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**a study of unsupported polonium-210
for ion exchange in soils and uptake
in vegetation**

**U.S. Atomic Energy Commission
contract no. A.T. (11-1) -1733**

MASTER

**department of radiology and radiation
biology**

**summary report for the period
1967 to 1972**

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SUMMARY REPORT FOR THE PERIOD

1967 to 1972

TO: U. S. ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
ARGONNE, ILLINOIS

ON: CONTRACT NO. AT(11-1)-1733
"A STUDY OF UNSUPPORTED POLONIUM-210
FOR ION EXCHANGE IN SOIL AND UPTAKE IN
VEGETATION"

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DATE: MARCH 1, 1972

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I. Summary and Conclusions from Previous Study

Under Contract AT(11-1)-1733

This study was an attempt to determine the fate of polonium-210 which may be deposited in watersheds or agricultural areas. Deposition of polonium-210 may occur because of the accidental loss of containment from a radionuclide power source. Information about the movement of polonium in soils and translocation to plants by root uptake and foliar absorption will help in the evaluation of the ingestion hazard to a population if an accidental release occurs. The natural production of polonium-210 from the uranium-238 decay chain may also produce measurable quantities in uranium bearing soils. This source of polonium is of interest in background determinations for soil and in estimates of natural polonium body burdens.

This is the final report on this study and summarizes project activities and information gathered between 1967 and 1972. The objectives were:

1. To determine distribution coefficients of ^{210}Po for the soil profiles of the midwestern soils as well as red-yellow podzols, ground water podzols and lateritic soil from the Southeastern United States and Puerto Rico.
2. To study the movement of ^{210}Po in $^{210}\text{PoO}_2$ contaminated soil under the influence of water percolation.
3. To characterize the ^{210}Po species in soil.

4. To determine natural ^{210}Po concentration in the soils and plants used in this study.
5. To measure the uptake by plants of unsupported polonium from soils contaminated with $^{210}\text{PoO}_2$.
6. To study the foliar absorption of ^{210}Po from $^{210}\text{PoO}_2$ contaminations.
7. To characterize the ^{210}Po species in plant tissue.

The following describes the summary results and conclusions of each of the above objectives:

1. Adsorption of $^{210}\text{PoO}_2$ in soils was studied by bulk determination of distribution coefficients (K_d) of 18 different top soils and 9 soil profiles from 6 soil groups. Distribution coefficients were correlated with the silt content of the top soils. An empirical equation describing agricultural top soil adsorption was derived as $\ln K_d = 3.2 + 0.046 (\text{Percent Silt})$. Figure 1 shows this relationship. The distribution coefficients of the combined data for the A, B and C horizons of all soil samples were correlated with soil pH and silt content. The empirical equation derived was $\ln K_d = -1.3 + 0.034 (\text{Percent Silt}) + 0.88 (\text{pH})$. Polonium oxide eluted through soil columns with water indicated the K_d predicted soil retention of $^{210}\text{PoO}_2$. The soil adsorption studies indicated movement of $^{210}\text{PoO}_2$ to a water supply would be minimal.

Figure 1. The distribution coefficients of 18 top soils versus the silt content of the soil. The line is the least squares fit of the data.

2. Uniform contamination of a Rocky Mountain watershed with $^{210}\text{PoO}_2$ would find the major contamination retained by the soil. A simulated snow-melt run-off experiment was conducted with a mountain Podzol soil from the Fraser Alpine Area, Colorado. $^{210}\text{PoO}_2$ was applied to the litter layer as a point source one meter from water collection vessels at the base of a 30 percent slope. Cores from the soil on which one mean annual rainfall (18.6 in.) of ice was melted indicated both vertical and horizontal movement of $^{210}\text{PoO}_2$ into the soil. The run-off water collected at the base of the slope at the bottom of the litter layer and A_2 horizon indicated only 10^{-7} of the original activity moved through these soil horizons. Data from soil cores were used to predict the movement of a uniform deposition of $^{210}\text{PoO}_2$ to a stream. The equations derived indicate only the first 50 cm bordering a stream contribute significant contamination to the water. The complete study is published as report CCO-1733-8.
3. The chemical species of ^{210}Po in soil solution were characterized by electrophoresis and dialysis experiments. Polonium-210 in soil solution subjected to an electric field indicated both positive and negative species in soil solution. The relative concentrations of the species varied with soil type. Figure 2 shows the relative species distribution after

PAPER ELECTROPHORESIS OF $^{210}\text{PoO}_2$ SOIL LEACHATE
 PODZOLIC SOIL, ONAWAY LINE SANDY LOAM
 SOIL SOLUTION pH 6.8
 OPERATING TIME 1 hr. AT 500V 5ma

Figure 2. Paper electrophoresis of $^{210}\text{PoO}_2$ in Onaway soil leachate. Onaway series soil solution used as buffer. Note predominant species are positive.

leaching one type of soil. Dialyzed soil solutions indicated approximately 34 percent of the ^{210}Po in soil solution would pass through a semi-permeable membrane. The addition of polonium oxide directly to soil solutions indicated soil solid phases after the dialyzed forms.

4. Measurements of the naturally occurring ^{210}Po in the soil samples indicated a range of 0.22 to 3.47 pCi/g in top soils. Measurements of the ^{210}Po in the vegetation used for controls in the greenhouse experiments indicated the source of naturally occurring ^{210}Po in plants was the fallout of the isotope and its radioactive precursors. The transfer coefficients determined from $^{210}\text{PoO}_2$ spiked soils were too low to account for the plant tissue activity of control plants grown in control soils.

Table 1 presents the control sample data for two plantings in Fort Collins silty clay loam. Since there were no changes in the irrigation, fertilization or analytical procedures for the two plantings, the higher ^{210}Po (RaF) concentrations in potato pulp, potato greens, and peas samples for the first planting, may be due to a slight cross contamination since the standard errors are quite large for these samples. The higher concentrations in the wheat samples which were grown at a later time are believed to be due to an increase

Table 1. Control plants ^{210}Po content - Fort Collins silty clay loam.

Species and Variety	Tissue	1st Planting	2nd Planting
		^{210}Po pCi/g dry weight $\pm$ S. E.	^{210}Po pCi/g dry weight $\pm$ S. E.
Barley (<u>Hordeum vulgare</u> , Betzes)	Kernels	0.030 ± 0.008	0.013 ± 0.004
	Stems and Leaves	0.050 ± 0.007	0.13 ± 0.03
Corn (<u>Zea mays</u> , Hybrid Sweet)	Kernels		Not Detected
	Cob		Not Detected
	Leaves		0.12 ± 0.02
	Stems		0.025 ± 0.004
Wheat (<u>Triticum spp.</u> , Chris)	Kernels	0.043 ± 0.035	0.30 ± 0.06
	Chaff	0.076 ± 0.007	15 ± 1.5
	Stems and Leaves	0.040 ± 0.009	54 ± 15
Onion (<u>Allium cepa</u> , Mountain Danver)	Bulbs	0.13 ± 0.05	0.11 ± 0.09
	Tops	0.13 ± 0.02	0.051 ± 0.014
Potato (<u>Solanum tuberosum</u> , Norgold)	Whole	0.027 ± 0.008	0.020 ± 0.004
	Pulp	0.16 ± 0.04	0.017 ± 0.005
	Peel	0.054 ± 0.011	0.040 ± 0.005
	Greens	0.45 ± 0.15	0.14 ± 0.02
Peanut (<u>Arachis hypogaea</u> , Spanette)	Nuts		0.033 ± 0.020
	Shells		0.63 ± 0.10
Radish (<u>Raphanus sativus</u> , Cavalier)	Bulbs	0.069 ± 0.011	0.097 ± 0.034
	Greens	0.11 ± 0.02	0.082 ± 0.019

Table 1., concluded.

Species and Variety	Tissue	1st Planting	2nd Planting
		^{210}Po pCi/g dry weight $\pm$ S. E.	^{210}Po pCi/g dry weight $\pm$ S. E.
Alfalfa (<u>Medicago sativa</u> , Ranger)	Plant (1st crop)		0.17 ± 0.02
	Plant (2nd crop)		0.115 ± 0.02
	Plant (3rd crop)		0.095 ± 0.02
Celery (<u>Apium graveolens dulce</u> , Golden Dwarf)	Edible Stem	0.055 ± 0.015	
	Stem	0.11 ± 0.04	
	Leaves	0.068 ± 0.006	
Spinach (<u>Spinacia oleracea</u> , Badger Savoy)	Leaves	0.086 ± 0.024	0.078 ± 0.020
	Stems		0.099 ± 0.019
Pea (<u>Pisum sativum</u> , Dwarf)	Peas	0.57 ± 0.21	0.025 ± 0.015
	Pod	0.42 ± 0.14	0.025 ± 0.007
	Vines	0.29 ± 0.10	0.16 ± 0.03
Tomato (<u>Lycopersion esculentum</u> , Marglobe)	Pulp	0.089 ± 0.021	0.028 ± 0.004
	Juice	Not Detected	Not Detected
	Leaves	0.038 ± 0.005	0.16 ± 0.05
	Stems	0.078 ± 0.009	0.19 ± 0.05

in the aerial deposition of RaF due to mist irrigation in the greenhouse.

5. Plant uptake of $^{210}\text{PoO}_2$ added to soil was measured and expressed as a transfer coefficient, U, which is the ratio of the amount of ^{210}Po per gram of dry plant material to the amount of ^{210}Po per gram of dry soil at the date of harvest. Transfer coefficients of 11 different fruit, grain, leafy and root crops ranged from 10^{-2} to 10^{-6} . The transfer coefficients were independent of the soil distribution coefficients.

Table 2 gives the transfer coefficients for a variety of plants in a silty clay loam. Calculations using U to estimate the ingestion hazards indicated 1 MCi deposited over 62 Mi^2 could produce maximum permissible body burdens of ^{210}Po .

6. Table 3 lists the summarized data for the foliar absorption of $^{210}\text{PoO}_2$ placed on plant leaves. The fraction of the total activity absorbed and translocated to the total pea plants ranged from $1.0 \times 10^{-4}/\text{g}$ to $6.1 \times 10^{-4}/\text{g}$. Translocation of ^{210}Po to the roots of the peas and in movement of the ^{210}Po to the total pea leaves ranged from $2.5 \times 10^{-4}/\text{g}$ to $5.5 \times 10^{-4}/\text{g}$ of the total amount applied to one leaf. The greatest amount of ^{210}Po was detected in pea leaves opposite the label and the new growth of the plants.

Table 2. Polonium oxide transfer coefficient (U) - Fort Collins silty clay loam, $K_d = 230$.

Species and Variety	Tissue	No. of Samples	Dry Wt. Transfer Coefficient $\pm$ S. E.	Wet Wt. Transfer Coefficient $\pm$ S. E.
Barley (<i>Hordeum vulgare</i> , Betzes)	Kernels	24	$(2.6 \pm 0.2) \times 10^{-4}$	$(2.1 \pm 0.2) \times 10^{-4}$
	Stems and Leaves	23	$(5.1 \pm 1.7) \times 10^{-3}$	$(9.1 \pm 3.1) \times 10^{-4}$
Corn (<i>Zea mays</i> , Hybrid Sweet)	Kernels	10	$(1.8 \pm 0.3) \times 10^{-5}$	$(3.5 \pm 0.7) \times 10^{-6}$
	Cob	10	$(3.6 \pm 0.6) \times 10^{-5}$	$(5.0 \pm 0.8) \times 10^{-6}$
	Tassel	9	$(5.4 \pm 1.1) \times 10^{-5}$	$(1.5 \pm 0.3) \times 10^{-5}$
	Leaves (50 days)	16	$(2.1 \pm 0.4) \times 10^{-3}$	$(2.6 \pm 0.5) \times 10^{-4}$
	Leaves (130 days)	13	$(1.2 \pm 0.3) \times 10^{-3}$	$(1.4 \pm 0.4) \times 10^{-4}$
	Stems (50 days)	22	$(1.4 \pm 0.4) \times 10^{-4}$	$(1.6 \pm 0.4) \times 10^{-5}$
	Stems (130 days)	12	$(3.9 \pm 0.9) \times 10^{-4}$	$(4.8 \pm 1.1) \times 10^{-5}$
Wheat (<i>Triticum spp.</i> , Chris)	Kernels	9	$(4.3 \pm 2.7) \times 10^{-4}$	$(3.7 \pm 2.3) \times 10^{-4}$
	Chaff	9	$(9.4 \pm 4.0) \times 10^{-3}$	$(8.7 \pm 3.7) \times 10^{-3}$
Onion (<i>Allium cepa</i> , Mountain Danver)	Bulb	25	$(5.6 \pm 1.2) \times 10^{-4}$	$(5.1 \pm 1.5) \times 10^{-5}$
	Tops	28	$(6.7 \pm 1.1) \times 10^{-4}$	$(4.9 \pm 0.9) \times 10^{-5}$
Peanut (<i>Arachis hypogaea</i> , Spanette)	Nut	12	$(1.6 \pm 0.6) \times 10^{-3}$	$(1.7 \pm 0.6) \times 10^{-4}$
	Shell	12	$(3.7 \pm 0.5) \times 10^{-2}$	$(3.6 \pm 0.5) \times 10^{-3}$
Potato (<i>Solanum tuberosum</i> , Norgold)	Whole	14	$(4.9 \pm 1.3) \times 10^{-3}$	$(6.2 \pm 1.6) \times 10^{-4}$
	Pulp	13	$(2.7 \pm 0.9) \times 10^{-3}$	$(3.4 \pm 1.1) \times 10^{-4}$
	Peel	7	$(3.4 \pm 0.5) \times 10^{-2}$	$(5.5 \pm 0.9) \times 10^{-3}$
	Greens	16	$(4.4 \pm 0.6) \times 10^{-3}$	$(3.5 \pm 0.4) \times 10^{-4}$

Table 2., concluded.

