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PRODUCTS—A PRELIMINARY REPORT

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THE ABSORPTION AND DISTRIBUTION OF RADIOACTIVITY IN PLANTS GROWN UPON SOILS CONTAMINATED WITH FISSION PRODUCTS — A PRELIMINARY REPORT*

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Since the advent of atomic fission, several reports (1, 2, 3, 4, 5, 6, 7) have been published concerning the growth and uptake of isotopes by plants grown on fission contaminated soils or soils artificially contaminated with radionuclides produced by fission. The results of Jacobson and Overstreet (2) are typical. Considerably more of the radioisotopes were adsorbed on the roots than were translocated to the above ground portions. Radiostrontium was taken up in considerable quantities. Rediske and Selders (5, 6), using Sr^{90} and its yttrium daughter (Y^{90}), found similar uptake and distribution. Strontium was translocated in much greater amounts than any of the other elements associated with fission (2, 3, 4, 7). Martin (3), Neel and co-workers (4), and Romney and associates (7) have reported that various radioactive elements accumulate in different plant parts. Martin (3) found little uptake of strontium by the fruits or seeds of tomato, but considerable by the stems, leaves and roots. Similar results with bean and barley were found by Neel, *et al.* (4) except that in beans strontium was found in the pods. Romney and co-workers (7) report considerable uptake of strontium by bean pods and seeds. Cs^{137} was absorbed in small quantities but with about half the activity in the pods and seeds as in the leaves.

Biddulph and Cory (1) observed what appeared to be calcium deficiency in plants grown on the coral atolls following fission, and more radioactivity was associated with the roots than the tops (gross autoradiograms). Jacobson and Overstreet contributed a similar injury to radiation damage (2). The results of Martin (3), however, suggest that the injury may have been from strontium toxicity.

PROCEDURE

Plant Growth: Seed of corn (*Zea Mays*, var. Golden Cross Bantam), bean (*Phaseolus vulgaris*, var. Sweetheart), and radish (*Raphanus sativus*, var. Comet) were planted in 4-inch pots of soil procured from an atomic blast area in the Pacific. The corn and beans were planted May 21 and the radishes June 4. Pots were sub-irrigated daily with distilled water and observations were made for symptoms of deficiencies, toxicities, or radiation injury.

Plant Tissue Radioactivity: Plants were harvested at three dates from seeding for assay of radioactivity; June 4 (corn and beans), July 6 and July 23 (corn, beans, and radishes). The first harvest consisted of the above ground parts of one plant from each of four replicates.

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The remaining two harvests were similar for corn and beans with two radish plants from each replicate. In the second and final harvest, plants were divided into various segments depending upon the nature of the plant (see Tables 2 and 3). Samples were oven dried (79°C.) for 49 hours and ground to pass through a forty mesh screen. Triplicate aliquots were weighed into "Coors" ashing capsules and the samples digested in concentrated hydrochloric acid and taken to dryness before muffling at 500°C. for 24 hours. The resulting ash was dissolved in dilute (3N) hydrochloric acid, dried and the radioactivity determined using a thin end window tube and a standard scaler circuit. Results were corrected for background* and coincidence. Recovery factor (first shelf) was 27.74% using a Ux^{234} beta standard. Standard errors of estimate were calculated by the formula:

$$se = \sqrt{(\bar{x} - x)^2 / N - 1}$$

Soil Fractionations: Samples consisting of 5 grams each of the radioactive soil were used for the fractionation and leaching studies. Two five-gram samples were leached with fifty ml. of N. hydrochloric acid and two additional five-gram samples with M. ammonium acetate adjusted to pH 7.0. The leachates were evaporated to dryness, dissolved in 0.5 ml. of hydrochloric acid and diluted to ten ml. One ml. aliquots were transferred to capsules for drying and radioassay. Samples were fractionated into organic matter and coral sand by flotation in water. The separation, while not complete, was nearly so. The resulting fractions were ashed and taken up in acid. The organic matter ash solution was transferred to three capsules, and the coral sand ash diluted to fifty ml. and three one ml. aliquots taken.

Half Life Determinations: Half life was determined by using two plant and two soil samples: (1) corn - first harvest, (2) bean - first harvest, (3) HCl Soil Extract, and (4) the organic matter fraction. Radioactivity as counts per minute was recorded at various times, corrected, and plotted on semi-log paper (Fig. 1).

Energy Determinations: The energies of the beta particles and gamma rays were determined by the use of aluminum and lead absorbers, and results plotted on semi-log paper (Fig. 2).

RESULTS AND DISCUSSION

Plant Growth: Growth of all species was normal for the first 10 to 14 days. Plants then gradually became chlorotic with necrotic leaf tips and death of the lower leaves on corn, chlorotic with irregular necrotic patches and defoliation of the lower leaves on bean, and death of the lower leaves and reddening of leaf veins on radish. The symptoms, particularly on radish, resembled the strontium toxicity symptoms described by Martin (3). Disorders with corn about the time of the first harvest resembled the calcium deficiency symptoms naturally attributed to Ca deficiency on corn. Early strontium toxicity symptoms may have been responsible; on the other hand, the level of activity may have been high enough to produce radiation injury (2). Further studies are necessary since high greenhouse temperatures prevailed during the study.

