SODIUM 2,2-DICHLOROPROPIONATE AND SODIUM 2,2,3-TRICHLOROPROPIONATE ABSORPTION AND TRANSLOCATION IN CERTAIN VEGETABLE CROPS AND RESIDUAL ACTIVITY IN SOIL

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TABLE OF CONTENTS

TABLE OF CONTENTS, Continued

LIST OF FIGURES

LIST OF PLATES

LIST OF PLATES, Continued

LIST OF PLATES, Continued

LIST OF TABLES

LIST OF TABLES, Continued

LIST OF TABLES, Continued

LIST OF APPENDIX TABLES

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INTRODUCTION

Since the discovery of the selective toxicity exhibited toward broad leaf plants by 2,4-D and related compounds, many agencies have searched for a growth regulator type herbicide exhibiting a reverse selectivity. In 1953, The Dow Chemical Company announced an experimental herbicide, 2,2-dichloropropionic acid (DPA), which showed a selective toxicity against grasses. Early reports (18, pp. 2-3) indicated that certain perennial grasses were killed after foliage applications which suggested a growth regulator type material capable of being translocated through the plant.

The American Cyanamid Company later released 2,2,3-trichloropropionic acid (TPA) which in preliminary tests (25) exhibited activity similar to that of DPA. As with 2,4-D and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), isopropyl N phenyl carbamate (IPC) and isopropyl N (3 chloro) phenyl carbamate (CIPC), DPA and TPA differ in chemical structure by only one chlorine atom. Although the phenoxyacetic acids and the carbamates display some similar characters of activity within their respective groups, 2,4-D differs from 2,4,5-T, and likewise IPC differs from CIPC. It is logical to assume that DPA and TPA will exhibit some similarities and some differences in activity.

A comparison of certain aspects of the behavior of DPA and TPA to that of such compounds as 2,4-D and 2,4,5-T could add to the accumulation of knowledge directed toward eventually reaching an understanding of the differential phytotoxic activities of compounds varying only slightly in chemical structure. Because of the possible utilization of DPA and/or TPA for the control of perennial grasses on agricultural cropland, two of the most important properties of these chemicals requiring study are the foliar absorption and subsequent translocation to other plant parts, and the residual activity in soil.

Since it has been demonstrated that the absorption and translocation of 2,4-D is comparable in annual and perennial plants (13, pp. 355-365 and 14, pp. 287-334), it was assumed for the purpose of this study that the same relationship would be true of DPA and TPA absorption and translocation in annual and perennial plants. To provide an indication of the absorption and translocation of DPA and TPA in different types of plants for comparison to similar studies conducted with 2,4-D and 2,4,5-T by several workers, bean and sweet corn plants were chosen as convenient representative monocotyledonous and dicotyledonous test plants.

Because plants of the grass family are especially sensitive to DPA and TPA soil applications, sweet corn was chosen as a representative crop to measure the residual activity of these chemicals in the soil.

The work reported here consists of two phases: a study of

foliar absorption of C^{14} labeled DPA and TPA and the translocation of C^{14} to other plant parts, and the residual activity of DPA and TPA in soil as influenced by time, temperature, and soil sterilization.

REVIEW OF LITERATURE

Absorption and Translocation

Following foliar application many herbicides can enter the leaves and move to the stems and in some cases even to the roots of plants. However, a number of weed-killers such as ammonium sulfamate, sodium chlorate, sodium arsenite and others, are not translocated from the leaves to other portions of the plant by normally functioning plant tissue. Numerous investigations reviewed by Robbins et al. (45, pp. 155, 229-238) indicate that these materials are immediately toxic to living cells. As the cells are killed and the cell walls made permeable, these compounds may gradually diffuse throughout the plant. Then, too, in times of water stress, the chemicals may move downward from the leaves to the roots by a mechanism which represents a reversal of the transpirational stream.

A number of herbicides such as 2,4-D, 2-methyl-4-chlorophenoxyacetic acid (MCP), 3-amino-1,2,4-triazole (ATZ), and maleic hydrazide have been designated as growth regulator or translocated herbicides. These materials appear to be absorbed and subsequently translocated throughout plants by living tissue before morphological responses to the chemical application becomes apparent. Of this group of chemicals 2,4-D has been studied most extensively. Linder et al. (34, pp. 628-632) found that 2,4,5-T and MCP follow the same pattern of absorption and translocation exhibited by 2,4-D. Several investigations (39, pp. 112-126; 14, p. 71; 15, pp. 272-280 and 54, p. 165)

have indicated that the effectiveness of maleic hydrazide depends on the same factors influencing uptake and movement of 2,4-D. Recent work by Rogers (46, pp. 5-11) shows that ATZ also fits into this category of growth regulators. Baldwin et al. (4, pp. 428-430) found that IPC, however, is translocated only from the roots, and not from foliar parts to any extent. 3-(P-chlorophenyl)-1, 1-dimethylurea (CMU or monuron), which has also been classified as a growth regulator in some cases, readily moves upward from plant roots, but only to a slight extent downward from the foliage (24, pp. 400-402; 38, pp. 65-73 and 27, pp. 177-187).

Early studies concerning the absorption and translocation of 2,4-D in plants depended on the observation of morphological responses of susceptible plants to the application of the substances. Since small amounts of this growth regulator can cause stem curvature, epinasty, and proliferation of various plant parts in sensitive species, many general conclusions could be drawn regarding the uptake and movement of 2,4-D or chemical complexes containing the active agent of 2,4-D.

Using fresh weight of leaves and stem curvature as criteria for the effect of the growth regulator, Weaver and DeRose (50, pp. 510-520) made a rather comprehensive study of foliar uptake and subsequent transport of 2,4-D in several plants. Tests conducted with Nasturtium and Coleus showed that regardless of which leaf surface was sprayed the amount of 2,4-D apparently absorbed remained the same. This would indicate that stomata were not an important port of

entry into the leaf unless the material was applied as an aerosol. To determine the speed of absorption these workers removed treated leaves from some plants, and applied artificial rain to other treated plants at various intervals following the application of 2,4-D. Both procedures resulted in the maximum plant response when six hours presentation time was provided. Longer periods of exposure did not increase the uptake of 2,4-D.