Species and Variety	Tissue	No. of Samples	Dry Wt. Transfer Coefficient $\pm$ S. E.	Wet Wt. Transfer Coefficient $\pm$ S. E.
Radish (<u>Raphanus sativus</u> , Cavalier)	Bulb	26	$(6.3 \pm 0.5) \times 10^{-3}$	$(5.8 \pm 0.7) \times 10^{-4}$
	Greens	23	$(5.3 \pm 1.0) \times 10^{-3}$	$(5.8 \pm 1.1) \times 10^{-4}$
Pea (<u>Pisum sativum</u> , Dwarf)	Peas	22	$(1.4 \pm 0.2) \times 10^{-4}$	$(3.5 \pm 0.5) \times 10^{-5}$
	Pods	27	$(3.9 \pm 0.6) \times 10^{-4}$	$(5.5 \pm 0.7) \times 10^{-5}$
	Vines	20	$(2.2 \pm 0.2) \times 10^{-3}$	$(3.3 \pm 0.3) \times 10^{-4}$
Tomato (<u>Lycopersion esculentum</u> , Marglobe)	Pulp	34	$(3.3 \pm 1.3) \times 10^{-5}$	$(3.7 \pm 1.5) \times 10^{-6}$
	Juice	30	--	$(3.3 \pm 0.7) \times 10^{-6}$
	Plant (30 days)	8	$(2.1 \pm 0.4) \times 10^{-3}$	$(1.7 \pm 0.3) \times 10^{-4}$
	Leaves (50 days)	26	$(1.4 \pm 0.2) \times 10^{-3}$	$(1.5 \pm 0.2) \times 10^{-4}$
	Leaves (130 days)	25	$(3.7 \pm 0.7) \times 10^{-4}$	$(5.5 \pm 1.0) \times 10^{-5}$
	Stems (50 days)	21	$(5.0 \pm 0.7) \times 10^{-4}$	$(3.0 \pm 0.4) \times 10^{-5}$
	Stems (130 days)	14	$(1.6 \pm 2.0) \times 10^{-5}$	$(1.1 \pm 2.1) \times 10^{-6}$
Alfalfa (<u>Medicago sativa</u> , Ranger)	Plant (1st crop)	14	$(9.2 \pm 3.3) \times 10^{-4}$	$(1.6 \pm 0.6) \times 10^{-4}$
	Plant (2nd crop)	21	$(2.9 \pm 0.9) \times 10^{-3}$	$(2.9 \pm 0.9) \times 10^{-4}$
	Plant (3rd crop)	15	$(2.9 \pm 0.6) \times 10^{-3}$	$(6.1 \pm 1.2) \times 10^{-4}$
Celery (<u>Apium graveolens dulce</u> , Golden Dwarf)	Edible Stem	21	$(2.7 \pm 0.3) \times 10^{-4}$	$(2.9 \pm 0.4) \times 10^{-5}$
	Stem	23	$(3.4 \pm 0.4) \times 10^{-4}$	$(4.0 \pm 0.5) \times 10^{-5}$
	Leaves	21	$(3.0 \pm 0.6) \times 10^{-4}$	$(3.2 \pm 0.6) \times 10^{-5}$
Spinach (<u>Spinacia oleracea</u> , Badger Savoy)	Leaves	12	$(7.3 \pm 0.5) \times 10^{-3}$	$(8.0 \pm 0.5) \times 10^{-4}$
	Stems	9	$(4.9 \pm 0.9) \times 10^{-3}$	$(5.2 \pm 1.0) \times 10^{-4}$

Table 3. Data Summary of Foliar Absorption of $^{210}\text{PoO}_2$

Plant Tissue	Fraction of activity moved to 1 g of tissue		
	Plant 1	Plant 2	Plant 3
Total plant, peas	1.0×10^{-4}	6.1×10^{-4}	1.6×10^{-4}
Leaves, peas		5.5×10^{-4}	2.5×10^{-4}
Stems, peas		6.7×10^{-4}	8.3×10^{-5}
Roots, peas	7.6×10^{-6}	1.7×10^{-4}	2.2×10^{-5}
Flowers, peas		4.7×10^{-4}	
Peas and Pods		3.3×10^{-5}	
Total plant, corn	5.0×10^{-5}		

These studies indicated that foliar absorption of Po in the oxide form did occur and could be significant if contamination were spread over the whole plant.

7. Alcoholic protein extracts of wheat and spinach were separated by paper chromatography to investigate possible organic forms of polonium. Paper chromatography indicated one at least organically complexed form of polonium-210 which represented 12 percent of the total in the wheat protein hydrolyzate. An organic form of ^{210}Po may increase the ingestion hazard associated with plant uptake of polonium from soil.

Polonium-210 detected in plants grown in soils containing added $^{210}\text{PoO}_2$ may enter roots as inorganic ions and undergo chemical change within the plant, or an active uptake mechanism in the root may form an organic species which is translocated to the aerial plant tissue. Transfer coefficients would indicate passive uptake of ^{210}Po is the route of entry into the plant. Rosenfeld and Beath suggested selenium, a possible chemical analog of polonium, entered plants as an inorganic ion. Selenite (SeO_3^{2-}) translocated to the leaves of plants was identified as the source of selenium in plants. Figgins speculated that polonite (PoO_3^{2-}) ion may exist. If polonite ion exists in soil solution it may act like selenite and enter plants

through the root system, undergoing chemical changes in the leaves of the plants.

Section II of this report will summarize recent studies on the microdistribution of Po in plant tissue and describe attempts to further characterize the ^{210}Po species. The final results of the microdistribution study will be presented in a special report later this year or early in 1973.

II. Recent Studies on the Microdistribution of Polonium in Plants

A. The Effects of Ca, S, P and N Nutrient Deficiencies Upon the PoO_2 Accumulation in Barley, Corn, Oat and Radish.

G. E. Powers and R. L. Watters

MATERIALS AND METHODS:

Soluble ions were removed from horticultural grade Perlite in disposable plastic pots two inches square and two and one-half inches deep by flushing them with distilled-deionized water. Oat (*Avena sativa* L., var. Park), Barley (*Hordeum vulgare* L., var. Hilands) and radish (*Raphanus sativus* L.) were planted three-fourths of an inch deep and corn (*Zea mays* L., var. Jacque) one inch deep and watered with distilled-deionized¹ water for nine days. On the tenth day after planting, all of the plants were watered with full strength complete nutrient solution (Table IV, Appendix A) since some of the young seedlings began to show symptoms of general mineral deficiencies with chlorosis being the most prominent symptom. Chlorosis disappeared by the thirteenth day and all of the seedlings were exposed at least one-half to two inches above the Perlite. At this time each pot was flushed with two liters of distilled-deionized water and allowed to drain 48 hours.

Plastic V-1 trays² which hold 24 pots were sealed with silicone rubber bathtub caulk³ and water proof adhesive tape (heating duct sealing tape) (see Figures 3 and 4, Appendix B). A one liter solution

¹ Barnstead Hose Type Cartridge #8902 Mixed Bed Resin

² American Plant Container Company

³ Dow Corning Corporation, Silicone Rubber Bathtub Caulk.

of polonium oxide ($.2064 \pm .0307$ microcuries per liter for the radish, corn, and barley and 13.54 ± 6.54 microcuries per liter for the oat) was poured into the sealed tray and distributed evenly between the two halves of the tray (see Figure 5, Appendix B). Two one milliliter samples of the polonium oxide solution were taken from each tray to verify the amount of spike to each group of plants (see Table V, Appendix A).

Four groups of six pots were placed in the polonium oxide solution as rapidly as possible (see Figure 6, Appendix B). The entire tray containing the spike solution and the plants was placed into another sealed tray also lined with six mil polyethylene sheet for secondary containment. The entire apparatus was placed on a wooden rack inside of a four foot square by six inch deep polyethylene lined box. The plants were not given any nutrients for 24 hours.

Five different nutrient solutions were prepared containing the concentrations previously listed in Table IV, Appendix A. The nutrient solutions were stored in the greenhouse in shaded five gallon polyethylene bottles and were made up as needed. Each group of plants (a group consisted of one tray of each species of plant) was watered with one of the specified nutrient solutions diluted with water 1:5 (one-fifth concentrate) by sprinkling each pot in the tray with an equal amount of solution. To prevent leaching of the initial spike solution from any one given pot, the water level of each tray was

maintained at one-fourth to three-fourth full during the experiment and the watering began with a different pot each time.

The plants were collected periodically from each tray by cutting the stem one-fourth inch above the surface of the perlite with a razor blade. Individual razor blades were used at each tray to prevent cross contamination. The location in the tray (by row and column), the time and the date of collection and the absent nutrient of interest were recorded on sample container. The samples were frozen until analysis. A few selected samples of oats were frozen in liquid nitrogen pending future analysis using Sephadex¹ column chromatography.

The leaves and the roots of the radish were analyzed independently and only in the aerial portion of the oats, barley, and corn were analyzed for total polonium content according to the method of Blanchard (1966). The plants were cut into one inch pieces, placed in pre-weighed 300 milliliter (ml) Erlenmeyer Flasks, wet weighed, and dried in a forced air oven for 48 to 72 hours at 110°C. After the dry weight was determined, concentrated nitric acid was added to the dried sample in the amount of 5 ml per gram of sample with a minimum of 15 ml per sample. The samples were allowed to sit overnight in the nitric acid, to ensure complete wetting, therefore, preventing the production of explosive peroxides upon the addition of 25 ml of

¹ Pharmacia Fine Chemicals AB, Uppsala, Sweden

70 percent perchloric acid. After perchloric addition samples were heated to 250°C until the samples were dissolved and foaming had ceased. Perchloric acid was not added to some of the bulky corn samples until after the samples had been heated in the concentrated nitric acid and the volume reduced to approximately 50 ml. After the fumes of nitrogen dioxide were no longer visible the temperature was gradually increased to $400-450^{\circ}\text{C}$, with additions of nitric acid if the samples appeared to be charring. The samples remained at increased temperature until the dense white fumes of the perchloric acid condensed only at the mouth of the flask. The samples were cooled, 25 ml of distilled water were added plus four drops of methyl red-bromothymol blue indicator, and then neutralized with 15 N sodium hydroxide. Eight ml of 12 N hydrochloric acid were added to each sample immediately after neutralization.

Pyrex baby bottles with the bottoms removed and the edge of the mouth dipped in milling maskant were used as plating bottles. A nickel disc 99 percent pure, 1.44 inches in diameter and 0.005 inches thick that had been washed in 3 N hydrochloric acid, ethanol, trichloroethylene, and acetone was placed in the bottle cap. The cap was placed on the baby bottle and tightened to form a seal between the milling maskant and the nickel disc. Fifty ml of water plus 500 ± 100 milligrams of L. ascorbic acid were added to each plating bottle to reduce the ferric ion that may interfere with the plating (Fink, 1950).

Each species of plant, and each of its nutrient subdivisions, were assigned a plating bottle that was to be used only for that plant nutrient combination to reduce possible cross contamination between sample sets.

The acidified samples were added to their respective plating bottles with three rinses of distilled water, and the total volume increased to 200 ml with distilled water yielding a 0.5 N hydrochloric acid solution. The plating bottles were placed in an 85°C water bath and stirred for three hours. The nickel discs were then removed, rinsed with distilled water, blotted dry and counted in a pre-flushed gas flow proportional counter.

