RADIOCESIUM IN PLANTS GROWN ON RONGELAP ATOLL SOILS[1]

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ABSTRACT

Tomato and squash plants were grown in greenhouse pot cultures using soil from Rongelap Atoll, which received fallout contamination in 1954. The treatments involved various combinations of N, P, and K. All fertilizer treatments markedly reduced the content of Cs-137 in the tissue. Also reported are the results of a field experiment on Rongelap Island in which fertilization with KCl at least temporarily reduced the content of Cs-137 in a native grass. Potassium and Cs-137 contents of foliar samples of several woody species collected on Rongelap Island are also included. In the most common pattern, K and Cs-137 contents of the upper foliage were higher than those of the lower leaves, but one species consistently showed higher K but lower Cs-137 in the upper foliage. Low K status of the soil and differences in mobility within the plant may explain these patterns.

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INTRODUCTION AND METHODS

The data reported here concern the uptake of Cs-137 by plants from soils of Rongelap Atoll, Marshall Islands, with special reference to fertilization of the soil with N, P, and K. The report includes the results of greenhouse pot culture tests using Rongelap top soil, as well as foliar analyses of native vegetation growing on the atoll. Rongelap Atoll was contaminated by radioactive fallout on March 1, 1954. The principal radionuclide found in plant tissues in 1958 and 1959 was Cs-137. Radionuclides in the soil remain in the top few inches with 90% or more of the radioactivity in the top two inches or less.

In the current greenhouse studies, tomato and squash plants were grown in Seattle on top soil (0 to 10 inches) collected in a coconut grove on Rongelap Island. The soil (perhaps better called soil material) consists entirely of calcium carbonate fragments derived from corals and foraminifera, into which is incorporated about 9% organic matter. In the rather coarse unsieved field soil the pH is 8.0; the cation exchange capacity is attributable entirely to the organic fraction and is about 8 meq per 100 gm; among the exchangeable cations there are about 80% Ca, 15% Mg, 4% Na, and 0.7% K; the soil is coarse, very friable, and highly porous.

The pot culture technique was essentially that o
et al. (1950). Fertilizer solutions were mixed with 6
portions of soil which were placed into 6-inch plasti
uniform seedlings were transferred to the pots, and d
were watered with distilled water as needed. Plants w
vested after about 30 days, and the tissue oven-drie
ground. The Cs-137 content of the dry material was de
by gamma ray spectroscopy using a three-inch thallium-
sodium iodide crystal in conjunction with a multich
analyzer. Tissue was dry ashed and the acid solution
for potassium by titration of the cobaltinitrite prec
with permanganate. Samples collected in the field usu
cluded leaves from the upper (younger) and lower (olde
foliage, and were composite samples from several plan
vicinity of a collecting point. The tissue was over
in the field headquarters, and was subsequently re-dr
and analyzed in the same manner as the greenhouse sam

RESULTS

Greenhouse Experiments

In a preliminary experiment with tomato, variety
the fertilizer treatments and the Cs-137 in disintegr

minute per gm dry tissue were: unfertilized control, 490; N-P-K, 100; N-P, 190; N-K, 240; P-K, undetectable. These results are particularly interesting because all fertilizer additions depressed the uptake of cesium. There was marked response in yield to the nitrogen and the potassium fertilization, but not enough for dilution to account for the differences in Cs-137 contents. The absence of radiocesium in the P-K treatment was associated with an unusually high K level in the plant tissue.

Following this preliminary experiment with tomato, a further greenhouse trial was made with squash, variety Hubbard. Squash was used because it is one of the few herbaceous plants successfully cultivated in the northern Marshall Islands. The treatments were set up in triplicate, replication was good, and the plants grew well except for some chlorosis which was not entirely corrected by the application of 1.5 mg Fe per pot as NaFeEDTA(Fe chelated by ethylenediaminetetraacetic acid). The plants were divided into upper leaf, lower leaf, and stem fractions at harvest. Since the results were qualitatively the same for the different fractions and space is limited, Table 1 presents the yields and K and Cs analyses on the basis of the entire shoot. The results of this experiment were in general similar to those with the tomato, although there was

no response in yield to potassium additions, and the tissue from the $N_0P_4K_2$ treatment contained Cs-137. In all cases the fertilizer amendments caused a sharp reduction in the Cs-137 content expressed on a d/m/gm dry basis, although this effect could not be associated with a particular fertilizer element. The depressive effect of fertilization on cesium uptake is also evident when the total Cs-137 in the shoot is calculated, indicating that dilution by a greater amount of dry yield can not explain the reduced cesium content. In the different portions of the squash shoots, Cs-137 was in all treatments highest in the upper leaves, lowest in the lower leaves, and intermediate in the stem. Squash plants grown on the same bench at the same time but in a greenhouse loam soil contained no Cs-137. Results of analyses for Ca, Mg, Na, and PO_4 in the tissue do not offer any obvious explanation for the differences in cesium uptake, although it should be noted that calcium levels were very high, especially in the lower leaves, in which Ca ranged from 690 to 930 meq per 100 gm of dry tissue.