A possible pathway for the transport of the 2,4-D stimulus was suggested by Weaver and DeRose (50, p. 516) after treating both leaves and roots of snap beans with 2,4-D after flaming the stem to disrupt all but the xylem tissue. Movement of the growth regulator response from the root to foliar parts was readily shown, but very little movement from leaves to roots could be detected. This would suggest that after foliar absorption the primary path of 2,4-D transport is through phloem tissue, and that the xylem serves to transfer 2,4-D from the roots to the upper plant parts. The fact that little or no translocation could be detected in plants kept in reduced light prior to and after treatment supported the suggestion that 2,4-D is moved through the plant with the products of photosynthesis which are generally believed to find the phloem the primary means of transport (50, pp. 516-517 and 34, pp. 628-632). Further work on this problem by Weintraub and Brown (51, pp. 141-149) included the addition of various sugar solutions to the 2,4-D and other growth regulating substances. All of the growth regulators tested were translocated in plants kept in darkness if any one of the sugars tested were

included in the treatment solution.

Rice (44, pp. 301-314) employed controlled conditions of temperature and light, and spectrophotometric analysis of the washings from treated leaves as well as fresh weight and stem curvature to study absorption and translocation of the ammonium salt of 2,4-D in bean plants. He found that more chemical was absorbed, and at a faster rate under high temperature (89 to 90° F.) than at lower temperatures (79 to 82° F. and 46 to 58° F.). Except at the lowest temperature used, absorption did not continue after four hours presentation time. More 2,4-D was taken up by plants kept in a dark room than by those maintained in a greenhouse at comparable temperatures. Dissolving the 2,4-D in Carbowax increased the amount of uptake, and extended the absorption period to seventy-two hours.

Another phase of Rice's research supported earlier work which indicated that translocation of 2,4-D was dependent on the movement of photosynthates out of the leaves to other portions of the plant. Although absorption of 2,4-D was increased in plants kept in the dark, translocation of the growth regulator did not take place until about twenty-four hours after moving the treated plants into a lighted room.

A more positive method of studying absorption and translocation of herbicides by plants was utilized by Mitchell and Linder (36, pp. 54-55 and 37, pp. 21-25) when they were able to synthesize 2,4-D-5-I^{131} (2,4-dichloro-5-iodo-phenoxyacetic acid). Morphological responses of treated plants were not required for the interpretation of results since by means of this radioactive tracer quantitative

measurements of the amount of I^{131} accumulated in various parts of treated plants provided an indication of the extent of translocation of the growth regulator stimulus. Three days after the application of 2,4-D-5-I^{131} to one primary leaf, the treated leaf was removed to obviate further translocation. Separation of the remaining plant parts followed by measurement of the radioactivity in each section showed that the I^{131} was concentrated primarily in the growing tip and the upper portion of the stem. Relatively small amounts were found in the root, and a very small quantity was detected in the untreated primary leaf. The addition of a surface active agent, Tween-20, to the treatment solution increased by 71 percent the amount of I^{131} accumulated in the root system. This increase of I^{131} translocated to the root system was probably due more to the increased absorption of 2,4-D-5-I by the treated leaf than to a direct influence of the Tween-20 on translocation.

Although the information obtained through the use of 2,4-D-5-I was valuable, there were indications that this compound was not as toxic as was regular 2,4-D. The synthesis of 2,4-D labeled with C^{14} in the carboxyl group was undertaken by Holley et al. (29, pp. 145-146). In kidney bean plants harvested eight hours, one, and seven days after treatment, the highest concentration of C^{14} was located in the upper portion of the stem. Relatively smaller quantities had accumulated in the lower stem, growing tip, root, and untreated primary leaf, in that order. The authors concluded that the greater portion of radioactive material was moved out of the treated leaf

downward through the stem toward the root, and at the same time a smaller amount moved upward toward the growing tip. At the end of the seven day experimental period a considerable percentage of the C^{14} originally applied could not be located in the plant tissue. Subsequent tests showed that $C^{14}O_2$ was given off by the kidney bean plants in quantities of the same order as the C^{14} not recovered in the plant tissue. It was assumed that the carboxyl group had been broken from the 2,4-D molecule and had been given off by the plants during respiration.

Fang et al. (23, pp. 249-255) synthesized and studied the absorption and translocation of 2,4-D labeled with C^{14} in the methylene group. Harvests at various intervals after treatment indicated that C^{14} was accumulated primarily in the stem of the bean plants. Lesser quantities were found in the root, growing tip and in the untreated primary leaf. As the presentation time lengthened the total recoverable radioactivity decreased indicating metabolism of the compound in the plant. Amounts of $C^{14}O_2$ of the same order as the quantity of C^{14} lost by the bean plants were recovered from another group of similarly treated plants.

It has often been observed that when the application of a growth regulator herbicide exceeded a critical rate, effectiveness of the chemical was reduced. It has been felt that heavy dosages injured the leaf tissue to the extent that absorption and/or translocation was inhibited. Fang et al. (23, p. 253) applied different amounts of radioactive 2,4-D to bean plants and observed that translocation from

the treated leaf was not increased by a raise in the rate of application from 100 to 150 µgm. This group of workers also reported that when plants at different stages of growth were treated, the youngest ones absorbed and translocated more C^{14} than the older plants.

Jaworski et al. (31, pp. 272-275) reported that no translocation of C^{14} was detected in etiolated bean plants kept in darkness after treatment with C^{14} labeled 2,4-D. Removal to the lighted greenhouse or the application of sugar, especially sucrose or glucose, to the treated leaves resulted in normal translocation of C^{14} through the plant. It would appear that 2,4-D and probably other growth regulators are transported with the photosynthetic product.

Since the grass plants do not display characteristic morphological responses to light applications of 2,4-D or related substances, the absorption and translocation of these compounds in grass plants was difficult to study by these means. Thus, the possibility that the selective toxicity of 2,4-D might be based on absorption and translocation in broadleaf plants long remained open to speculation.

Fang and Butts (22, pp. 56-60) used C^{14} labeled 2,4-D to show that this compound is absorbed and translocated through corn and wheat plants, though in smaller quantity and at a slower rate than in bean plants. They suggested that in grass plants there may be a partial block in the intercalary meristem which hinders translocation. However, there appears to be adequate uptake and movement to eliminate these processes as being responsible for the differential toxicity exhibited by 2,4-D toward broadleaf and grass plants.