DISCUSSION:

Perlite, an expanded siliceous rock, as chosen for the root supporting media because of its tremendous porosity which traps air and increases aeration of the roots. With this support stagnation did not occur, indicating that sufficient aeration existed during the experiment.

A chemical analysis of perlite made by the Perlite Institute (1958) found an average analysis to contain the oxides presented in Table VI, Appendix A.

The nutrient solution was maintained at pH 5 to prevent the excessive release of aluminum from the Perlite which may cause nutrient toxicity (Green, 1968). Also, since PoO_2 was used in a neutral

aqueous solution rather than an acid solution, the nutrient solutions were maintained at the buffered pH to minimize the variation of the solubility of PoO_2 . However, Manzel (1966) reports that with sudan grass, red clover and astragalus the uptake of polonium originally dissolved in a hydrochloric acid - nitric acid mixture was independent of pH.

RESULTS:

The nutrient deficient symptoms became apparent within three days after the addition of the Po spike. Figure 7 (Appendix B) illustrates the effects of the various nutrient deficiencies eight days following the spike and twenty-two days after planting.

All but one calcium deficient radish plant had died by the thirtieth day after spiking. Figure 8 (Appendix B) shows the radish and corn plants thirty-four days after spiking. Bits of perlite can be seen on the fibrous root system which were removed before analysis of polonium was made. A complete statistical analysis has not been performed yet but there appears to be in the case of radish, corn, and oat an increased total amount of polonium uptake in the phosphorus deficient plants (see Figures 9, 10, 11 and 12 in Appendix B). If the concept that the presence of phosphates in the soil precipitate heavy metals also holds for polonium, this may be the reason for increased polonium uptake in the phosphorous deficient plants. The solubility product of polonium phosphate is not known but it is probably greater

than the amount of polonium used in the spike. However, since polonium oxide is extremely insoluble and probably colloidal in solution the possibility exists that in the flats that contained phosphates precipitation of polonium phosphate within the colloidal particle made the polonium less accessible.

The apparent peaking between the twentieth and fourtieth day in the radish, corn, and barley has not been explained. Data are presently being collected from the horticultural department concerning the light intensities during this period and will be checked for significance.

The rate of uptake of polonium in the nitrogen deficient plants is less than with other nutrient deficiencies and is indicative of total amount of the growth rate. In general, there does not appear to be any effect upon PoO_2 uptake and the deficiency of the remaining nutrients. A summary of the present available data is given in Appendix A (Tables VIIa-Xe).

B. Ultra-Centrifugation Separation of Plant Cellular Organelles Containing Polonium

G. E. Powers, C. T. Rankin, and R. L. Watters

INTRODUCTION:

The development of zonal centrifugation has made it possible to separate pure samples of subcellular organelles in quantity. We have used this process to determine the degree of association of polonium with a given organelle. Identification of organelles in the various fractions from the zonal centrifuge runs has, at present, been limited to light microscopy.

Two basic types of centrifugation were used; swinging bucket with a step gradient and zonal centrifugation using a continuous gradient of sucrose.

All tables will be found in Appendix A and all figures in Appendix B.

MATERIALS AND METHODS

Swinging Bucket: The leaves of two month old sugar beet plants that had been grown in eight inch diameter disposable plastic pots containing one microcurie of PoO_2 in 2500 grams of potting soil (58 percent silt loam, 40 percent sand, and 2 percent peat moss by weight) were used for the centrifugation study. The leaves were cut off one inch above the soil level, to prevent surface contamination that may have occurred during watering, and placed into plastic bags packed in ice to reduce enzyme activity. Approximately six grams of deribbed

leaves were soaked one to three minutes in 0.05 M calcium chloride to increase the turgidity of the cells and aid in rupturing the cell wall during homogenization. The leaves were drained and placed in a Waring Blender with 150 ml of modified Honda's medium (2.5 percent Ficoll, 5 percent Dextran, 0.25 M Sucrose, 0.05 M Tris at pH 7.8, β -Mercaptoethanol, 0.001 M Magnesium Chloride, M Calcium Chloride) and homogenized at maximum speed for ten to fifteen seconds. The homogenate was filtered through three layers of Miracloth¹ and retained for further analysis. The filtrate was centrifuged at 2500 g for ten minutes. The supernatant was saved for mitochondrial isolation. Following the chloroplast isolation technique of Whitfeld and Spencer (1968) and the step gradient of Tewari and Wildman (1966) the chloroplast-nuclei pellet was resuspended in 15 ml of the homogenizing medium and 5 ml aliquots were layered over 10 ml 60 percent sucrose, 15 ml 45 percent sucrose, and 15 ml 20 percent sucrose respectfully in the modified Honda medium in one inch by three inches nitrocellulose tubes.

The samples were centrifuged at 1.3×10^4 revolutions per minute for 6.6 hours in a HB-4 Sorvall Rotor. Microscopic examination revealed that nuclei, starch and cell wall material collected at the bottom of the tube. and the chloroplasts collected between the 60 to 45 percent interface and at the 45 to 20 percent interface.

¹ Chicopee Mills, Inc., New York, N. Y.

At the 60 to 45 percent sucrose interface the chloroplasts appeared to be contaminated with nuclei and at the 45 to 20 percent interface the chloroplasts contained a few mitochondria. The two chloroplast layers were removed with a pipette and the supernatant poured off of the pellet. The three fractions were saved for the analysis of polonium. The original supernatant was recentrifuged at 10,000 g for twenty minutes to pellet the mitochondria and its supernatant was centrifuged at 90,000 g for five hours in a SW 25.1 Rotor to pellet the microsomes from the soluble fraction.

The nuclei and 20 to 45 percent sucrose layer of chloroplasts were filtered and rinsed with the homogenizing solution on a 0.45 micron Millipore filter, dried and weighed. The mass of the nuclei was 0.23 grams and the chloroplasts 0.025 grams, little emphasis is placed upon the mass of the nuclei and the chloroplasts since complete removal of the sucrose could not be performed without destroying the organelle of interest. The polonium content was determined by the methods of Blanchard (1966) and the results are presented in Table XI.

The residue remaining in the Miracloth, composed mainly of unbroken cells and vascular tissue, was rehomogenized in the blender at maximum speed in 250 ml of water for ten minutes to ensure complete release of all cell organelles. The cell wall homogenate was filtered through one layer of Miracloth and analyzed for polonium.

The data from this experiment suggested that two primary fractions should be considered in detail, the 20 to 45 percent chloroplasts layer and the "soluble fraction" layer. To separate each fraction into their respective compartments, zonal centrifugation was chosen because of the larger sample size that could be used to increase the total activity.

Zonal Centrifugation: Three gradient solutions were evaluated on the basis of cost and effect upon the organelles of interest and the possible effect upon polonium. Honda's medium was rejected because of the cost of ficoll, Breidenbach's (1968) gradient was rejected because of the EDTA content which might have altered any biologically bound polonium, and the content of BSA (bovine serum albumin), which if the polonium were combined with soluble proteins, the serum albumin might interfere with the subsequent protein molecular weight determinations. The gradient of Still and Price (1967) was modified by using 0.05 M Tris pH 7.8 instead of Tricine and adding two millimeters β -Mercaptoethanol as a protective agent to keep the functional sulfhydryl groups of the enzymes in a reduced state (Bonner, 1965). The stock media (20 mM β -mercaptoethanol, 0.5 M Tris, 0.01 M magnesium chloride, and 0.01 M calcium chloride) which was less sucrose was made up at ten times the concentration to be used and the pH adjusted with 6N hydrochloric acid to between 7.4 and 7.8. It was kept in a cooler at 4°C for at least twelve hours, ensuring complete

cooling. The overlay was prepared by diluting the stock ten fold with distilled water and the grinding media was prepared by diluting the stock ten fold in 0.5 M sucrose. A Model 141 Beckman High Capacity Gradient Pump was used to fill the rotor with the desired gradient. The displacement solution used to empty the rotor consisted of sucrose five to ten percent more concentrated than the upper limit of the gradient.

Two basic rotor types were used: the B-15 Titanium Rotor having a maximum volume of 1,665 ml and a radius of 8.890 centimeters which gives a maximum relative centrifugal force at the edge of the rotor of 121,000 g at 35,000 revolutions per minute, and an A-12 Plexiglas Rotor by International having a maximum volume of 1,300 ml and a radius of 18 centimeters which gives a relative centrifugal force of 7,100 g at the periphery at 6,000 revolutions per minute.

The samples were prepared in the same manner as the samples for the swinging bucket rotor after the gradient had been placed in the rotor. A sample and overlay were loaded into the gradient while the B-15 rotor was spinning at 500 rpm. As soon as the overlay was in place the $\omega^2 t$ integrator was started and the rotor was brought to its operating speed. An integrator was not available for the A-12 rotor so a stop watch was used for timing and the speed was read from the instrument panel. A xenon strobe light was used to check the speed of the A-12 rotor. Figure 13 illustrates the sample in the

A-12 rotor at loading, at the starting zone and at the end of the run.

At the completion of a run the rotor speed was reduced to 500 rpm and 40 ml samples collected. The percent of sucrose in each fraction was determined by a Bauch and Lomb Refractometer for use in the Oak Ridge computer program for the determination of sedimentation coefficients (Bishop, 1966). Table XII summarizes the sucrose gradients and the integrated $\omega^2 t$ values for the described runs.

Centrifuge runs four (Figure 14) and five (Figure 15) were made on the leaves and root of a sugar beet, the preparation of the root being identical to that of the leaves. Microscopic examination of the various fractions indicated that the organelles (nuclei and chloroplasts) were extremely damaged and this was attributed to the fact the pH of the gradient was not 7.8 but pH 10.4. The damage to the organelles made it impossible for them to sediment as a unit band. The chloroplasts were expected to begin isopycnic banding in fractions 27 to 30. There were no visible indications that the chloroplasts were banding. Figure 13c shows the location of many broken chloroplasts near the sample starting zone and Figure 14 presents a plot of the activity in pCi for each of the 40 ml fractions. Centrifuge runs six, seven, and eight were made during the same day. Runs six and seven were started within fifteen minutes of each other in separate B-15 rotors and both samples were the result of one preparation. Run eight was started one hour after the end of run six, using a freshly prepared sample.

Figures 16, 17 and 18 illustrate the results of these runs. Isopycnic banding of chloroplasts and mitochondria appears to have taken place in the region of fraction 30 ($\rho = 1.217$) of run six. However, it will take electron micrographs to verify the banding of the mitochondria and the structural condition of these organelles. Runs seven, eight and ten (Figure 20) begin to show the slow movement of a radioactive band that comprises the majority of polonium. The present estimate on the sedimentation coefficient of this peak is in the range of 18-25 which corresponds to the sedimentation coefficients of soluble proteins (Price, 1970). The verification or rejection of the hypothesis that soluble proteins contain the polonium will be determined by isolating these fractions, and accurately finding the sedimentation coefficient and M W on a Model E analytical centrifuge and verified using Sephadex and the standard Lowry et al. (1951) method of protein analysis. Centrifuge run number nine (Figure 19) suggests that polonium is also associated with ribosomes. Tables XIII-XVII summarize the sedimentation coefficients for given densities for the series of fractions obtained from a given centrifuge run.

C. Amino Acid Analysis of Astragalus osterhouti Grown in Soil Containing Polonium Oxide

G. E. Powers and R. L. Watters

INTRODUCTION:

Astragalus osterhouti is known to be a selenium accumulator (Rosenfeld, 1964). Selenium is believed to be an analog of sulphur in sulfur containing compounds (Martin, 1971). Since polonium is located in the same chemical grouping as sulfur and selenium the possibility that polonium could also act as an analog was investigated. The plant extracts were chromatographed on a modified Beckman/Spinco Model 120B amino acid analyzer.

MATERIALS AND METHODS:

Greenhouse grown A. osterhouti plants were spiked with 5 μ Ci polonium oxide solution by injecting the soil around the roots with a disposable hypodermic syringe filled with the polonium oxide solution.

The plants were harvested two weeks after spiking and 2 grams of plant tissue were immediately hand homogenized in a homogenizer with 10 ml of 70 percent ethanol to extract the soluble amino acids. The homogenate (extract) was filtered and its volume reduced to 0.5 to 1.0 ml on a hot plate. The pH of the extract was adjusted to 2 with 0.1 N HCl and then 4 ml of sodium citrate buffer (pH 2.2) was added.

One ml of the extract was placed on a 0.9 x 52 cm Aminex A-4 cation exchange resin¹ bed at 52°C. The elution procedure was:

¹ Bio Rad Laboratories, Richmond, California

a flow rate of 60 ml/hr, first citrate buffer at pH 3.22, second citrate buffer at pH 4.25, buffer change at 80 minutes with a ninhydrin flow rate of 30 ml/hr.