Plant Radioassay: The results (Tables 1, 2, 3) show an accumulation and distribution of activity typical of radiostrontium (2, 3, 4, 5, 7, and 8). The increase became less in corn and bean as the symptoms became more marked with a slowing of growth. Radish continued to grow rapidly until near the final harvest and did not show a drop in radioactivity. This corresponds with the results of Selders (8) and Romney (7). The radioactivity of bean flowers was high at the second harvest, but dropped at the final harvest. Neel (4) reported radioactivity in bean pods but little in the seeds while Romney (7) reported considerable radioactivity in the fruits of several plants. Neither observed a drop in radioactivity in the fruit.

*"Coors" ashing capsules have a background 15-30% above normal because of naturally occurring radioisotopes in the porcelain.

The radioactivity of the roots was high, undoubtedly because of surface adsorption (2).

Soil Fractionations: From the results presented in Table 4, it would appear that most of the activity was associated with the organic fraction. Some fine particles of organic material were observed in the coral sand fraction and probably were responsible for most of its activity. However, this does not preclude the presence of some Ca^{45} in the calcareous coral sand (1). The difference in the HCl and NH_3Ac leachates indicated that the radionuclides are rather tightly bound to the organic colloids. This agrees with results of others (2, 4, 7).

Half Life Determinations: Data for half life are presented in Fig. 1, although the elapsed time was not long enough for absolute accuracy. However, it appears that the half life is rather short (about 24-25 days). This is in disagreement with Biddulph (2) who reported a half life of 275 days for the radioactivity associated with certain soils recovered from atomic blast areas. It is also interesting to note that the half lives representing radioactive decay for HCl leachate and organic matter are parallel. However, there is some evidence of a slight preferential absorption of radionuclides by the plants.

Energy Determinations: By use of aluminum and lead absorbers, range (R) of the beta was determined as $1.1 \text{ g/cm}^2 \text{ Pb}$ with a corresponding energy of 2.2 m.e.v. Mu/P of the gamma present was calculated as $1/8.9 = 0.115$ with a corresponding energy of 0.61 m.e.v. (Fig. 2). The beta probably was from Y^{90} (2.18 m.e.v.) but the gamma could belong to one or several of the isotopes of the strontium-yttrium series.

SUMMARY

Corn, bean and radish plants were grown upon a soil contaminated with fission products. The plants exhibited injury symptoms, which resembled strontium toxicity, after 10 to 14 days' growth. Little visible growth occurred after the symptoms became severe. The radionuclides appear to be adsorbed rather strongly upon the soil organic matter fraction. The half life of the material was 24 to 25 days with slight variation between half lives of plant and soil materials indicated some preferential absorption by the plants. The radioactivity probably results from a mixture of short and long half lived elements including strontium and yttrium.

FUTURE STUDIES CONTEMPLATED

Further studies will be continued using the radioactive contaminated soil and soil leachates, with and without supplemental nutrients, to get further information on the physiological disorders observed. Translocation will be followed by leaf counting and autoradiographic techniques which will aid in the identification of isotopes.

Table 1—Radioactivity of Corn and Bean Plants from the First Harvest of the Above Ground Parts. Mean Value of Four Plants Harvested June 4

<u>Plant</u>	<u>Dry Weight grams/plant</u>	<u>Radioactivity counts/minutes per gram</u>
Corn	0.0391	519 ± 91
Bean	0.3391	412 ± 6

Table 2—Radioactivity from the Second Harvest of the Plant Parts of Corn, Bean, and Radish. Mean Value of Four Plants Harvested July 6

<u>Plant Parts</u>	<u>Dry Weight grams/plant</u>	<u>Radioactivity counts/minutes per gram</u>
RADISH		
Peel—Storage Root	0.0599	1592 ± 59
Leaves	0.1461	1634 ± 40
Peeled Storage Root	0.0782	397 ± 16
Feeder Roots	0.0144	6410 ± 29
CORN		
Roots	0.0549	6345 ± 0
Tops	0.4684	619 ± 27
BEANS		
Stems and Petioles	0.4476	1263 ± 9
Inflorescences	0.0324	1817 ± 172
Leaves	0.5488	1613 ± 11

Table 3—Radioactivity of the Plant Parts of Corn, Bean, and Radish of the Last Harvest. Mean Values of Four Plants Harvested July 23

<u>Plant Parts</u>	<u>Dry Weight grams/plant</u>	<u>Radioactivity counts/minutes per gram</u>
RADISH		
Peel, Tap and Feeder Roots	0.1562	1965 ± 25
Peeled Storage Root	0.1230	1782 ± 17
Tops	0.3709	1338 ± 24
CORN		
Culms	0.3150	602 ± 13
Leaves	0.6470	658 ± 13
BEANS		
Stems and Petioles	0.8223	1180 ± 12
Flower and Fruits	0.0669	767 ± 25
Leaves	0.7800	1740 ± 9

Table 4—Radioactivity of Leachates and Soil Fractions (5 Gram Soil Samples)

<u>Extract or Fraction</u>	<u>Radioactivity counts/minute</u>
HCl Extract (1 Normal)	2740 $\pm$ 70
NH ₄ Ac Extract (1 Molar)	483 $\pm$ 85
Organic Fraction	29,407 $\pm$ 720
Coral Sand Fraction	5,900 $\pm$ 75

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Fig. 1—Determination of the radioactive decay of soil extracts and that from plant materials grown on radioactive soils.

Fig. 2—Determination of energy of beta particles and gamma rays by absorption in lead of the radioactivity found in the organic soil fraction.