Crafts (11, pp. 51-55 and 13, pp. 293-334) has studied absorption and translocation of growth regulators by means of radioautographs prepared after treating plants with radioactive chemicals. Through this technique he arrived at essentially the same conclusions as those previously discussed in regard to uptake and transport of 2,4-D in plants. The combination of a pictorial presentation and quantitative measurements of the accumulation of radioactive materials in plants makes the interpretation of the results much easier.

Although, as has been indicated, the work on absorption and translocation of 2,4-D has been rather extensive, there have been relatively few trials comparing 2,4-D and 2,4,5-T in this regard. However, the results of these few tests are consistent. Three reports (34, p. 630; 12, p. 293 and 21) indicate that 2,4-D was more readily absorbed, and was translocated more rapidly than 2,4,5-T. Linder (34, p. 630) found that whereas 2,4-D treated plants developed curvature within four hours after treatment, 2,4,5-T treated plants required twenty-four hours to exhibit a similar degree of curvature. Crafts (12, p. 293) suggested that "theoretically the chlorine substitutions in these molecules are lipophylic, and the third chlorine may hinder the partition of the molecule from the lipid phase of the leaf or the cell surface into the aqueous medium of the living cell."

At present only a limited amount of research regarding absorption and translocation of DPA by plants has been reported. In announcing DPA as a new growth regulator type herbicide toxic to grasses, The Dow Chemical Company (19, pp. 2-3 and 20, p. 2) indicated

that single drop tests to leaves of grass seedlings, spray applications to grass foliage, and dip tests of barley leaves all supported the suggestion that DPA could be absorbed by the foliar portions of the plant and transported to other plant parts. The application of high concentrations caused leaf burning which inhibited further uptake and movement of DPA. Morphological responses of grass plants to DPA were reported (19, pp. 2-3; 20, p. 2 and 6, p. 16) as being very similar to those induced by sodium trichloroacetate (TCA). However, research has shown that TCA is not actively absorbed by the foliar plant parts though it is taken up by the root system (5, p. 50 and 7, p. 275).

Santlemann and Willard (47, pp. 21-29) conducted several experiments to study the uptake and transport of DPA in quackgrass. They found that injuring the leaves by puncturing with pins did not bring about increased absorption which would indicate that DPA was absorbed quite readily through the intact leaf surface. By washing any remaining DPA off treated leaves, and by removing leaves to which the chemical had been applied, the investigators reached the conclusion that although DPA was absorbed into the leaf very quickly, a considerable time lapse was necessary for appreciable quantities to move to other parts of the plant. Washing the leaves five minutes after treatment did not remove sufficient DPA to prevent subsequent malformation of the quackgrass leaves and thirty minutes contact before washing was sufficient to cause eventual death of the plants. However, removal of the treated leaf prior to three hours following the application resulted in no serious plant injury.

Further trials conducted by the same workers to investigate translocation included the treatment of one leaf arising from a small length of rhizome, and subsequent observations of any other leaves supported by the same rhizome. The response of the untreated leaves varied from relatively slight growth regulator symptoms to death in some cases. The response to DPA treatment traveled either from primary to secondary leaves, or from secondary to primary leaves of the same rhizome.

In an attempt to relate DPA translocation to movement of the products of photosynthesis, Santlemann and Willard treated plants kept in the dark, and in some cases applied sucrose to the treated leaf. There was some evidence of translocation in the plants in darkness, but plants maintained under light showed a much greater movement of the DPA active agent. The sucrose did not influence translocation.

Translocation of Cl^{36} labeled DPA in bean and barley plants was investigated by Wilkinson (52, pp. 81-95). Radioautographs showed that DPA-Cl^{36} moved out of the treated primary leaf of bean plants to the stem, the growing tip, and the petiole of the untreated primary leaf within six hours after treatment. Movement from immature barley leaves was restricted, but treatment of more mature leaves resulted in translocation of the Cl^{36} throughout the plant. Wilkinson postulated that the intercalary meristem limited movement out of the young leaves of grass plants. He felt that this limitation of translocation in grasses may cause a toxic accumulation of

DPA in grass leaves resulting in the selective toxicity displayed by DPA toward grasses.

TPA has been reported to have many herbicidal characteristics similar to those of DPA (26, and 6, p. 16). No information has been found in the literature concerning the absorption and translocation of this compound.

Residual Activity in Soil

The extensive literature relating to the persistence of several chemicals in soil has been reviewed by Robbins et al. (45, pp. 199-208, 241-318). Of the growth regulator type herbicides, 2,4-D and its residual activity in various soils has received the most attention. The same factors responsible for the loss of 2,4-D toxicity in soil are reported to be active in reducing the activity of MCP and 2,4,5-T (1, pp. 257-260) and maleic hydrazide (55, pp. 431-440) in various soils. A review of the activity of herbicides following soil applications by Aldrich (1, pp. 257-260) indicated that the growth regulator herbicides, or the toxic properties of these herbicides, appear to be removed from the soil primarily by leaching, fixation on the soil colloids, or decomposition by soil micro-organisms.

2,4-D apparently is sufficiently water soluble to be leached downward in the soil profile by normal rainfall. DeRose (16, pp. 584-585) applied different amounts of 2,4-D to a soil consisting of one part silt loam and one part medium sand which was then leached with various quantities of water. That 2,4-D was removed from the soil was indicated when the collected leachate caused the leaves of

tomato plants to exhibit typical 2,4-D induced stem curvature and epinasty, and when tomato plants seeded in the heavily leached soil grew normally. Crafts (10, p. 154) reported that 2,4-D was removed from Yolo fine sandy loam soil much quicker than from Yolo clay loam soil subjected to similar irrigation. Ogle and Warren (42, p. 262) leached the toxic effects of 2,4-D out of six inch soil columns containing fine sandy loam, silt loam, and muck soil by the application of two, eight, and sixteen inches of water respectively.

That the differential loss of 2,4-D from different textured soils may be in part due to adsorption on the soil colloids was shown by Weaver (49, pp. 74-78) when he studied the reaction of growth regulators with ion exchangers. 2,4-D and 2,4,5 T were both adsorbed in fairly large quantity on both anion and cation exchangers. Although approximately the same amount of 2,4-D and 2,4,5-T were held by the anion exchangers, 2,4-D was adsorbed in much greater quantity than was 2,4,5-T on the cation exchangers. It was also indicated that the 2,4-D adsorbed on these cation exchangers was held so that it could not be absorbed by plant roots.