Fractions were taken every three minutes for 210 minutes and analyzed for polonium according to Blanchard (1966).

RESULTS AND DISCUSSION:

Figure 21 presents an amino acid chromatograph of A. osterhouti and the radioactive peaks of sulfur-35 added to the plant prior to analysis (Martin and Gerlach, unpublished). Figure 22 presents the amino acid chromatograph of A. osterhouti and the corresponding polonium activity in 3 ml increments. The increase of polonium activity in the 130 to 140 ml eluted region is interesting. But until the resolution is improved in the 130 to 140 ml eluted region and the elution characteristics of polonium known on the resin used, no further inferences can be made about the possible existence of polonium containing amino acids.

III. Publications Supported by Contract AT(11-1)-1733

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APPENDIX A

TABLE IV

ION CONCENTRATION OF NUTRIENT SOLUTIONS
(parts per million)

Nutrient	Complete	-Ca	-S	-P	-N
Calcium (Ca)	200.0	-0-	200.0	301.0	100.0
Magnesium (Mg)	48.6	48.6	12.2	48.6	12.2
Potassium (K)	235.0	626.0	235.0	391.0	782.0
Nitrogen (N)	210.0	210.0	217.0	210.0	-0-
Phosphorus (P)	31.0	31.0	31.0	-0-	31.0
Sulfur (S)	64.2	64.0	-0-	385.0	321.0
Iron (Fe)	5.0	5.0	5.0	5.0	5.0
Manganese (Mn)	.503	.503	.503	.503	.503
Zinc (Zn)	.05	.05	.05	.05	.05
Copper (Cu)	.0203	.0203	.0203	.0203	.0203
Chlorine (Cl)	.648	.648	.648	.648	.648
Boron (B)	.500	.500	.500	.500	.500
Molybdenum (Mo)	.048	.048	.048	.048	.048

TABLE V
²¹⁰Po ADDED TO NUTRIENT STUDY PLANTS

Plant	Nutrient	Total Activity per tray μ Ci		Standard Deviation
Barley	Complete	.228	$\pm$	.0085
	-Ca	.214	$\pm$	.0141
	-S	.222	$\pm$	.0219
	-P	.226	$\pm$	.0064
	-N	<u>.146</u>	$\pm$	<u>.0394</u>
	Mean Activity	.207	$\pm$	.0357
Corn	Complete	.196	$\pm$	.0049
	-Ca	.219	$\pm$	.0056
	-S	.140	$\pm$	.0530
	-P	.220	$\pm$	.0141
	-N	<u>.232</u>	$\pm$	<u>.0064</u>
	Mean Activity	.201	$\pm$	.0394
Radish	Complete	.212	$\pm$	.0170
	-Ca	.223	$\pm$	.0099
	-S	.199	$\pm$	.0156
	-P	.211	$\pm$	.0028
	-N	<u>.210</u>	$\pm$	<u>.0170</u>
	Mean Activity	.211	$\pm$	.02927
Oat	Complete	10.95	$\pm$	.212
	-Ca	13.54	$\pm$	8.153
	-S	12.10	$\pm$	1.273
	-P	20.55	$\pm$	13.081
	-N	<u>10.58</u>	$\pm$	<u>1.167</u>
	Mean Activity	13.54	$\pm$	6.45
Barley, Corn, and Radish		.2064	$\pm$	.03074

TABLE VI
CHEMICAL ANALYSIS OF PERLITE

Silicon dioxide (SiO_2)	73.2%
Aluminum oxide (Al_2O_3)	13.08%
Potassium oxide (K_2O)	4.44%
Sodium oxide (Na_2O)	3.31%
Calcium oxide (CaO)	0.72%
Ferric oxide (Fe_2O_3)	0.89%
Magnesium oxide (MgO)	0.18%
Titanium dioxide (TiO_2)	0.09%
Traces of: Manganese, Chromium, Barium, Lead, Nickel, Copper, Boron, Beryllium, Molybdenum, and Arsenic	

TABLE VIIa

Radish - complete

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.271	51 53	.0702	16.853		
7 24 71	1.271	24 32	.0588	11.380		
7 25 71	2.167	44 43	.0607	57.561		
7 26 71	3.229	62 33	.0527	29.695		
7 28 71	5.292	21 33	.0855	121.66		
7 31 71	8.250	11 43	.1455	482.31		
8 3 71	11.271	41 33	.2895	225.64		
8 7 71	15.167	64 23	.3905	549.17		
8 11 71	18.958	12	.2546	1327.6		
8 11 71	18.958	43	.1863	705.60		
8 14 71	22.271	22	.7838	247.04	2.741	25.58
8 18 71	26.000	53	.4300	294.34	6.199	20.42
8 18 71	26.000	63	.4258	372.42	5.198	30.50
8 21 71	28.979	23	.3758	341.78	5.349	24.01
8 21 71	28.979	21	.3721	333.78	4.070	30.52
8 21 71	28.979	42	.5093	88.339	6.089	7.389
8 26 71	34.250	14	.7843	142.69	5.812	19.25
8 31 71	39.146	52	2.9543	23.329	26.019	2.649
8 31 71	39.146	34	1.5204	146.55	14.237	15.65
8 31 71	39.146		1.2012	192.36	12.627	18.30
9 8 71	47.125	32	1.266	153.49	12.782	15.202
9 8 71	47.125	24	1.691	122.52	14.038	14.755
9 13 71	52.292	51	2.425	67.364	22.187	7.362
9 13 71	52.292	23	1.007	64.179	8.865	7.292

TABLE VIIa
(Continued)

Radish - complete (root)

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
8 11 71	18.958	12	.1005	1818.3		
8 11 71	18.958	43	.3668	172.55		
8 14 71	22.271	11	.3788	380.55	5.367	26.85
8 21 71	28.979	23	.4658	235.69	9.233	11.89
8 21 71	28.979	21	.6788	155.13	12.447	8.460
8 21 71	28.979	42	.1327	238.85	1.691	18.75
8 21 71	28.979	63	.5553	289.72	12.525	12.84
8 21 71	28.979	53	.6293	143.74	16.631	5.439
8 26 71	34.250	14	1.5404	103.84	22.698	7.047
8 31 71	39.146	52	1.0195	200.78	12.781	16.02
8 31 71	39.146	34	2.1927	117.81	22.690	11.39
8 31 71	39.146		1.2666	121.42	18.920	8.129
9 8 71	47.125	32	1.679	126.99	30.619	6.964
9 13 71	52.292	51	2.293	64.445	30.874	4.785
9 13 71	52.292	23	.9302	24.529	10.876	2.098

TABLE VIIb

Radish - calcium

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.271	12 52	.0867	4.749		
7 24 71	1.271	14 53	.0670	53.448		
7 25 71	2.167	51 33	.0773	64.570		
7 26 71	3.229	24 42	.1049	133.09		
7 28 71	5.292	64 33	.0841	153.57		
7 31 71	8.250	44 53	.1162	282.89		
8 3 71	11.271	12 43	.2229	477.69		
8 7 71	15.167	24 33	.2085	711.45		
8 11 71	18.958	42	.0716	503.56		
8 11 71	18.958	63	.1135	573.17		
8 14 71	22.271	21 23	2.120	77.209	.7363	222.36
8 18 71	26.000	53	.0996	766.24	.7386	103.28
8 18 71	26.000	62				
8 21 71	28.979	13 32	.2092	711.94	.4513	330.05
8 21 71	28.979	51	.0886	192.56	.8442	20.20
8 21 71	28.979	12 42	.1584	1169.7	.5149	359.93

TABLE VIIb
(Continued)

Radish - calcium (root)

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
8 11 71	18.958	42	.0345	490.11		
8 11 71	18.958	63	.0914	646.62		
8 21 71	28.979	51	.0768	193.51	.7865	18.91
8 21 71	28.979	32	.0726	401.35	1.080	26.98
8 21 71	28.979	42	.0506	1753.2	.6677	132.89

TABLE VIIIc

Radish - sulfur

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.271	31 43	.0395	96.161		
7 24 71	1.271	34 52	.0379	38.059		
7 25 71	2.167	33	.0186	910.68		
7 26 71	3.229	31 42	.0537	29.308		
7 28 71	5.292	44 42	.0920	190.28		
7 31 71	8.250	24 33	.0951	140.76		
8 3 71	11.271	31 23	.2579	325.00		
8 7 71	15.167	1 33	.3206	496.18		
8 11 71	18.958	33	.2003	676.30		
8 11 71	18.958	62	.0933	400.15		
8 14 71	22.271	42	.1058	243.27	1.097	23.451
8 18 71	26.000	32	.4529	224.03	5.335	19.018
8 18 71	26.000	63	.2814	206.13	3.246	17.872
8 21 71	28.979	34	.2393	475.13	2.714	41.894
8 21 71	28.979	51	.1987	164.33	1.977	16.514
8 26 71	34.250	31	.3385	189.74	2.202	29.17
8 26 71	34.250	23	.3437	199.66	3.132	21.91
8 31 71	39.146	52	.2846	35.602	2.912	3.479
8 31 71	39.146	11	.3215	78.234	4.084	6.159
9 8 71	47.125	61	.4098	126.90	4.229	12.296
9 8 71	47.125	12	.5223	89.268	5.254	8.875
9 13 71	52.292	41	.4961	34.824	5.543	3.117
9 13 71	52.292	24	.3291	115.51	3.661	10.384

TABLE VIIc
(continued)

Radish - sulfur (root)

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
8 11 71	18.958	33	.2493	347.13		
8 11 71	18.958	62	.0861	229.48		
8 14 71	22.271	42	.0912	322.53	1.312	22.635
8 21 71	28.979	34	.5168	215.58	9.436	11.808
8 21 71	28.979	51	.3128	124.49	6.482	6.008
8 21 71	28.979	32	.3960	173.03	8.510	8.050
8 21 71	28.979	63	.4567	99.103	9.925	4.560
8 21 71	28.979	43	.1939	375.74	4.220	17.263
8 26 71	34.250	31	.4583	183.30	6.306	13.32
8 26 71	34.250	23	.6045	384.97	9.581	24.29
8 31 71	39.146	52	.5704	12.012	9.183	.7460
9 8 71	47.125	61	.4403	173.67	4.793	15.954
9 8 71	47.125	12	.7349	117.06	9.135	9.418
9 13 71	52.292	41	.3709	35.934	4.601	2.897
9 13 71	52.292	24	.3632	105.27	6.550	5.838

TABLE VIId

Radish - phosphorus

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.271	63 43	.0678	6.898		
7 24 71	1.271	31 32	.0467	32.565		
7 25 71	2.167	61 22	.0320	59.129		
7 26 71	3.229	31 43	.0595	51.053		
7 28 71	5.292	63 22	.1039	96.746		
7 31 71	8.250	63 42	.1137	53.030		
8 3 71	11.271	31 52	.1238	615.79		
8 7 71	15.167	44 32	.1798	622.92		
8 11 71	18.958	32	.0901	1563.0		
8 11 71	18.958	64	.1839	492.76		
8 14 71	22.271	11 33	.3508	644.10	2.471	91.441
8 18 71	26.000	34	.1434	830.26		
8 21 71	28.979	13	.0830	984.87	.5925	137.90
8 21 71	28.979	23	.0832	1557.7	.5428	238.78
8 21 71	28.979	41	.1331	544.53	1.108	65.40
8 26 71	34.250	42 21	.1640	603.15	1.172	84.37
8 31 71	39.146	14 23	.2702	235.85	2.012	31.67
9 4 71	43.250	22	.0561	1216.4	.5024	135.82
9 4 71	43.250	63	.0886	514.62	.5978	76.26
9 8 71	47.125	62	.4508	40.890	.5184	35.56
9 8 71	47.125	33	.0289	172.20	.2607	19.06
9 13 71	52.292	31	.0519	432.53	.3762	59.66
9 13 71	52.292	43	.0146	274.30	.0901	44.42

TABLE VIId
(Continued)

Radish - phosphorus (root)

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
8 11 71	18.958	32	.0265	1761.8		
8 11 71	18.958	64	.1482	25.622		
8 18 71	26.000	43	.1243	779.97	.9304	104.20
8 21 71	28.979	13	.0352	3050.8	.2663	403.72
8 21 71	28.979	41	.1233	530.52	1.039	62.97
8 21 71	28.979	34	.2294	431.12	3.368	29.37
8 21 71	28.979	43	.0937	514.40	1.194	40.38
8 26 71	34.250	42 21	.2915	601.54	2.246	78.08
9 4 71	43.250	22	.0327	904.30	.1224	241.36
9 4 71	43.250	63	.1886	208.81	1.3829	28.48
9 8 71	47.125	62	.0246	1211.8	.2091	142.28
9 13 71	52.292	31	.0176	413.97	.2023	36.04
9 13 71	52.292	43	.0092	1900.6	.0491	354.95