Analyses of Leaf Tissue Collected on Rongelap Atoll

Foliage samples have been collected in the field, primarily from woody plants, which dominate the atoll environment. In most cases separate samples were taken of the upper and the

lower foliage of the plants. Representative values for K and Cs-137 in three of the common species are given in the lower part of Table I. Potassium contents of the upper foliage have consistently proved to be much higher than those in the lower foliage. On the other hand, Ca and Mg levels have been consistently higher in the lower than in the upper leaves. In the case of Cs-137, the pattern is consistent in the samples of a particular species, but there are differences between the species. In Messerschmidia and Pandanus, Cs-137 levels are higher in the upper than in the lower foliage, which is the same pattern that was observed in the squash grown in the greenhouse. In contrast, Scaevola shows higher levels of Cs-137 in the basal than in the upper leaves.

In one instance the effect of mineral fertilization in the field was tested. Two 1/80 acre plots in a coconut grove on Rongelap Island were treated with a broadcast application of KCl in August 1958, at a rate of 140 pounds K_2O per acre. The dominant ground vegetation, a grass (Lepturus sp.) was sampled in March 1959 from the fertilized and control areas. Average values for the content of K(meq per 100 dry gm) and Cs-137 (d/m/gm) were as follows: Control- 10.1 K, 65 Cs-137; Fertilized-16.5 K, 20 Cs-137. Samples from the same locations

collected in September 1959 showed no significant difference in either K or Cs contents, however, so the depressive effect of the K fertilization on Cs-137 was apparently transitory, although the possibility of seasonal differences exists.

DISCUSSION

N, P, and K fertilization in various combinations depressed the uptake of Cs-137 in all cases in the greenhouse experiments. It was clear that dilution by increase of dry yield with fertilization could not explain the reduction of the Cs-137 levels, but no general explanation for the effects of the three elements can be given at this time. One fact of possible interest in this connection was the considerably higher uptake of K which was observed with the P-K treatments (i. e. without N) with both squash and tomato.

The results of the pot cultures do not distinguish clearly between the effects of the different fertilizer elements on Cs-137 content of the plants, since no treatments involved single elements. There was an indication in the tomato that high K content was associated with lower Cs-137 content, but this was not confirmed by the tests using squash. A possible explanation for this difference lies in the fact that

tomato responded in yield to K additions but squash did not. In the fertilization with K in the field, at least a temporary depression of Cs-137 uptake was effected. This is consistent with the results of Nishita, et al. (1960), who observed a decreased absorption of Cs-137 with K fertilization of soil which was low in K. The Rongelap soils are low in K as evidenced by soil analyses and by the very low levels of K in the older leaves of the plants growing on them.

The differences between upper and lower foliage in their content of the various ions is of special interest. The most usual pattern shows both K and Cs-137 higher in the upper leaves than in the lower leaves. Field-collected Scaevola foliage consistently has higher K but lower Cs in the upper than in the lower leaves. This would be in accord with a previous study (Rediske and Selders, 1953) which showed Cs to function as a relatively immobile element in bean plants. Data from additional field samples of a greater number of plant species is being accumulated at present with the hope of establishing more clearly the differences between species in this respect and the significance of the sharp differences between the older and younger leaves.

The K and Cs-137 contents of field-collected leachates from Rongelap soil have been shown to be greatest immediately

following a dry period (Cole, et. al., 1960). Since there are marked seasonal differences in precipitation at Rongelap Atoll this may have a bearing on some of the results which have been discussed.

TABLE I

Cesium and potassium contents of squash and of native species

Description	Average dry yield (gm)	meq K per 100 gm	Cs^{137} d/m/g[1]
Squash in greenhouse pot cultures (total shoot)			
No fertilizer	4.5	29.6	410±34
N_3 P_4 K_0[2]	8.0	17.7	170±11
N_3 P_4 K_2	7.4	36.3	130±14
N_0 P_4 K_2	5.5	47.5	150±14
N_3 P_0 K_2	8.4	26.8	120±16
N_3 P_4 K_2 Fe	10.2	26.3	220±15
Foliage collected from woody plants on Rongelap Island			
Messerschmidia argentea (soil pit 25)	upper leaves	33	240±8
	lower leaves	6.6	150±7
Scaevola sericea (soil pit 25)	upper leaves	35	110±6
	lower leaves	12	150±7
Pandanus tectorius (village-2)	upper leaves	18.5	263±5
	lower leaves	8.9	135±4

[1]Error given is 95% counting error.

[2]Subscripts refer to rate of application per acre of N, P_2O_5, or K_2O, in hundreds of pounds.

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