Several factors conducive to the growth and development of soil micro-organisms appear to influence the rate of loss of growth regulators from soil. Brown and Mitchell (8, p. 317) found that after two months storage at 70° F. an original application of 30 pounds per acre of 2,4-D was equal in toxicity to only 10 and 2 pounds per acre in soil stored at 50 and 30° F. respectively. After applying 2,4-D or 2,4,5-T to soil having a moisture content equal to 60 percent of the moisture equivalent, DeRose and Newman (18, p. 223)

stored the soil at 10, 15, 20, 25, and 30° C. Periodically soil samples were removed and planted to soybeans. Both compounds disappeared twice as fast at 30° C. as at 10° C. storage. Under the 30° C. storage temperature it took 21 to 36 days for 2,4-D, and 166 to 190 days for 2,4,5-T to be lost from the soil.

The same two groups of workers also investigated the influence of soil moisture content (when leaching was prevented) on the length of time that 2,4-D remains toxic in the soil. Brown and Mitchell (8, p. 319) treated soils containing amounts of moisture varying from the wilting point to the moisture equivalent percentage. They found that as the soil moisture content was increased, the length of time that 2,4-D remained active in the soil was decreased. DeRose and Newman (18, p. 224) reported that 2,4-D and 2,4,5-T remained toxic to kidney bean plants for six weeks in soil containing water equal to 60 percent of its moisture equivalent. In soil containing 100 percent of its moisture equivalent, however, 2,4-D was lost within one week while 2,4,5-T remained effective over a six week period.

The organic matter content of a soil also influences both the soil micro-organism population and the length of residual activity of 2,4-D in soil. It would appear that an increased amount of organic matter is directly correlated with an increase in the rate of deactivation of 2,4-D (8, p. 319 and 42, p. 260).

Soil sterilization to eliminate micro-organism activity further substantiated the suggestion that biological breakdown plays an important role in the loss of 2,4-D toxicity in soil. In sterilized

soil 2,4-D remained effective for very long periods of time (8, p. 318 and 18, p. 225).

After studying the breakdown of 2,4-D and 2,4,5-T by micro-organisms Audus (3, p. 171) suggested that there are three distinct phases in the decomposition of organic herbicides by micro-organisms:

1. immediate initial adsorption onto the soil colloids,
2. lag phase of varying duration in which there is little or no breakdown, and
3. final rapid detoxication.

During the lag phase the micro-organism population is thought to be increasing so that when the final detoxication takes place it is accomplished rapidly. The lag phase for 2,4-D was 14 days, and for 2,4,5-T 270 days under the conditions of Audus' experiments.

The carbamates form another group of herbicides which exhibit phytotoxicity following soil application. Freed (25, pp. 50-56) found that the reduction of IPC activity in soil depends on the same factors which operate in the loss of 2,4-D from soil. IPC was leached from the soil by rainfall or irrigation; increased temperature and moisture hastened IPC breakdown; and autoclaving the soil prior to treatment reduced the subsequent rate of IPC loss markedly. Several investigations (17, p. 142; 33, p. 10; 40, p. 175 and 53, pp. 45-46) have indicated that CIPC retained its activity in soil much longer than did IPC. Here again, as with 2,4-D and 2,4,5-T, the extra chlorine in the chemical molecule apparently contributed to a longer period of soil residual activity.

TCA is somewhat similar in chemical structure to DPA and TPA,

and when applied to the soil induces morphological responses in grass plants which resemble those resulting from DPA or TPA soil or foliage treatments. It has been reported that leaching is a major factor in the loss of TCA from the upper portion of the soil profile. That the rate of leaching depended to some extent on the soil texture was demonstrated when TCA was retained longer by clay or muck soils than by sandy soils (43, p. 275 and 35, p. 324).

Experiments conducted by Loustalot and Ferrer (35, pp. 323-324) suggested that TCA is also decomposed by micro-organisms. In treated soil stored at 10° C. TCA toxicity toward corn plants was still evident after two months. In comparison, TCA apparently was broken down within two weeks when stored at 45° C. Moisture studies showed that twice as long a time was required for TCA to be decomposed in soil containing 20 percent moisture as in soil containing 36 percent moisture (field capacity).

At the time the experiments described in this paper were initiated very little information was available concerning the persistence of DPA or TPA in soil. Preliminary trials (20, p. 2 and 26) had indicated that neither material remained active in the soil for extensive periods of time. DPA applied at 40 pounds per acre lost its effectiveness toward grass plants within twelve months.

Recently, more information regarding the decomposition and loss of DPA following soil treatment has become available. Thiegs (48, pp. 2-4) studied the breakdown of DPA in three soils varying in moisture content, and stored at different temperatures. His conclusions were based on chemical determinations of the DPA present in

the soil at regular intervals following the original treatments. The soil types employed had little influence on DPA breakdown, but increased temperature and moisture greatly reduced the time required for DPA to be deactivated. The addition of organic matter, as peat or manure, to each of the soils of the experiment increased the rate of DPA breakdown. Further evidence of the importance of microorganisms in the detoxication of DPA was demonstrated when repeated applications of the chemical were made to soil samples. It was indicated that the microorganisms were able to build up in sufficient numbers after the initial treatment so that the second application was decomposed very rapidly.

The influence of temperature, moisture, organic matter content, and the addition of lime to the soil on the persistence of DPA in several soils was studied by Holstun and Loomis (30, pp. 209-214). In contrast to Thiegs, these men used the growth of Large Yellow millet as an indication of the amount of DPA remaining in the soil following the various treatments. Their conclusions agreed with those of Thiegs in that the factors favorable to the growth and development of microorganisms contributed to a more rapid decomposition of DPA mixed in soil.

Holstun and Loomis (30, pp. 207-208) also determined that the water soluble DPA is quite subject to leaching. The addition of sand to a particular soil increased the loss of DPA while the incorporation of organic matter into the same soil apparently reduced the loss of DPA from the upper portion of the soil profile.

Information regarding the residual activity of TPA in soil could not be found in the literature nor through personal correspondence.