TABLE VIIe

Radish - nitrogen

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.271	21 33	.0565	4.398		
7 24 71	1.271	54 33	.0479	28.33		
7 25 71	2.167	51 23	.0805	12.19		
7 26 71	3.229	13 32	.1248	26.97		
7 28 71	5.292	21 53 66 43	.1448	50.76		
7 31 71	8.250	12 21 42 52 64	.1675	47.20		
8 3 71	11.271	11 33	.0791	145.7		
8 7 71	15.167	62 43	.0743	219.7		
8 11 71	18.958	53	.0266	61.51		
8 11 71	18.958	63	.0359	342.6		
8 14 71	22.271	44 52 51 23	.1774	138.6	.6413	38.33
8 18 71	26.000	44 41	.0592	1318.5	.1329	587.51
8 18 71	26.000					
8 21 71	28.979	33	.0030	1596.3	.2266	21.3
8 21 71	28.979	31	.0920	73.81	.4997	13.60
8 26 71	34.250	53 11 22 33 44	.1421	376.9	.6194	86.42
8 31 71	39.146	42 43 52 51	.1615	104.5	1.175	14.36
9 4 71	43.250	14	.0316	194.77	.1888	32.59
9 8 71	47.125	34	.0229	149.71	.1615	21.19
9 8 71	47.125	42	.0187	205.26	.0969	39.68
9 13 71	52.292	12	.0233	43.439	.1697	5.975
9 13 71	52.292	53	.0789	138.99	.6005	18.27

TABLE VIIe
(Continued)

Radish - nitrogen (root)

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
8 11 71	18.958	53	.0155	69.03		
8 11 71	18.958	63	.0267	610.4		
8 21 71	28.979	33	.0606	112.6	.8031	8.497
8 26 71	34.250	53 11			.7127	147.05
9 4 71	43.250	32	.0793	322.39	.3908	65.38
9 4 71	43.250	14	.0870	198.49	.2244	76.99
9 8 71	47.125	34	.1605	239.94	1.259	30.59
9 8 71	47.125	42	.0151	772.90	.0733	158.80
9 13 71	52.292	53	.0276	104.37	.2305	12.50

TABLE VIIIa

Barley - complete

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	22 43	.0542	7.860		
7 22 71	1.000	21 32	.0368	23.470		
7 23 71	2.312	13 52	.0409	11.205		
7 25 71	4.208	54 52	.0553	16.508		
7 26 71	5.271	41 53	.0625	45.070		
7 28 71	7.333	13 52	.1080	47.083		
7 31 71	10.292	31 53	.1745	77.164		
8 3 71	13.312	32 54	.4087	158.19		
8 7 71	17.203	11 33	.3168	155.87		
8 11 71	21.000	23 64	.3580	159.90		
8 14 71	24.312	11 53	1.3165	14.737	5.498	3.53
8 18 71	28.042	32 54	.8481	160.21	6.878	19.76
8 21 71	31.021	34	.7631	175.69	3.307	40.55
8 21 71	31.021	33	.8082	52.53	5.010	8.47
8 21 71	31.021	43	.7535	77.49	4.064	14.37
8 21 71	31.021	51	.4858	130.28	2.983	21.21
8 26 71	36.292	44	2.7119	92.30	13.336	18.77
8 31 71	41.187	42	1.2356	86.88	6.236	17.22
8 31 71	41.187	34	1.2488	33.38	5.506	7.67
9 4 71	45.292	14	1.1507	62.362	4.990	14.38
9 4 71	45.292	33	1.2345	66.879	5.686	14.52
9 8 71	49.167	42	.9135	58.440	3.799	14.05
9 8 71	49.167	62	.8748	100.75	3.151	27.97
9 13 71	54.333	23	1.6873	32.665	6.745	8.142
9 13 71	54.333	31	1.2199	69.785	4.714	18.06

TABLE VIIIb

Barley - calcium

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCl) gm Dry wt	Wet Weight	Act. (pCl) gm Wet wt
7 21 71	.167	42 63	.0471	12.189		
7 22 71	1.000	52 61	.0434	21.598		
7 23 71	2.312	14 32	.0458	13.762		
7 25 71	4.208	43 51	.0378	24.378		
7 26 71	5.271	43 63	.0630	12.600		
7 28 71	7.333	42 64	.0600	22.550		
7 31 71	10.292	53 41 44 33	.2180	22.306		
8 3 71	13.312	14 43	.1841	73.206		
8 7 71	17.208	34 42	.1976	109.98		
8 11 71	21.000	43 61	.1970	61.011		
8 14 71	24.312	31 53	.4337	198.06	2.082	41.26
8 18 71	28.042	33 62	.8154	141.86	4.911	23.55
8 21 71	31.021	64	.2351	110.29	1.205	21.52
8 21 71	31.021	22	.5851	102.12	2.430	24.58
8 21 71	31.021	54	.3936	62.387	1.159	21.19
8 21 71	31.021	12	.3602	71.858	1.757	14.74
8 26 71	36.292	34	.7837	106.20	2.181	38.16
8 31 71	41.187	23	.5937	70.626	1.608	26.08
8 31 71	41.187	41	.6833	40.701	2.611	10.65
9 4 71	45.292	24	.4687	38.414	1.139	15.81
9 4 71	45.292	43	.4540	49.964	2.380	9.532
9 8 71	49.167	22	.5864	39.589	3.081	7.535
9 8 71	49.167	62	.6116	49.148	1.847	16.27
9 13 71	54.333	44	.8231	18.833	4.158	3.728
9 13 71	54.333	32	1.0237	36.392	4.198	8.975

TABLE VIIIc

Barley - sulfur

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	24 52	.0407	4.836		
7 22 71	1.000	11 23	.0252	32.460		
7 23 71	2.312	11 43	.0376	13.801		
7 25 71	4.208	42 63	.0468	25.135		
7 26 71	5.271	33 64	.0402	54.611		
7 28 71	7.333	14 43	.0635	36.517		
7 31 71	10.292	23 64	.0931	152.18		
8 3 71	13.312	33 63	.2538	100.63		
8 7 71	17.208	24 42	.2209	208.13		
8 11 71	21.000	43 62	.2218	125.49		
8 14 71	24.312	11 34 52 61	.4990	148.78	2.414	30.75
8 18 71	28.042	32 63	.5787	383.51	3.555	62.43
8 21 71	31.021	41	.3329	150.91	2.152	23.35
8 21 71	31.021	23	.4472	100.97	2.848	15.86
8 21 71	31.021	52	.3290	113.98	1.980	18.93
8 21 71	31.021	21	1.0136	71.867	4.400	16.56
8 26 71	36.292	42 64	1.4401	134.61	8.400	23.08
8 31 71	41.187	53	.6271	65.377	3.969	10.33
8 31 71	41.187	31	.8221	85.725	4.636	15.20
9 4 71	45.292	53	.4629	76.348	2.035	17.37
9 4 71	45.292	13	1.344	95.344	4.874	26.29
9 8 71	49.167	14	.6205	145.90	2.596	34.87
9 8 71	49.167	23	.9181	69.841	5.277	12.15
9 13 71	54.333	32	.8820	36.717	4.559	7.103
9 13 71	54.333	12	.7611	94.958	4.039	17.89

TABLE VIIIId

Barley - phosphorus

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	12 52	.0415	4.726		
7 22 71	1.000	14 23	.0354	34.178		
7 23 71	2.312	41 43	.0422	18.319		
7 25 71	4.208	13 42	.0654	14.841		
7 26 71	5.271	32 44	.0660	44.646		
7 28 71	7.333	13 52	.1004	28.754		
7 31 71	10.292	21 43	.0738	280.84		
8 3 71	13.312	34 42	.1981	95.974		
8 7 71	17.208	62 53	.1742	180.89		
8 11 71	21.000	43 62	.1765	209.74		
8 14 71	24.312	14 33 52 54	.3870	236.12	1.673	54.61
8 18 71	28.042	23 64	.3253	484.91	1.329	118.70
8 21 71	31.021	12 22	.2126	146.49	.976	32.90
8 21 71	31.021	43 54	.1930	177.87	.910	37.72
8 26 71	36.291	32 51	.5999	147.99	2.240	39.63
8 31 71	41.187	13 42	.6944	155.39	2.367	33.85
9 4 71	45.292	53	.1748	122.46	.7078	27.77
9 4 71	45.292	13	.1161	151.92	.2440	72.26
9 8 71	49.167	61	.2169	139.23	.5389	56.05
9 8 71	49.167	33	.0838	168.83	.4291	32.97
9 13 71	54.333	22	.1406	95.757	.5342	25.21
9 13 71	54.333	44	.2160	145.19	.7904	39.67

TABLE VIIIe

Barley - nitrogen

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	34 22	.0461	4.212		
7 22 71	1.000	54 43	.0341	19.276		
7 23 71	2.312	51 53	.0404	13.118		
7 25 71	4.208	54 33	.0477	21.974		
7 26 71	5.271	14 43	.0508	40.389		
7 28 71	7.333	41 43	.0736	38.041		
7 31 71	10.292	13 52	.1023	16.423		
8 3 71	13.312	24 42	.0472	119.90		
8 7 71	17.208	64 33	.0940	59.575		
8 11 71	21.000	63 22	.1304	35.547		
8 14 71	24.312	14 23 42 54	.0560	425.04	.0802	296.90
8 18 71	28.042	12 53 13 33	.1902	774.26	.5050	291.68
8 21 71	31.021	14 32 34 52	.2423	94.407	.7463	30.66
8 26 71	36.291	61 43	.1335	142.84	.1954	97.62
8 31 71	41.187	62 42	.2629	68.915	.8452	21.43
9 4 71	45.292	21 53	.1876	66.647	.4158	30.08
9 8 71	49.167	64 23	.2464	71.245	.5737	34.32
9 13 71	54.333	23	.1319	50.534	.3067	21.72
9 13 71	54.333	51	.0840	79.166	.2273	29.26

TABLE IXa

Oat - complete

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.104	11 62	.0502	11.867		
7 24 71	1.104	14 22	.0390	15.318		
7 25 71	2.000	61 43	.0980	163.10		
7 26 71	3.063	23 43	.0666	331.63		
7 28 71	5.125	64 53	.0877	397.90		
7 31 71	8.083	33 51	.1293	2585.0		
8 3 71	11.104	34 42	.2372	3266.4		
8 7 71	15.000	24 52	.4072	1768.6		
8 11 71	18.792	43 61	.4420	3484.1		
8 14 71	22.104	13 43	.8194	2069.1	4.566	371.44
8 18 71	25.833	64 33	.9731	4438.1	7.304	591.18
8 21 71	28.812	32	.9529	2458.9	7.124	328.89
8 21 71	28.812	12	1.2130	1947.9	8.448	279.71
8 21 71	28.812	53	1.2761	2583.2	8.651	381.0
8 21 71	28.812	61	1.1114	2603.2	7.390	391.47
8 26 71	34.083	34	3.1128	1598.5	18.705	266.03
8 31 71	38.979	52	1.6244	2791.9	9.258	489.85
8 31 71	38.979	21	2.0554	1810.9	12.178	305.63
9 4 71	43.083	31	1.6691	2180.5	8.649	420.79
9 4 71	43.083	22	2.4287	2525.8	12.600	486.86
9 4 71	43.083	43	.6309	2343.2	2.953	500.61
9 8 71	46.958	54	2.1377	2387.7	7.988	638.97
9 8 71	46.958	32	1.7883	2734.0	7.317	668.18
9 13 71	52.125	41	1.8437	2067.9	7.026	542.66
9 13 71	52.125	43	1.4559	1916.1	6.177	451.63

