NEUBAUER'S PLANTLET METHOD - AN ALTERNATIVE PROCEDURE FOR EVALUATING THE EFFECTIVENESS OF POTASSIUM BASED FERTILIZERS IN REDUCING RADIOCAESIUM TRANSFER FROM SOIL TO PLANT

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Summary

Accidental releases of radiocaesium into the environment have necessitated the search for effective soil-based countermeasures to reduce its transfer along foodchains. As field experiments can be impractical and protracted to predict rapidly the effectiveness of chemical treatments of radioactive contaminated soils to reduce soil-to-plant transfer of radionuclides, laboratory experiments are a suitable alternative for rapid evaluation of the most appropriate countermeasure to apply under a range of different circumstances in the event of accidental radioactive contamination of agricultural lands.

Taking into account these considerations our study focuses on the use of a laboratory experiment based on Neubauer's plantlet method to evaluate the effectiveness of *potassic salt 30%* applied on two soil types (alluvial and brown-reddish forest type) contaminated with ^{137}Cs for reducing uptake of the radionuclide to wheat plants grown-up on these soils.

The experimental results evidence diminished values for $^{137}Cs/K$ quotient in wheat plantlets grown-up on soils treated with *potassic salt 30%*, compared to those registered for wheat plantlets grown-up on untreated soils. The diminished values of $^{137}Cs/K$ quotient result from the reduced uptake of ^{137}Cs to plantlets accompanied by the enhanced uptake of potassium.

1. Intoduction

The plantlet method of Neubauer & Schneider has been used for many years to check up the soil capacity in providing the necessary potassium for plants in agricultural areas

[Bergmann,1958]. The method is based on the findings that growing an excessive number of plants on a limited quantity of soil, available soil potassium will be exhausted in a short time. Thus, in the limited soil nutrient conditions of this method, the plantlets will use mostly or completely the readily available potassium from soil and, occasionally, even part of the less available forms.

Our choice for the plantlet method as an alternative/complementary procedure of the modified batch equilibrium technique to evaluate the effectiveness of potassic fertilisers as a countermeasure in reducing soil-to-plant radiocaesium transfer relies on the following two suppositions:

- the excessive number of plants grown up on a relative small quantity of soil contaminated with radiocaesium (simulating the case of normal density of plants cultivated on soils less supplied with available potassium), exhausting quickly the available potassium could complete their need for potassium by extracting available radiocaesium easier than less available potassium (by virtue of the similar bio-geo-chemical behaviour of radiocaesium with that of potassium, as chemical analogue);

- because the soil conditions in the plantlet method could be considered as "critical" (referring to the limited available potassium resources of soil for the excessive number of plantlets), adding the potassic fertiliser to a soil contaminate with radiocaesium (which to satisfy the plant need for potassium) its effect on reducing soil-to-plant radiocaesium transfer could be more evidently expressed than in experiments using a "normal" number of plants.

2. Materials and methods

Portions of 100g dry soil/sample (previously ground and passed through a steel sieve with mesh size of 2mm) of alluvial and brown reddish forest type soils, contaminated in the autumn of 1993 with ^{137}Cs in the form of chloride, were mixed with washed quartz sand at a ratio of 2:1, in PVC pots pots (11cm in diameter, 8cm in height). The main physical, chemical and mineralogical parameters of the soils used for the experiment are shown in Table 1. The soil and sand mixture was then covered with a 250g quartz sand layer, to provide a seed bed. One hundred selected wheat seeds (having a germinative capacity over 90%) were placed in the seed bed. In each experimental sample, enough distilled water (approx. 80ml) containing 160mg dissolved *potassic salt 30%* (corresponding to a normal application rate in field of 200kg K/ha) was added slowly to the surface, to bring the soil mass to field capacity. The control samples were watered only with distilled water. Plants were grown in a laboratory (approx. 20°C, not exposed directly to sunlight) for 17 days, during which time pots were brought daily to field capacity. On the 17-th day the shoots were excised 0.5cm above the surface of the sand.

The processing of plant material included oven drying at 105°C (up to attaining a constant weight) and ashing in a muffle furnace at a temperature not exceeding 500°C. Plant samples were weighed dry and in ashed states.

Because the vegetal material had to be measured both for ^{137}Cs (by gamma spectrometry) and potassium (by mass atomic spectrometry) the ash from each sample was dissolved by repeated digestion with concentrated HNO_3 and HF. After the last step of digestion the samples were prepared in 8M HNO_3.