MATERIALS AND METHODS

Absorption and Translocation

A series of experiments was designed and conducted to study the absorption of radioactive DPA and TPA, and the subsequent translocation of C^{14} to various parts of bean and sweet corn plants.

Plant Culture

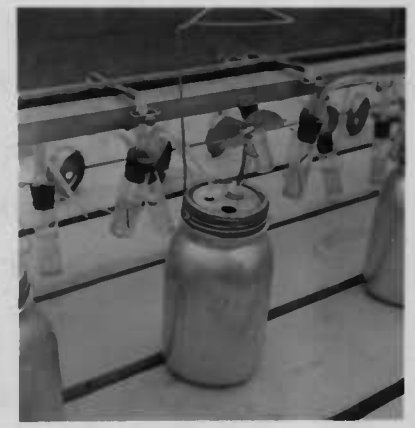
Snap bean (Phaseolus vulgaris, var. Black Valentine) and sweet corn (Zea Mays, var. Golden Cross Bantam) plants were germinated in six inch petri dishes lined with moistened filter paper. After three or four days the one to two inch long primary roots of the seedlings were inserted through a plastic mesh screen into large pans filled with one-fourth strength Hoagland's solution (28, pp. 36-37). Approximately five days later uniform plants were selected and transplanted into one-quart mason jars which had been painted an aluminum color to eliminate algal growth and to prevent increased temperatures of the nutrient solution. Initially the jars were filled with one-fourth strength Hoagland's solution. As needed, full strength Hoagland's solution was added to the jars. The nutrient solution was aerated continuously throughout the experimental period. Plate 1 shows the petri dishes, plastic mesh covered pans, and mason jars with the aeration system.

Radioactive Chemicals and Method of Treatment

Radioactive sodium 2,2-dichloropropionate-2-C^{14} (DPA-2-C^{14}) and radioactive sodium 2,2,3-trichloropropionate-2-C^{14} (TPA-2-C^{14}) each

A

B



C

D

Plate 1. Plant culture for absorption and translocation studies: A. Transferring seedlings from petri dishes to pans; B. Transferring young plants to mason jars; C and D. Transplanted bean and sweet corn plants in mason jars with aeration system in operation.

with a specific activity of 0.98 mc per mM, were utilized for this study. To facilitate application of the chemical to the plants, the radioactive chemicals were dissolved in 95 percent ethanol containing 0.1 percent Tween 20. With a calibrated micrometer driven hypodermic syringe the solution was spread over the mid vein of one primary leaf blade of the bean plants or over the distal two inches of the second leaf blade of the sweet corn plants respectively (Plate 2).

Measurement of Radioactivity

At the time the various treatments were made a measured quantity of the radioactive chemical being used was deposited on filter paper and stored in petri dishes to be handled in a manner similar to plant samples being tested for radioactivity. Thus the theoretical amount of C^{14} applied to any plant at any time could be determined, and evaluation be made accordingly.

Upon harvest of the treated plants, one plant from each group in the first and third phases of each experiment was used to prepare radioautographs. The plants were spread out and dried between sheets of heavy blotting paper on which the hot air stream from an electric heater was directed. The dried plants were then placed on uncontaminated sheets of blotting paper, and in a darkroom were brought into contact with Kodak no-screen medical x-ray film. Several plants with their respective films were separated by sheets of cardboard and bound together in a plant press. The bundle was wrapped in black paper and left in the darkroom for ten or eleven days. At the conclusion of the exposure period the films were

A

B

C

D

Plate 2. Treatment of bean and sweet corn plants for absorption and translocation studies: A. Micrometer driven syringe; B and C. Treatment of plants at first stage of growth; D. Plants at second stage of growth.

developed in Kodak D-19 developer.

Immediately after harvest all other plants were sectioned into the following parts:

Beans	Sweet Corn
Treated primary leaf blade	Treated tip of 2nd leaf
Treated primary leaf petiole	1st leaf sheath
Untreated primary leaf blade	1st leaf blade
Untreated primary leaf petiole	2nd leaf sheath
Growing tip	2nd leaf blade minus tip
Stem	3rd leaf sheath
Root	3rd leaf blade
1st trifoliate leaf blades	4th leaf sheath
1st trifoliate leaf petioles	4th leaf blade
2nd trifoliate leaf blades	5th leaf
2nd trifoliate leaf petioles	6th leaf
	7th leaf
	Root

The plant sections were pooled according to treatment and dried at 60° C. in a vacuum oven equipped with an aspirator for at least twenty-four hours. Each pooled sample was then ground to a very fine powder using a mortar and pestle, and completely oxidized by a micro dry combustion method (9, pp. 82-88).

The apparatus for this combustion included a source of oxygen, a sulfuric acid pressure regulator, a combustion tube and Fisher micro combustion furnace, a carbon dioxide absorber, and a Mariotte bottle. The suction of the Mariotte bottle drew the gases through the fritted disperser in the absorber, and the pressure supplied by the pressure regulator maintained the current of oxygen into the combustion train. Carbon dioxide from the combustion train was absorbed in a sodium hydroxide solution and later precipitated as barium carbonate.

In the first experiment conducted, Absorption of DPA-2-C^{14} and Translocation of C^{14} in Bean Plants, the barium carbonate was deposited on a weighed sintered-glass filter, dried overnight at 110° C., and the amount of barium carbonate obtained was determined. After grinding, a weighed portion of the barium carbonate was suspended in a 2:1 Ethanol-Ether mixture and deposited on a one inch copper disk. The disk containing the dried sample was mounted on a three-eighth inch tall ring pedestal for the radioactivity measurement. In all other experiments in which carbon dioxide was precipitated as barium carbonate, a more rapid method of preparing the barium carbonate for radioactivity measurement was utilized. The barium carbonate was precipitated directly on No. 3 MM Whatman filter paper and was dried under a heat lamp. The filter paper was then placed in shallow stainless steel cups for counting the amount of radioactivity present. The radioactivity in all barium carbonate samples was measured by means of a "Tracerlab autoscaler" with a thin mica window tube (1.9 mg. per cm^2) The scale selector was set at 2048 counts. The activity of each barium carbonate sample was corrected to zero thickness, and appropriate calculations gave the total radioactivity in each plant sample. Duplicate determinations were made from each barium carbonate sample.