TABLE IXb

Oat - calcium

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.104	11 62	.0671	4.943		
7 24 71	1.104	61 53	.0631	7.401		
7 25 71	2.000	24 53	.0652	21.370		
7 26 71	3.063	41 33	.0565	43.451		
7 28 71	5.125	34 43	.1268	712.17		
7 31 71	8.083	54 32	.1674	509.44		
8 3 71	11.104	41 23	.3258	1206.4		
8 7 71	15.000	62 32	.3642	2783.0		
8 11 71	18.792	65 33	.3102	2599.6		
8 14 71	22.104	12 43	.7510	1584.5	4.141	287.37
8 18 71	25.833	62 52	.8278	3224.1	5.241	509.25
8 21 71	28.812	53	.8244	5773.3	4.790	993.53
8 21 71	28.812	13	.4750	6614.6	2.388	1315.75
8 21 71	28.812	33	.6359	7908.1	3.764	1336.08
8 21 71	28.812	54	.3056	3895.1	1.937	614.35
8 26 71	34.083	64	1.7399	4323.9	7.000	1074.71
8 31 71	38.979	53	1.1403	4356.0	5.289	939.12
8 31 71	38.979	31	1.1762	2693.1	5.582	567.54
9 4 71	43.083	34	.7815	10478.	3.421	2393.66
9 4 71	43.083	52	1.0212	4168.4	4.279	994.81
9 4 71	43.083	31	.9944	8192.8	3.655	2228.86
9 8 71	46.958	44	1.1452	8373.5	3.932	2438.84
9 8 71	46.958	32	.9001	6173.9	3.448	1611.72
9 13 71	52.125	11	.9501	6998.5	2.561	2596.25
9 13 71	52.125	32	1.130	7137.6	3.916	2060.42

TABLE IXc

Oat - sulfur

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.104	14 41	.0559	13.909		
7 24 71	1.104	11 33	.0526	10.017		
7 25 71	2.000	22 24	.0322	25.509		
7 26 71	3.063	21 53	.0462	46.561		
7 28 71	5.125	54 33	.0544	265.78		
7 31 71	8.083	44 42	.1347	352.74		
8 3 71	11.104	64 22	.2325	3038.2		
8 7 71	15.000	51 42	.2319	3015.7		
8 11 71	18.792	61 33	.3142	18.561		
8 14 71	22.104	51 23	.8757	2799.5	4.994	490.99
8 18 71	25.833	62 53	1.0064	1994.6	6.454	311.12
8 21 71	28.812	53	.2182	1971.9	1.626	264.58
8 21 71	28.812	52	.8783	1753.0	5.393	285.50
8 21 71	28.812	44	.3313	3316.5	2.322	473.13
8 21 71	28.812	13	.8886	2978.1	4.706	562.32
8 26 71	34.083	34 61	1.2815	1710.1	6.466	338.91
8 31 71	38.979	43	1.0230	2718.7	6.170	450.76
8 31 71	38.979	63	1.0132	2755.0	5.214	535.33
9 4 71	43.083	24 43	2.2972	2041.7	11.750	399.15
9 4 71	43.083	21	1.0984	1507.6	5.150	321.53
9 4 71	43.083	43	.5369	1660.7	2.790	319.55
9 8 71	46.958	32	1.5260	919.57	6.760	207.59
9 8 71	46.958	63	.9166	2031.5	3.610	515.79
9 13 71	52.125	64	1.321	2087.1	4.830	570.99
9 13 71	52.125	33	1.073	1687.6	5.004	361.77

TABLE IXd

Oat - phosphorus

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.104	41 32	.0573	1.660		
7 24 71	1.104	44 32	.0651	6.286		
7 25 71	2.000	44 22	.0618	18.227		
7 26 71	3.063	62 42	.0935	30.274		
7 28 71	5.125	21 53	.1045	131.62		
7 31 71	8.083	31 43	.1430	346.96		
8 3 71	11.104	42 54	.1832	1375.1		
8 7 71	15.000	11 33	.2800	5855.8		
8 11 71	16.792	61 42	.1206	7692.3		
8 14 71	22.104	13 52	.4123	4753.8	1.555	1260.58
8 18 71	25.833	66 43	.2596	4418.0	1.093	1049.31
8 21 71	28.812	11 33	.4713	20298.	2.383	4014.23
8 21 71	28.812	53 14	.4223	4171.8	1.984	887.95
8 26 71	34.083	31 52	.6151	11554.	2.626	2706.59
8 31 71	38.979	51 23	.7991	10295.	3.384	2431.12
9 4 71	43.083	32	.2522	5076.4	.9972	1283.89
9 4 71	43.083	62	.4818	6480.3	2.703	1155.05
9 8 71	46.958	61	.3745	12232.	1.119	4093.57
9 8 71	46.958	43	.1770	6287.8	.5209	2136.30
9 13 71	52.125	12	.3535	9024.2	1.147	2780.99
9 13 71	52.125	52	.5168	6135.8	1.926	1646.42

TABLE IXc

Oat - nitrogen

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 23 71	.104	21 42	.0446	42.944		
7 24 71	1.104	12 53	.0430	4.456		
7 25 71	2.000	14 42				
7 26 71	3.063	61 52	.0349	74.118		
7 28 71	5.125	41 23	.0819	48.134		
7 31 71	8.083	44 42	.0681	161.08		
8 3 71	11.104	31 53	.1210	149.73		
8 7 71	15.000	14 33	.1021	590.13		
8 11 71	18.792	62 32	.2019	331.56		
8 14 71	22.104	34 42	.1938	725.57	.665	211.44
8 18 71	25.833	54 22	.1845	396.06	.654	111.70
8 21 71	28.812	11 34 23 52	.4841	530.99	1.891	135.94
8 26 71	34.083	44 22	.5795	1288.3	1.841	405.51
8 31 71	38.979	12 53	.3260	877.14	1.240	230.59
9 4 71	43.083	51	.1485	4440.0	.4265	1545.72
9 4 71	43.083	33	.1021	117.78	.2002	60.05
9 8 71	46.958	21 43	.2254	440.30	.4942	200.85
9 13 71	52.125	31	.2316	2260.5	.6829	766.60
9 13 71	52.125	23	.1617	3480.6	.4341	1296.84

TABLE Xa

Corn - complete

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	14 32	.2090	1.641		
7 22 71	1.000	31 33	.1282	7.893		
7 23 71	2.312	51 53	.2604	2.871		
7 25 71	4.208	64 43	.2101	8.701		
7 26 71	5.271	41 42	.2302	9.552		
7 28 71	7.333	31 53	.2142	13.873		
7 31 71	10.292	23 42	.5865	11.989		
8 3 71	13.312	63 52	.9181	15.588		
8 7 71	17.208	41 33	1.4077	16.325		
8 11 71	21.000	31	.4187	36.153		
8 11 71	21.000	52	.5174	15.094		
8 14 71	24.312	63 43	2.6187	8.624	17.766	1.271
8 18 71	28.042	54 33	2.5460	7.555	22.480	.8556
8 21 71	31.021	51	2.6754	14.102	19.077	1.978
8 21 71	31.021	14	2.5572	35.215	18.216	4.943
8 21 71	31.021	43	1.2944	8.584	11.092	1.002
8 21 71	31.021	32	1.7818	9.610	12.875	1.330
8 26 71	36.292	52	1.3578	11.546	12.048	1.297
8 26 71	36.292	21	6.1833	16.842	38.011	2.740
8 31 71	41.187	44	6.7293	1.986	44.604	.2996
8 31 71	41.187	32	6.9372	10.425	54.636	1.324
9 8 71	49.167	22	6.403	13.178	42.429	1.989
9 8 71	49.167	13	8.057	11.419	51.137	1.799
9 13 71	54.333	14	9.190	14.315	56.362	2.334
9 13 71	54.333	53	17.966	9.924	90.932	1.961

TABLE Xb

Corn - calcium

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	13 42	.1913	18.164		
7 22 71	1.000	11 53	.1747	6.012		
7 23 71	2.312	31 42	.2056	2.019		
7 25 71	4.208	12 23	.2726	5.724		
7 26 71	5.271	41 53	.2126	7.456		
7 28 71	7.333	54 33	.2329	10.964		
7 31 71	10.292	13 22	.4538	19.127		
8 3 71	13.312	61 53	1.1545	15.005		
8 7 71	17.208	63 23	.9852	17.606		
8 11 71	21.000	62 33	1.4833	13.522		
8 14 71	24.312	41 32	2.9977	19.437	20.570	2.833
8 18 71	28.042	64 53	2.4750	12.243	20.168	1.503
8 21 71	31.021	21	2.1802	25.215	20.826	2.640
8 21 71	31.021	43	4.9213	17.765	36.480	2.397
8 26 71	36.292	52	5.1008	11.249	36.662	1.565
8 26 71	36.292	11	3.4200	2.627	25.633	.3504
8 31 71	41.187	42	7.1235	4.289	54.584	.5597
8 31 71	41.187	24	7.4574	18.682	50.838	2.740
9 8 71	49.167	31	7.7938	8.9154	66.933	1.038
9 8 71	49.167	13	4.0267	13.190	33.769	1.573
9 13 71	54.333	32	5.6402	13.289	46.287	1.619
9 13 71	54.333	54	9.7516	9.2015	71.178	1.261

TABLE Xc

Corn - sulfur

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	11 43	.1468	24.341		
7 22 71	1.000	44 52	.1745	6.182		
7 23 71	2.312	62 33	.1576	5.499		
7 25 71	4.208	31 54	.2296	5.660		
7 26 71	5.271	12 32	.2563	25.968		
7 28 71	7.333	61 43	.3935	14.172		
7 31 71	10.292	51 43	.3893	20.833		
8 3 71	13.312					
8 7 71	17.208	21 33	.7617	49.629		
8 11 71	21.000	62 32	1.2839	35.352		
8 14 71	24.312	44 42	1.3282	18.715	9.608	2.587
8 18 71	28.042	54 44	1.4567	24.876	11.254	3.220
8 21 71	31.021	12	.5642	55.659	4.019	7.813
8 21 71	31.021	33	.9993	32.432	7.901	4.102
8 26 71	36.292	31	1.5920	29.655	11.752	4.017
8 31 71	41.187	53	4.3201	4.695	29.565	.6860
8 31 71	41.187	41	3.9450	16.882	28.254	2.357
9 8 71	49.167	32	1.6456	18.675	12.646	2.430
9 8 71	49.167	61	1.8375	17.741	13.092	2.490
9 13 71	54.333	24	3.8538	28.532	23.935	4.594
9 13 71	54.333	51	2.9935	20.446	18.660	3.280

TABLE Xd

Corn - phosphorus

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	12 32	.2254	2.636		
7 22 71	1.000	24 43	.0814	4.016		
7 23 71	2.312	41 33	.2629	1.715		
7 25 71	4.208	61 23	.3008	7.341		
7 26 71	5.271	63 43	.2249	11.411		
7 28 71	7.333	31 33	.3518	22.079		
7 31 71	10.292	61 43	.2395	15.328		
8 3 71	13.312	41 23				
8 7 71	17.208	34 42	1.0538	37.733		
8 11 71	21.000	63 32	.9745	46.467		
8 14 71	24.312	42 51	.4718	24.750	3.255	3.587
8 18 71	28.042	41 34	.6177	42.074	4.291	6.057
8 21 71	31.021	12	.8590	89.232	5.547	13.82
8 21 71	31.021	23	.3033	114.88	2.672	13.04
8 26 71	36.292	14 52	1.6907	162.08	8.433	32.49
8 31 71	41.187	54	1.3432	52.194	7.768	9.025
8 31 71	41.187	31	1.3574	79.345	7.482	14.39
9 8 71	49.167	51	.9122	59.872	4.144	13.179
9 8 71	49.167	42	.3081	177.02	1.184	46.07
9 13 71	54.333	33	.3008	141.72	1.261	33.81
9 13 71	54.333	62	1.6426	44.539	7.163	10.21

TABLE Xe

Corn - nitrogen

Date Collected	Days since Spike	Location of Plants	Dry Weight	Act. (pCi) gm Dry wt	Wet Weight	Act. (pCi) gm Wet wt
7 21 71	.167	52 63	.2631	.972		
7 22 71	1.000	14 33	.2424	2.854		
7 23 71	2.312	32 24	.1434	4.983		
7 25 71	4.208	31 42	.2533	5.440		
7 26 71	5.271	13 23	.3928	8.360		
7 28 71	7.333	64 52	.3953	5.881		
7 31 71	10.292	11 43	.2298	9.527		
8 3 71	13.312	24 32	.6468	14.299		
8 7 71	17.208	62 43	.5005	14.798		
8 11 71	21.000	63 23	.3858	19.299		
8 14 71	24.312	11 42	.4652	25.858	1.939	6.204
8 18 71	28.042	31 32	.6182	29.057	2.860	6.281
8 21 71	31.021	21	.2368	37.944	1.145	7.847
8 21 71	31.021	33	.3008	28.572	1.448	5.936
8 26 71	36.292	64 22	.6778	36.948	3.180	7.875
8 31 71	41.187	34 52	.6049	23.590	2.883	4.950
9 8 71	49.167	43	.1096	41.622	.4708	9.691
9 8 71	49.167	62	.4463	36.830	1.842	8.925
9 13 71	54.333	33	.4760	27.428	1.828	7.142
9 13 71	54.333	51	.9332	28.875	3.497	7.706

