before and after wetting and drying with and without K addition (3). Clay analyses were performed on the $<2\ \mu m$ fraction of these samples using X-ray diffraction, transmission electron microscopy and chemical analysis.

Results and discussion. Although the average drainage in 1985 and 1986 was 337 mm in K0 and 289 mm in K2, K leaching in both plots was lower than 10 kgK ha^{-1} y^{-1} (Table 1). These values resulted from concentrations in the soil solution of 1.5 mgK l^{-1} for K0 and 2.4 mgK l^{-1} for K2.

		K0	K2
	Yield (t ha^{-1})	1.7	4.6
Input	Rain	4	4
	Fertilizer	0	138
Output	Grain	7	22
	(Straw)	(9)	(84)
	Drainage	5	7
Balance		-8	+113

Table 1: Average K balance under maize cultivation in 1985 and 1986 (kgK ha^{-1} y^{-1}, straw retained)

The potassium removed with the grain did not exceed 20 kgK ha^{-1} y^{-1}, even with a yield of 4.6 t ha^{-1}, as the concentration in grain was 0.31 %dm whatever the treatment. If the straw had been removed, K in the straw would have been the major output. The difference in K in the straw between K0 and K2 was much bigger than the difference in yield, as K concentration in straw was 0.22 %dm for K0 and 1.32 %dm for K2.

On the 1976-1986 period, the balance was -372 kgK ha^{-1} for K0 and +255 kgK ha^{-1} for K2 (K2-K0 = 627 kgK ha^{-1}). Removal of straw during the

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first five years of the experiment resulted in an output of 255 kgK ha^{-1} for K0 and 420 kgK ha^{-1} for K2.

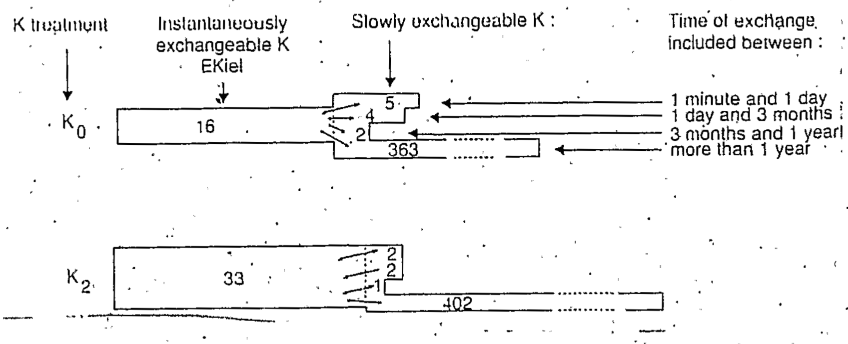

Figure 1. The different compartments of K in the soil from isotopic exchange (mgK kg^{-1})

In the soil, the difference between the two plots was 574 kgK ha^{-1} for total K and 450 kgK ha^{-1} for acetate exchangeable K in the 0-160 cm layer (2). Soil balance based on total values were then consistent with the input-output balance, but the soil balance based on exchangeable values was too low. By wetting and drying the samples, the isotopically exchangeable potassium (about 10 % higher than 1M NH4-Ac extractable K) increased by an average of 31 mgK kg^{-1}. Wetting and drying the samples after K addition resulted in an increase of isotopically exchangeable potassium about 20 % lower than the K applied. Release and fixation of K were then significant in this Ferralsol. The time of exchange between the different compartments was deduced from isotopic exchange determinations (1) and represented as a mamellary model (Figure 1). The difference between K0 and K2 in the pool exchangeable in more than one year accounted for 78 % (41 mgK kg^{-1}) of the total difference between the two treatments. This result suggests that the K from the fertilizer fixed on the soil was not available to the crops within a cropping season.

The clay analyses revealed that the most abundant mineral was kaolinite (about 80 %), while interstratified clays represented around 2 % of the $<2\,\mu m$ fraction. These interstratified minerals could explain the fixation and release observed.

Conclusion. The strong deficiency in potassium that affects the Ferralsol of Southern Togo after a few years of maize cultivation stems mainly from the removal of crop residues. The losses by leaching below the root zone were almost compensated by rainfall inputs.

The soil can fix and release K, probably because of small quantities of interstratified clay minerals. The release could explain why crop yields are poorly correlated to exchangeable potassium in depleted soil. The fixation decreases the availability of the K fertilizer added by about 20 %. The occurrence of such interstratified clay minerals in several tropical soils suggests that the phenomenon could be widely spread.

In these conditions, the fertilization of the crop should match the input-output balance with an additional 20 %. A level of 50 kgK $ha^{-1}\,y^{-1}$ is recommended to increase the production without depleting the soil.

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