The change in the procedure of barium carbonate sample preparation resulted in higher radioactivity measurements for the plant samples from the first experiment than for those of the other experiments. Since the self-absorption curves prepared for the two methods are very similar, it is indicated that the apparent

difference in radioactivity detected was due to the difference in distance of the different barium carbonate samples from the auto-scaler window tube. Since appropriate checks of the theoretical amount of radioactivity applied to various plants were made, the results of the different experiments can be compared.

Methods of Study

Four separate experiments formed the basis for this study. Absorption of DPA-2-C^{14} and Translocation of C^{14} in Bean Plants. Absorption of TPA-2-C^{14} and Translocation of C^{14} in Bean Plants. Absorption of DPA-2-C^{14} and Translocation of C^{14} in Sweet Corn Plants. Absorption of TPA-2-C^{14} and Translocation of C^{14} in Sweet Corn Plants. Each experiment was divided into three phases:

1. Rate of absorption and translocation. Thirty plants were divided into six groups of five plants each. All plants were treated with 100 µgm. of the appropriate chemical when the first trifoliate leaf of the bean plants was beginning to unfold, and when the fourth sweet corn leaf was just emerging from the sheath. The individual groups were harvested 2 hours, 1, 2, 3, 5, and 7 days after treatment.

2. Absorption and translocation in plants treated with various amounts of chemical. At the same stage of growth mentioned under phase 1, a series of sixteen plants was selected and divided into four groups of four plants each. To plants in the respective groups was applied 50, 150, 200 and 300 µgm. of either DPA-2-C^{14} or TPA-2-C^{14}. All groups were harvested twenty-four hours later.

3. Absorption and translocation influenced by plant stage of growth. Two groups of five plants each were treated with 100 µgm. of chemical at later growth stages than those described in phase 1. To one group the chemical was applied at the time the second trifoliate leaf of the bean plants was beginning to unfold, or at the time the fifth corn leaf was beginning to emerge from the sheath. The other group was treated when the third trifoliate leaf of the bean plant began to unfold, or when the sixth corn leaf began to emerge. Each group was harvested twenty-four hours after treatment.

Absorption and Translocation as a Basis for Selective Toxicity

Since both bean and sweet corn plants are sensitive to DPA and TPA, it was also considered desireable to obtain an indication of the absorption of DPA-2-C^{14} and TPA-2-C^{14} and the subsequent translocation of C^{14} from the leaves to other portions of a plant tolerant to the application of these chemicals.

Birdsfoot Trefoil (Lotus corniculatus), a plant that has demonstrated considerable tolerance to the application of DPA was used in this trial. Four month old seedlings were spotted out in a greenhouse flat containing Dantor (exploded silica) and irrigated regularly with one-quarter strength Hoagland solution. When the trefoil plants were about four inches tall and making good growth the following treatments were made:

1. Thirty µgm. of DPA-2-C^{14} applied to one leaflet near the top of two plants.

2. Thirty µgm. of DPA-2-C^{14} applied to one leaflet near the base of two plants.

3. Thirty μgm. of TPA-2-C^{14} applied to one leaflet near the top of two plants.

4. Thirty μgm. of TPA-2-C^{14} applied to one leaflet near the base of two plants.

All of the plants were removed from the Dantor twenty-four hours later, the Dantor was washed from the roots, and the plants were dried between sheets of heavy blotting paper on which a stream of hot air from an electric heater was directed. Radioautographs were prepared in the manner described previously.

Loss of Radioactivity

The loss of a certain amount of the radioactivity theoretically applied to a plant is to be expected. However, as will be pointed out in the presentation of results, the C^{14} recovery from DPA-2-C^{14} and TPA-2-C^{14} treated sweet corn plants was much lower than the C^{14} recovery from similarly treated bean plants. Therefore, two experiments were conducted in an attempt to determine at what stage in the procedure employed to study the absorption and translocation in sweet corn plants that this loss occurred.

1. Loss of C^{14} Through Respiration by Bean and Sweet Corn Plants. Four bean and four sweet corn plants were grown as previously described, and treated with 100 μgm. of DPA-2-C^{14} when the beans and corn were at the first stage of growth described above. After treatment the bean and sweet corn plants were placed under separate bell jars illuminated by a bank of fluorescent lamps. An aspirator served to replenish the atmosphere within the bell jars,

and to draw the gases through a carbon dioxide absorber containing sodium hydroxide solution. The solution was replaced at twenty-four hour intervals for three days. After three days the entire plants were removed from the bell jars.

The carbon dioxide absorbed by the sodium hydroxide solution was precipitated as barium carbonate and the radioactivity content was determined.

The nutrient solution in which the plants were maintained under the bell jars was evaporated to dryness and tested for radioactivity.

The treated leaves of each plant species were pooled and extracted with 80 percent ethanol by means of a mortar and pestle. The remaining portions of the plants were pooled by species and extracted with 80 percent ethanol in a Waring Blender. Duplicate one-half milleliter samples of each plant tissue extract were plated directly into small stainless steel cups, dried under a heat lamp, and measured for radioactivity content.

2. Measurement of Radioactivity by Direct Plating of Plant Extract. Phase one of the experiment, Absorption of DPA-2-C^{14} and Translocation of C^{14} in Sweet Corn Plants, was repeated. Groups of four plants each were harvested 2 hours, 1, 3, 5, and 7 days after treatment. The treated leaves, and the other portions of the plants combined, were pooled, extracted with 80 percent ethanol as described above, and measured for radioactivity content. The essential difference in this procedure as compared to the methods utilized for sample preparation of plant tissue in the four basic experiments appeared to be that here the plant samples were not dried in the

vacuum oven after harvest.

Residual Activity in Soil

A series of experiments was designed to study the influence of time and temperature of storage, and soil sterilization on the residual activity of DPA and TPA incorporated into different soils.

For these tests sodium salt formulations of 2,2-dichloropropionic acid (DPA) and 2,2,3-trichloropropionic acid (TPA) containing 68 and 72 percent acid equivalent respectively were utilized. The residual activity of these compounds was determined in Chehalis clay loam soil, Chehalis loam soil, and sterilized Chehalis loam soil by various growth responses of sweet corn plants (Zea mays, var. Golden Cross Bantam).