TABLE XI
SWINGING BUCKET ORGANELLE SEPARATION RESULTS

Sample Fraction	Activity in pCi
Nuclei	.816
Nuclei filtrate	1.01
45-60% chloroplast layer	.70
20-45% chloroplast layer	.17
20-45% chloroplast layer filtrate	23.37
Mitochondria	8.48
Microsomes	8.14
Cell wall	7.84
Soluble fraction $S \leq 80$	197.36

TABLE XII

METHODOLOGY SUMMARY FOR THE ULTRACENTRIFUGE EXPERIMENTS

Run #	Rotor	Gradient Range (% sucrose)	ω^2	Sample Volume (in ml)	Overlay (in ml)
4	A-12	10 - 45	$\sim 11.8 \times 10^7$	50	200
5	A-12	10 - 45	$\sim 11.8 \times 10^7$	50	200
6	B-15	10 - 50	3.495×10^{10}	70	100
7	B-15	10 - 35	4.7374×10^{11}	70	100
8	B-15	10 - 30	112885×10^7	70	100
9	B-15	10 - 30	13159×10^7	50	100
10	B-15	10 - 30	44890×10^7	50	100
11	A-12	10 - 45	$\sim 69 \times 10^7$	50	200

TABLE XIII

Run #6	$w^2t = 3.495 \times 10^{10}$	Gradient 10 - 50%	Rotor B-15	Cut Volume 40 ml					
Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.75
2.5	9.40	1.0381	52.0	39.4	36.5	35.1	34.4	33.9	33.4
3.5	11.75	1.0480	168.	118.	107.	103.	100.	98.4	96.8
4.5	14.80	1.0612	312.	198.	177.	168.	163.	160.	157.
5.5	17.10	1.0713	496.	279.	245.	231.	224.	219.	214.
6.5	18.40	1.0771	709.	358.	310.	291.	281.	274.	268.
7.5	20.00	1.0843	1010.	438.	374.	349.	336.	328.	320.
8.5	21.70	1.0921	1580.	522.	439.	408.	391.	381.	371.
9.5	23.80	1.1018		615.	509.	469.	448.	435.	423.
10.5	25.20	1.1084		714.	579.	531.	506.	490.	476.
11.5	27.00	1.1170		825.	655.	596.	566.	547.	530.
12.5	28.60	1.1246		950.	735.	664.	628.	607.	587.
13.5	30.00	1.1315		1090.	821.	735.	693.	668.	645.
14.5	31.00	1.1364		1240.	909.	808.	759.	730.	703.
15.5	32.30	1.1428		1410.	1000.	885.	828.	794.	764.
16.5	33.30	1.1478		1610.	1100.	964.	898.	860.	826.
17.5	34.20	1.1523		1820.	1200.	1040.	971.	928.	889.
18.5	34.80	1.1553		2043.	1310.	1130.	1040.	995.	951.
19.5	35.70	1.1599		2300.	1420.	1210.	1120.	1060.	1020.
20.5	36.20	1.1624		2570.	1530.	1300.	1190.	1130.	1080.
21.5	37.00	1.1665		2880.	1640.	1390.	1270.	1210.	1150.
22.5	38.00	1.1717		3260.	1770.	1480.	1350.	1280.	1220.
23.5	39.40	1.1789		3810.	1910.	1580.	1440.	1360.	1300.
24.5	40.60	1.1852		4660.	2080.	1700.	1540.	1450.	1380.
25.5	42.20	1.1937		6860.	2270.	1840.	1650.	1560.	1470.
26.5	43.40	1.2001			2500.	1990.	1780.	1670.	1570.
27.5	45.10	1.2092			2790.	2170.	1930.	1800.	1690.

TABLE XIII
(Continued)

Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.75
28.5	46.60	1.2174			3150.	2390.	2100.	1960.	1830.
29.5	48.10	1.2256			3600.	2650.	2310.	2140.	1990.
30.5	49.20	1.2317			4100.	2910.	2520.	2320.	2160.
31.5	51.00	1.2417			4870.	3290.	2810.	2570.	2380.
32.5	50.60	1.2395			5550.	3630.	3070.	2800.	2580.
33.5	51.35	1.2437			6350.	4020.	3370.	3050.	2800.
34.5	51.20	1.2428			7110.	4380.	3650.	3290.	3010.
35.5	51.30	1.2434			7870.	4750.	3930.	3540.	3220.
36.5	51.20	1.2428			8610.	5100.	4200.	3770.	3430.
37.5	51.60	1.2451			9420.	5490.	4490.	4020.	3650.
38.5	51.60	1.2451			10230.	5870.	4780.	4270.	3870.
39.5	51.60	1.2451			11000.	6260.	5070.	4520.	4090.

TABLE XIV

Run #7	$\omega^2 t = 4.7374 \times 10^{11}$	Gradient 10 - 35%	Rotor B-15	Cut Volume 40 ml					
Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.75
3.5	8.30	1.0336	3.55	2.81	2.62	2.54	2.49	2.46	2.67
4.5	10.60	1.0432	9.73	7.25	6.68	6.43	6.28	6.19	6.63
5.5	12.30	1.0504	16.13	11.49	10.48	10.04	9.79	9.63	10.19
6.5	13.50	1.0555	22.75	15.50	14.03	13.39	13.03	12.81	13.51
7.5	14.90	1.0616	29.91	19.44	17.44	16.59	16.12	15.82	16.63
8.5	16.05	1.0666	37.59	23.29	20.74	19.66	19.07	18.70	19.59
9.5	17.20	1.0717	46.46	27.12	23.96	22.64	21.93	21.47	22.43
10.5	18.20	1.0762	56.44	30.93	27.10	25.54	24.69	24.15	25.19
11.5	19.30	1.0811	68.68	34.77	30.23	28.40	27.40	26.78	27.87
12.5	20.20	1.0852	83.82	38.64	33.32	31.20	30.06	29.35	30.48
13.5	21.10	1.0893	104.27	42.55	36.39	33.97	32.68	31.88	33.06
14.5	22.10	1.0939	139.71	46.57	39.48	36.75	35.29	34.39	35.61
15.5	23.00	1.0981	251.05	50.69	42.60	39.52	37.90	36.89	38.16
16.5	24.00	1.1028		55.00	45.77	42.33	40.52	39.40	40.68
17.5	24.70	1.1060		59.39	48.95	45.12	43.12	41.89	43.17
18.5	25.40	1.1093		63.88	52.15	47.91	45.71	44.37	45.66
19.5	26.20	1.1131		68.56	55.40	50.73	48.32	46.85	48.13
20.5	26.80	1.1160		73.33	58.66	53.54	50.92	49.33	50.58
21.5	27.40	1.1189		78.24	61.94	56.36	53.52	51.79	53.06
22.5	28.20	1.1227		83.41	65.32	59.23	56.15	54.29	55.53
23.5	28.80	1.1256		88.77	68.73	62.12	58.80	56.80	57.99
24.5	29.30	1.1280		94.26	72.17	65.02	61.44	59.29	60.44
25.5	29.80	1.1305		99.92	75.64	67.92	64.09	61.79	62.91
26.5	30.40	1.1334		105.84	79.18	70.86	66.76	64.31	65.36
27.5	30.80	1.1354		111.88	82.73	73.80	69.43	66.82	67.91
28.5	30.80	1.1354		118.26	86.36	76.79	72.13	69.36	70.42

TABLE XIV
(Continued)

Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.75
29.5	31.80	1.1403		124.80	90.02	79.79	74.83	71.89	72.92
30.5	32.00	1.1413		130.66	93.26	82.44	77.21	74.13	75.19
31.5	32.40	1.1433		137.20	96.80	85.31	79.80	76.55	77.61
32.5	33.00	1.1463		144.23	100.48	88.28	82.45	79.03	80.05
33.5	33.20	1.1473		151.36	104.16	91.24	85.10	81.51	82.49
34.5	33.60	1.1493		158.85	107.93	94.26	87.80	84.02	84.96
35.5	33.80	1.1503		166.50	111.73	97.29	90.50	86.54	87.42
36.5	34.20	1.1523		174.63	115.66	100.41	93.27	89.13	89.94
37.5	34.30	1.1528		182.85	119.60	103.53	96.06	91.71	92.50
38.5	34.70	1.1548		191.70	123.72	106.78	98.93	94.39	95.32
39.5	35.00	1.1563		201.13	128.00	110.14	101.91	97.16	
40.5	36.10	1.1619		213.12	132.95	113.96	105.27	100.27	

TABLE XV

Run #8	$\omega^2 t = 1.129 \times 10^{12}$	Gradient 10 - 30%	Rotor B-15	Cut Volume 40 ml					
Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.7
3.5	5.40	1.0217	1.15	.999	.957	.938	.926	.919	.913
4.5	7.10	1.0286	2.98	2.51	2.38	2.33	2.29	2.27	2.26
5.5	9.00	1.0365	4.85	3.95	3.72	3.62	3.56	3.52	3.49
6.5	11.00	1.0449	6.87	5.38	5.02	4.86	4.77	4.71	4.66
7.5	12.60	1.0517	9.05	6.78	6.27	6.05	5.92	5.84	5.78
8.5	13.25	1.0545	11.18	8.11	7.45	7.16	7.00	6.89	6.82
9.5	15.00	1.0620	13.68	9.47	8.63	8.26	8.06	7.93	7.84
10.5	15.90	1.0660	16.33	10.80	9.77	9.33	9.09	8.93	8.82
11.5	16.90	1.0704	19.26	12.13	10.89	10.37	10.08	9.90	9.78
12.5	17.80	1.0744	22.55	13.46	12.00	11.39	11.06	10.85	10.70
13.5	18.50	1.0775	26.16	14.77	13.08	12.38	12.00	11.76	11.60
14.5	19.30	1.0811	30.34	16.08	14.14	13.36	12.93	12.66	12.48
15.5	20.10	1.0848	35.41	17.41	15.21	14.32	13.85	13.55	13.34
16.5	21.00	1.0889	42.25	18.77	16.28	15.29	14.76	14.43	14.20
17.5	21.60	1.0916	51.13	20.13	17.33	16.24	15.66	15.29	15.04
18.5	22.20	1.0944	64.11	21.50	18.38	17.18	16.54	16.14	15.87
19.5	23.00	1.0981	102.07	22.90	19.45	18.13	17.43	17.00	16.70
20.5	23.40	1.1000	1680.30	24.30	20.49	19.06	18.30	17.83	17.51
21.5	24.10	1.1032		25.74	21.55	19.99	19.17	18.66	18.32
22.5	24.80	1.1065		27.22	22.62	20.93	20.04	19.50	19.13
23.5	25.20	1.1084		28.70	23.68	21.85	20.91	20.32	19.93
24.5	25.80	1.1112		30.22	24.75	22.78	21.77	21.15	20.73
25.5	26.40	1.1141		31.79	25.83	23.72	22.64	21.97	21.53
26.5	26.70	1.1155		33.35	26.90	24.65	23.49	22.79	22.31
27.5	27.20	1.1179		34.95	27.98	25.58	24.35	23.60	23.10
28.5	27.80	1.1208		36.62	29.08	26.51	25.21	24.42	23.89

TABLE XV
(Continued)

Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.7
29.5	28.20	1.1227		38.31	50.18	27.45	26.07	25.24	24.68
30.5	28.60	1.1246		39.85	31.17	28.29	26.84	25.97	25.38
31.5	28.90	1.1261		41.53	32.24	29.19	27.67	26.75	26.13
32.5	29.20	1.1276		43.23	33.31	30.10	28.49	27.53	26.88
33.5	29.60	1.1295		45.00	34.40	31.01	29.33	28.32	27.64
34.5	29.90	1.1310		46.80	35.51	31.94	30.17	29.11	28.40
35.5	30.40	1.1334		48.71	36.64	32.88	31.03	29.92	29.18
36.5	30.70	1.1349		50.67	37.80	33.84	31.90	30.74	29.97
37.5	31.20	1.1373		52.77	39.01	34.84	32.80	31.59	30.78
38.5	31.70	1.1398		55.03	40.28	35.88	33.74	32.47	31.63
39.5	32.30	1.1428		57.53	41.64	36.99	34.73	33.40	32.52

XVI

Run #9 $\omega^2 t = 1.316 \times 10^{11}$ Gradient 10 - 30% Rotor B-15 Cut Volume 40 ml

Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.7
3.5	9.80	1.0398	21.35	15.90	14.64	14.08	13.77	13.56	13.42
4.5	12.60	1.0517	49.59	34.15	30.94	29.55	28.77	28.28	27.94
5.5	14.20	1.0586	79.52	51.53	46.17	43.89	42.63	41.82	41.27
6.5	14.90	1.0616	108.54	67.49	60.03	56.89	55.15	54.06	53.30
7.5	15.80	1.0655	138.35	82.63	73.01	69.00	66.81	65.42	64.46
8.5	16.50	1.0686	168.70	97.00	85.21	80.34	77.68	76.01	74.85
9.5	17.60	1.0735	202.99	111.23	97.10	91.32	88.18	86.20	84.84
10.5	18.60	1.0780	242.56	125.38	108.73	102.00	98.35	96.07	94.50
11.5	19.60	1.0825	290.71	139.59	120.21	112.47	108.30	105.69	103.90
12.5	20.20	1.0852	345.22	153.50	131.33	122.57	117.87	114.94	112.93
13.5	20.80	1.0880	409.52	167.20	142.15	132.36	127.13	123.88	121.65
14.5	21.50	1.0912	494.63	180.90	152.82	141.97	136.20	132.61	130.17
15.5	21.90	1.0930	597.91	194.28	163.17	151.26	144.94	141.03	138.37
16.5	22.80	1.0972	850.09	208.05	173.61	160.57	153.69	149.43	146.54
17.5	23.50	1.1004		222.04	184.05	169.83	162.36	157.75	154.62
18.5	24.20	1.1037		236.30	194.52	179.06	170.98	166.00	162.63
19.5	24.70	1.1060		250.62	204.89	188.17	179.47	174.13	170.51
20.5	25.20	1.1084		265.04	215.20	197.19	187.85	182.14	178.28
21.5	25.70	1.1107		279.61	225.47	206.1	196.16	190.06	185.95
22.5	26.20	1.1131		294.36	235.73	215.03	204.40	197.91	193.54
23.5	26.70	1.1155		309.36	246.01	223.90	212.59	205.71	201.08
24.5	27.30	1.1184		324.83	256.40	232.83	220.82	213.53	208.63
25.5	27.60	1.1198		340.27	266.68	241.63	228.92	221.22	216.05
26.5	28.30	1.1232		356.49	277.21	250.59	237.14	229.01	223.56
27.5	28.40	1.1237		372.35	287.48	259.31	245.14	236.59	230.87
28.5	28.60	1.1246		388.08	297.59	267.88	252.99	244.02	238.03

TABLE XVI
(Continued)

Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.7
29.5	29.10	1.1271		404.31	307.82	276.51	260.88	251.49	245.22
30.5	29.30	1.1280		418.76	316.87	284.12	267.83	258.05	251.54
31.5	30.00	1.1315		435.40	326.99	292.58	275.52	265.32	258.51
32.5	30.10	1.1319		451.89	336.98	300.92	283.11	272.47	265.38
33.5	30.20	1.1324		468.28	346.86	309.16	290.60	279.53	272.17
34.5	30.40	1.1334		484.85	356.76	317.40	298.08	286.58	278.94
35.5	30.90	1.1359		502.37	367.00	325.87	305.76	293.80	285.87

TABLE XVII

Run #10	$\omega^2t = 4.489 \times 10^{11}$	Gradient 10 - 30%	Rotor B-15	Cut Volume 40 ml					
Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.7
3.5	8.30	1.0336	5.38	4.26	3.98	3.85	3.78	3.73	3.70
4.5	12.00	1.0491	13.06	9.39	8.60	8.25	8.05	7.93	7.84
5.5	13.80	1.0568	21.35	14.35	12.96	12.36	12.03	11.82	11.68
6.5	15.00	1.0620	29.99	19.06	17.05	16.19	15.72	15.43	15.22
7.5	16.10	1.0669	39.19	23.60	20.92	19.81	19.19	18.81	18.54
8.5	17.00	1.0708	48.98	27.98	24.61	23.23	22.47	21.99	21.66
9.5	17.80	1.0744	59.47	32.22	28.14	26.48	25.58	25.01	24.62
10.5	18.60	1.0780	71.07	36.37	31.55	29.61	28.56	27.90	27.45
11.5	19.10	1.0802	83.28	40.36	34.81	32.59	31.40	30.65	30.14
12.5	19.80	1.0834	97.25	44.30	37.98	35.48	34.14	33.30	32.73
13.5	20.30	1.0857	112.72	48.14	41.04	38.26	36.77	35.85	35.21
14.5	21.00	1.0889	132.05	51.98	44.06	40.99	39.35	38.33	37.64
15.5	21.50	1.0912	155.55	55.76	47.01	43.64	41.85	40.74	39.99
16.5	22.20	1.0944	191.76	59.57	49.94	46.27	44.32	43.12	42.30
17.5	22.80	1.0972	261.86	63.40	52.84	48.85	46.75	45.46	44.57
18.5	23.80	1.1018		67.42	55.82	51.49	49.22	47.82	46.87
19.5	24.00	1.1028		71.32	58.70	54.03	51.59	50.09	49.08
20.5	24.50	1.1051		75.25	61.56	56.55	53.94	52.34	51.26
21.5	24.80	1.1065		79.13	64.36	59.01	56.23	54.53	53.38
22.5	25.60	1.1103		83.18	67.23	61.51	58.55	56.74	55.53
23.5	26.00	1.1122		87.25	70.07	63.98	60.84	58.93	57.64
24.5	26.40	1.1141		91.34	72.90	66.42	63.10	61.08	59.72
25.5	26.60	1.1150		95.37	75.66	68.82	65.32	63.19	61.76
26.5	27.00	1.1170		99.44	78.43	71.19	67.51	65.28	63.78
27.5	27.40	1.1189		103.56	81.19	73.56	69.69	67.35	65.78
28.5	28.00	1.1218		107.84	84.00	75.96	71.90	69.44	67.79

TABLE XVII
(Continued)

Cut #	% Sucrose	Density	Sedimentation Coefficients at indicated particle densities						
			1.1	1.2	1.3	1.4	1.5	1.6	1.7
29.5	28.60	1.1246		112.31	86.87	78.39	74.13	71.55	69.83
30.5	29.40	1.1285		116.60	89.54	80.64	76.18	73.49	71.69
31.5	29.80	1.1305		121.35	92.46	83.08	78.40	75.59	73.71
32.5	30.00	1.1315		126.12	95.36	85.51	80.61	77.67	75.71
33.5	30.30	1.1329		130.99	98.28	87.94	82.82	79.75	77.71
34.5	30.60	1.1344		135.98	101.24	90.40	85.05	81.85	79.73
35.5	30.80	1.1354		141.05	104.21	92.86	87.28	83.95	81.74
36.5	31.10	1.1369		146.28	107.24	95.36	89.54	86.08	83.78
37.5	31.40	1.1383		151.72	110.35	97.91	91.85	88.25	85.86
38.5	31.60	1.1393		157.32	113.51	100.51	94.19	90.45	87.97
39.5	32.40	1.1433		163.68	116.95	103.31	96.71	92.80	90.22
40.5	33.50	1.1488		171.45	120.89	106.46	99.52	95.43	92.73

APPENDIX B

Figure 3. Sealed V-1 tray. Bottom of V-1 trays with silicone Rubber Bathtub Caulk sealing the drain holes. The polyethylene rope used to mark off the radioactive area of the greenhouse bench is also visible.

Figure 4. Addition of PoO_2 solution to V-1 trays. Waterproof adhesive tape was also used to prevent leakage of the $^{210}\text{PoO}_2$ solution which is being added from a 1000 ml volumetric flask. Also, note the planchets that contain 1 ml samples of the spike solution.

Figure 5. Distribution of polonium oxide solution. After the polonium oxide solution was added to the tray, the tray was tipped slightly to ensure equal distribution of the solution between the two halves of the tray.

Figure 6. Placing the plants in groups of six into the spike solution.

Figure 7. Plant arrangement in greenhouse.

This photograph was taken twenty-two days after planting and eight after spiking. From left to right are the control plants (given complete nutrient media), calcium deficient, sulfur deficient, phosphorus deficient and nitrogen deficient. The arrangement of the plants within each nutrient group is

Windows		
Radish	Oat	Barley
—	—	Corn

Figure 8. Radish and corn nutrient deficient symptoms. Thirty-four days after spiking the control or complete nutrient radish plants were mature. The effects of the various nutrient deficiencies upon growth can be seen. The root system of the nitrogen deficient corn was over 45 cm long and spread uniformly in the bottom of the V-1 tray.

Figure 9. Uptake Dynamics of Polonium Oxide in Radish.

The solid dots represent activity in pCi/gram dry weight and the open circles represent total activity in the plant. From the tenth day forward the activity per gram dry weight appears to be significantly higher. The negative slope that develops after the thirtieth correlates with the atrophying phosphorous deficient plants.

Figure 10. Uptake Dynamics of Polonium Oxide in Oats.

The solid dots represent activity in pCi/gram dry weight and the open circles represent total activity in the plant. The activity per gram dry weight levels out at a higher level in the phosphorous deficient plants. The decreased rate of uptake in the nitrogen deficient plants can be explained by the fact that the lower older leaves died and dropped off as the plant matured.

Figure 11. Uptake Dynamics of Polonium Oxide in Barley.

The solid dots represent activity in pCi/gm dry weight and the open circles represent the total activity in the plant. The phosphorous effect as previously described does not appear to be significant, however, the decreased uptake rate in the nitrogen deficient plants is evident.

Figure 12. Uptake Dynamics of Polonium Oxide in Corn.

The solid dots represent activity in pCi/gm dry weight and the open circles represent the total activity in the plant. The phosphorous effect as previously described is significant in corn and also the decreased uptake rate of the nitrogen deficient plants.

Figure 13. A-12 Zonal Rotor and Loading.

- a) Photograph of an A-12 rotor at a speed of 500 RPM just after the sample has been added and before the overlay.

- b) The sample has been pushed by overlay to 8 cm from the center of the rotor, the sample starting zone yielding an initial sample width of 1 cm.

- c) The appearance of a sample in an A-12 rotor after centrifugation. The illustrated sample shows poor separation due to high pH. Note the presence of chlorophyll in the starting zone left there from broken chloroplasts that have since moved.

Figure 14. Sugar beet leaf organelle separation in A-12 rotor. ($\omega^2 t = 1.18 \times 10^8$). The linear with radius gradient ranged from 10 to 45 percent ω/ω sucrose and the $\omega^2 t$ for the centrifuge run was approximately 11.8×10^7 . See Figure 13c for photograph of run just prior to unloading.

Figure 15. Sugar beet root organelle separation in A-12 rotor. ($\omega^2 t = 1.18 \times 10^8$). The linear with radius gradient ranged from 10 to 45 percent ω/ω sucrose and the approximate $\omega^2 t$ value for the centrifuge run was 11.8×10^7 . The apparent blending from fraction 5 to 25 is probably due to ununiform sedimentation of the larger organelles that have been broken.

Figure 16. Sugar beet leaf organelle separation in B-15 rotor (run #6). ($\omega^2 t = 3.5 \times 10^{10}$). Note the isopycnic banding of chloroplasts and mitochondria in the region of fractions 25-35. The bottom graph presents an equivalent sedimentation coefficient for a given group of particle densities and also the density of the gradient at each fraction.

Figure 17. Sugar beet leaf organelle separation in B-15 rotor (run #7). ($\omega^2 t = 4.7 \times 10^{11}$). A radioactive peak can be seen moving out of the starting zone having a suspected sedimentation coefficient of 20 to 40 and is suspected to be heavy soluble proteins.

Figure 13. Sugar beet leaf organelle separation in B-15 rotor (run #8). ($\omega^2t = 1.13 \times 10^{12}$). Centrifuge runs 6, 7 and 8 were done in sequence and runs 7 and 8 were run on identical gradients. Note that the peak at fraction 20 has a sedimentation coefficient of 20 to 50 depending upon the density of the sedimenting particle. The activity remaining in the starting zone has not been explained.

Figure 19. Sugar beet leaf organelle separation in B-15 rotor (run #9). ($\omega^2 t = 1.3 \times 10^{11}$). Fractions 14, 17, 21, 23 and 26 suggest that there may be some polonium contained in ribosomes and polysomes but the majority of the activity remains in the sample starting zone. The dashed line is a 280 m μ absorbance curve.

Figure 20. Sugar beet leaf organelle separation in B-15 rotor (run #10). ($\omega^2 t = 4.5 \times 10^{11}$) Again the peak that contains the majority of activity has moved from the starting zone and appears to have a sedimentation coefficient of 20-50, suggesting soluble proteins. The dashed is the 280 m μ absorbance curve

Figure 21. Analysis of soluble amino acids in Astragalus osterhouti spiked with sulfur-35. A flow through anthracene crystal was used to determine the sulfur-35 activity.

Figure 22. Analysis of soluble amino acids in Astragalus osterhouti spiked with polonium oxide. Note the lack of sharply defined peaks of polonium activity.