Table 1: Physical, chemical and mineralogical properties of the soils used for the experiment

Properties	**Soil type**	
	Alluvial	**Brown reddish forest type**
Texture class	sandy-loamy	clayey-loamy
Organic matter (%)[1]	4.8	3.6
Mineral matter (%)[1]	95.2	96.4
Coarse sand (%)[1,2] [2.0 - 0.2 mm]	6.4	3.2
Fine sand (%)[1,2] [0.2 - 0.02 mm]	54.4	32.4
Silt (%)[1,2] [0.02 - 0.002 mm]	20.5	30.8
Clay (%)[1,2] [< 0.002 mm]	18.7	33.6
$pH(H_2O)$		
pH(KCl)		
CEC (meq/100g)[1]	16.3	22.3
Ex K^+ (meq /100g)[1]	0.6	0.5
^{137}Cs (kBq/kg)[1]	128.4	125.8

[1] dry weight; [2] percent of mineral fraction only

3. Results and discussion

The experimental results on the effectiveness of *potassic salt 30%* in reducing soil-to-plant ^{137}Cs transfer from alluvial soil and brown reddish forest type soil to wheat plants, evaluated by the plantlet method, are shown in Tables 2 and 3.

The application of fertiliser reduced the ^{137}Cs uptake by wheat plantlets by a factor of 2.37 for those grown on the alluvial soil, and by a factor of 2.08 for those on the brown reddish forest type soil. The lower level of ^{137}Cs in plants was accompanied by an increase in potassium concentration by a factor of 1.89 on the alluvial soil, and by a factor of 1.73 on the brown reddish forest type soil.

Corresponding to the changes in opposite directions of the ^{137}Cs and potassium concentrations in plants, for both soils treated with potassic fertiliser, the value of $^{137}Cs/K$ ratio decreased by a factor of 4.5 in samples collected from the alluvial soil, and by a factor of 3.5 in samples collected from the brown reddish forest type soil. In previous batch equilibrium experiments [Mocanu,1994], when the same treatment was applied to the same soil types , the reduction in $^{137}Cs/K$ quotients in the liquid phase of the soils was the consequence of the increment factors for potassium which were higher than those for ^{137}Cs.

In general, the highest effectiveness of potassium fertilisers applied to reduce the soil-to-plant radiocaesium transfer is achieved in soils with very low levels (< 10μM) of available potassium [Shaw,1993, Nisbet et al.,1993]. At low levels of exchangeable potassium and soil solution concentrations of potassium below about 20μM, a reduction factor of about 5 was achieved for radiocaesium [Nisbet et al.,1993].

Considering the potassic fertility state of a soil as function of exchangeable potassium and clay contents, the alluvial soil and brown reddish forest type soil used in present experiment belong to the categories normally and medium supplied soils, respectively. Even if the concentrations of exchangeable potassium in the soils used in our experiment were high enough to determine a reduced soil-to-plant ^{137}Cs transfer, applying *potassium salt 30%* at the maximum rate of 200kg/ha (as it was recommended by the IAEA [IAEA-FAO,1994]), the positive effect of the treatment was still detectable, getting reduction factor of about 2 for ^{137}Cs in plants (see Tables 2 and 3). The effect was observed in situation in which the treatment was applied after one and a half years since the soil was contaminated with radiocaesium (about half of the period supposed to be necessary for a largely complete fixation of ^{137}Cs in soil [IAEA-FAO,1994]). This is consistent with the results of a previous study [Squire and Middleton,1966] showing that the application of potassium treatment at later stages after contamination would be more effective in reducing the soil-to-plant radiocaesium transfer.

Table 2: Effect of *potassic salt 30%* on ^{137}Cs transfer from alluvial soil to wheat plants

Parameters	Sample	
	Control	Experimental
Treatment (mg *potassic salt 30%*)	-	160
Dry mass of shoots (g)*	5.368	6.556
Ash mass of shoots (g)*	0.585	0.978
^{137}Cs in shoots (kBq/kg dry mass)	2.437	1.030
Reduction factor for ^{137}Cs	-	2.37
K in shoots (g/kg dry mass)	33.963	64.082
Enhancement factor for K	-	1.89
$^{137}Cs/K$ ratio in shoots	0.072	0.016
Reduction factor for $^{137}Cs/K$ ratio	-	4.5

* the values are given for a pool of 4 samples

Table 3: Effect of *potassic salt 30%* on ^{137}Cs transfer from reddish forest type soil to wheat plants

Parameters	Sample	
	Control	Experimental
Treatment (mg *potassic salt 30%*)	-	160
Dry mass of shoots (g)*	5.385	6.685
Ash mass of shoots (g)*	0.573	0.961
^{137}Cs in shoots (kBq/kg dry mass)	1.764	0.847
Reduction factor for ^{137}Cs	-	2.08
K in shoots (g/kg dry mass)	35.666	61.658
Enhancement factor for K	-	1.73
^{137}Cs/K ratio in shoots	0.049	0.014
Reduction factor for ^{137}Cs/K ratio	-	3.5

* the values are given for a pool of 4 samples

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