Chehalis soil to a depth of six inches was collected from the Oregon State College Vegetable Farm near Corvallis, Oregon. The soil was passed through a one-fourth inch wire screen and was thoroughly mixed to insure uniformity. From samples of this mixture, mechanical analysis (hydrometer method), organic matter content (Walkley-Black method), moisture equivalent percentage, and fifteen-atmosphere percentage determinations were made by the Oregon State College Soils Department. The determinations showed this soil to be a clay loam containing 3.65 per cent organic matter, and having moisture equivalent and fifteen-atmosphere percentages of 30.4 and 13.4, respectively (Appendix Table1). From the same area, but at a later date, more soil was obtained from the surface six inches. While screening this second batch of soil, however, mason sand was

added and mixed thoroughly. Determinations made as described above showed this mixture to have a loam texture with 1.80 organic matter content, and with moisture equivalent and fifteen-atmosphere percentages of 20.9 and 9.2, respectively (Appendix Table 2). A portion of this loam soil was later sterilized with steam at fifteen pounds per square inch for two hours.

The chemical treatments utilized to study the residual activity in the three soils were:

Clay Loam	Loam	Sterilized Loam
TPA at 10 ppm.	TPA at 10 ppm.	TPA at 10 ppm.
TPA at 50 ppm.	TPA at 50 ppm.	DPA at 10 ppm.
DPA at 10 ppm.	DPA at 10 ppm.	Control
DPA at 50 ppm.	DPA at 50 ppm.	
Control		

The concentrations of 10 and 50 ppm. were chosen since these concentrations of DPA and TPA in the upper three inches of the soil in a field would be roughly equivalent to soil applications of 10 and 50 pounds per acre. The suggested application rates of DPA for the control of perennial weedy grasses fall between these concentrations.

The procedure for applying the chemicals to the soil included first the preparation of "stock mixtures". These were made up by mixing appropriate quantities of chemical and finely screened oven dry soil with a mortar and pestle. Then the amounts of stock mixture necessary to obtain the proper coneentrations were mixed with weighed (oven dry basis) amounts of soil (adjusted to 25 percent moisture). This mixing was accomplished by tumbling the soil and chemical in a five gallon milk can fitted as shown in Plate 3. Next,

untreated soil (adjusted to 20 percent moisture) was placed in the lower two-thirds of ten pound berry tins. A three inch layer of treated soil was then added and the cans were covered with tight lids and stored in temperature control rooms as follows:

Clay Loam	Loam	Sterilized Loam
32 to 40° F.	32 to 40° F.	32 to 40° F.
55 to 60° F.	55 to 60° F.	72° F.
72° F.	72° F.	

At three week intervals for fifteen weeks cans representing four replicates of each treatment in the clay loam and loam soils were removed from storage. The sterilized soil was stored and sampled in the same way except that the twelve week storage time was not represented. Upon removal from the temperature rooms the cans were all placed in water bath constant temperature tanks maintained at 72 ± 1° F. (Plate 3). Approximately three to four hours later, five sweet corn seeds (soaked in water for about one hour) were planted one inch deep in each can of clay loam soil. In the loam and sterilized loam soils, seven seeds were planted, and depending on germination the stand was later thinned to five plants per pot. The moisture content in each can was maintained in such a manner that moisture was not a limiting factor.

Three weeks after the sweet corn seed was planted the cans and plants were moved from the constant temperature tanks to regular greenhouse benches for an additional three weeks.

The residual activity of DPA and TPA in the soil after various periods in storage at different temperatures was measured

A

B

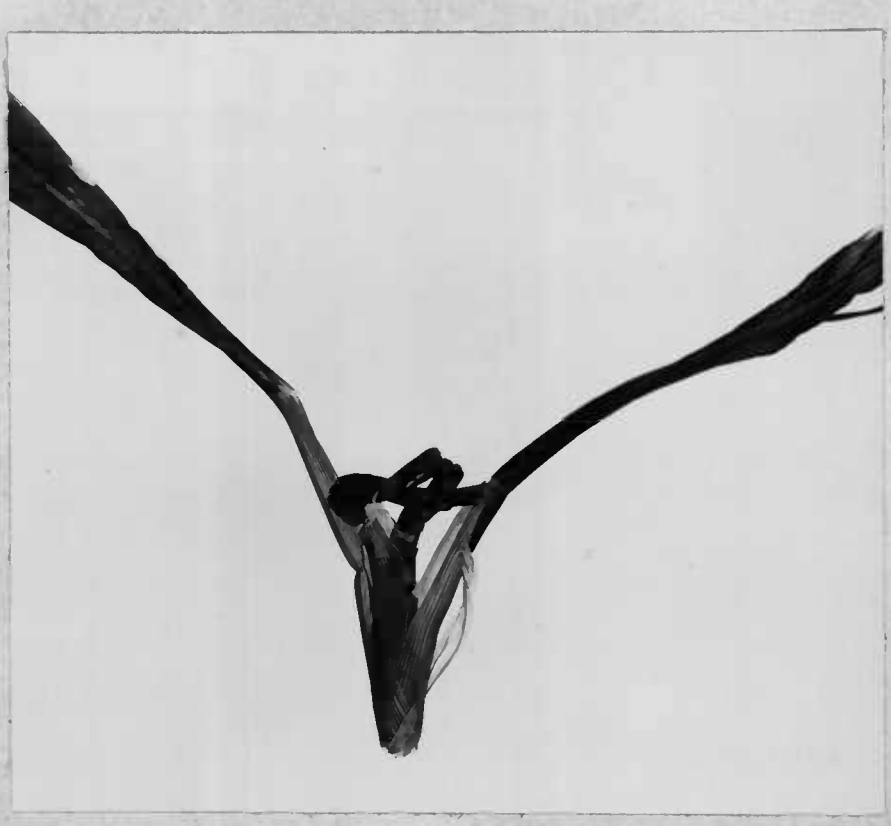
Plate 3. (A) Five gallon milk can and stand used to mix soil and chemical. (B) Cans of growing sweet corn plants in the water bath constant temperature tank.

by:

1. Dry weight per plant.
2. Fresh weight per plant.
3. Average height of the surviving plants three weeks after planting.
4. Average height of surviving plants six weeks after planting.
5. Number of plants per pot (maximum of five) displaying typical morphological responses induced by DPA and TPA applications (Plate 4).
6. Number of plants per pot (maximum of five) surviving six weeks after planting.

Statistical Treatment of Data

The experiments were originally designed to permit the use of the analysis of variance method of statistical analysis for the separation of the effects of length of storage, temperature of storage, and chemical treatments influencing the residual activity of DPA and TPA in the three soils investigated. However, the effects of length of storage and temperature of storage could not be evaluated statistically since length of storage was confounded by the differences in environment at the various times the test plants were grown, and facilities for replication of storage temperatures were not available. Consequently, only the treatments for each period of storage at each temperature could be evaluated statistically (Appendix Table 3).



A

B

Plate 4. Typical morphological responses of sweet corn plants induced by foliar or soil applications of DPA or TPA.

RESULTS

Absorption and Translocation

Absorption of DPA-2-C^{14} and Translocation of C^{14} in Bean Plants

The results of this study are presented in the form of tabular data, graphs, and radioautographs. Each entry in the tables and graphs represents a group of four plants pooled after harvest. The graphs present the most pertinent information derived from the tabular data, and the radioautographs were made from single plants treated at the same time and in the same manner as those represented in tabular and graphic form.

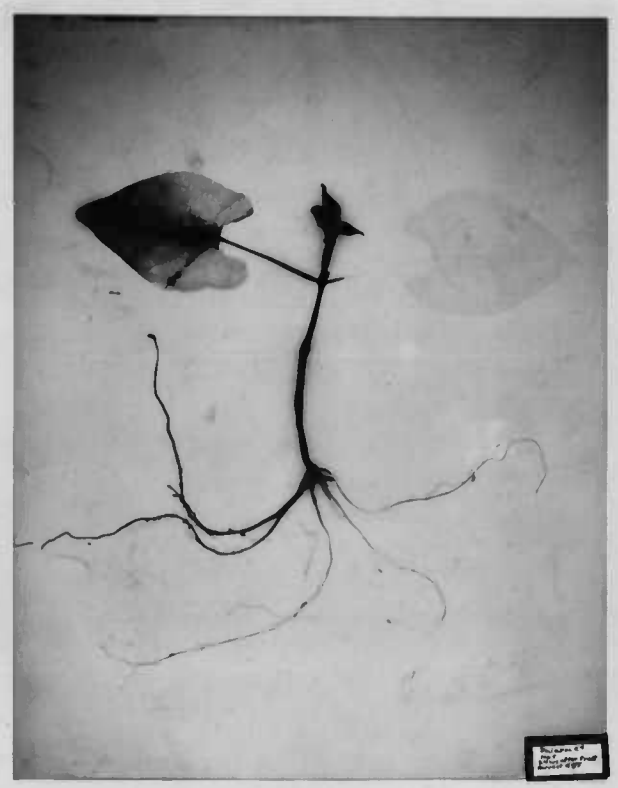
1. Rate of Absorption and Translocation. It is apparent from the radioautographs presented in Plates 5-7 that DPA-2-C^{14} was absorbed into the treated leaf blade and that the C^{14} was rapidly translocated through the bean plant. The data in Table 1 show that activity could be detected in all of the plant parts two hours after treatment, although at this time the amount of radioactivity was not sufficient in the root and the untreated leaf blade to show clearly in the radioautographs. Within twenty-four hours radioactive carbon had been translocated in varying quantities throughout the plant. The radioautographs clearly show that as the presentation time lengthened, and as new tissue developed, C^{14} was moved into these rapidly growing areas.

Graphic illustrations (Figure 1) of some of the data found in Table 1 show that within one day after treatment all parts of the

plant except the growing tip contained as much or more radioactivity as they accumulated during seven days. The amount of C^{14} in the growing tip continued to increase through three days, at which point it accounted for 55.2 percent of the radioactivity originally applied to the plant. During the final four days of the experiment the C^{14} accumulation in the stem and root decreased slightly, and that in the growing tip (including the rapidly developing trifoliate leaves) was reduced sharply. Throughout the seven day presentation period the amount of C^{14} accumulated in the untreated primary leaf blade and petiole remained at a very low level.

Figure 1 also shows that the amount of radioactivity in the treated leaf decreased rapidly from 367.2×10^3 to 131.9×10^3 counts per minute during the first forty-eight hours of the experiment and then more slowly to the end of seven days when it measured only 31.5×10^3 counts per minute. During the first three days, the total radioactive carbon in the plant parts, exclusive of the treated leaf, increased almost in proportion to the decrease of radioactivity in the treated leaf. The fact that total recoverable radioactivity remained fairly constant during these first three days would indicate that considerable amounts of C^{14} were translocated from the treated leaf to the other portions of the plant. From the third day to the end of the experiment the radioactivity in the entire plant and in the entire plant minus the treated leaf decreased markedly. This would indicate that DPA-2-C^{14} probably has a relatively short biological half-life in the bean plant.

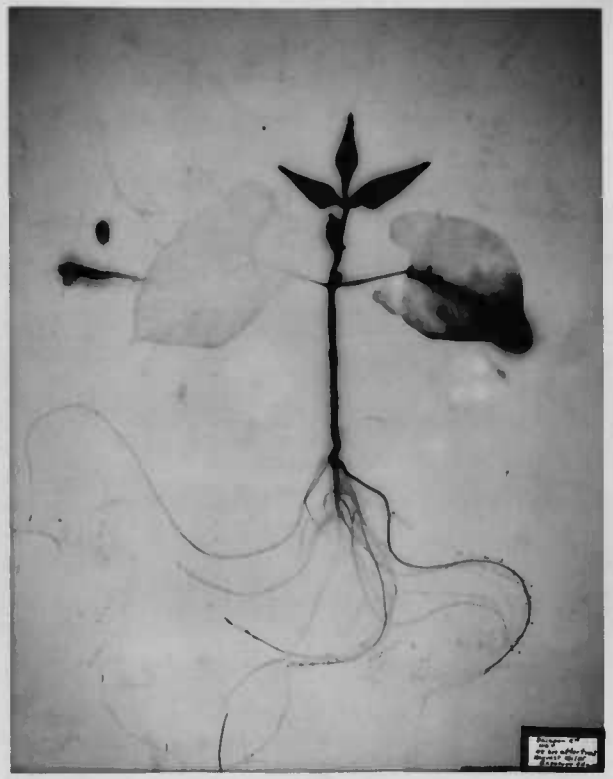
A



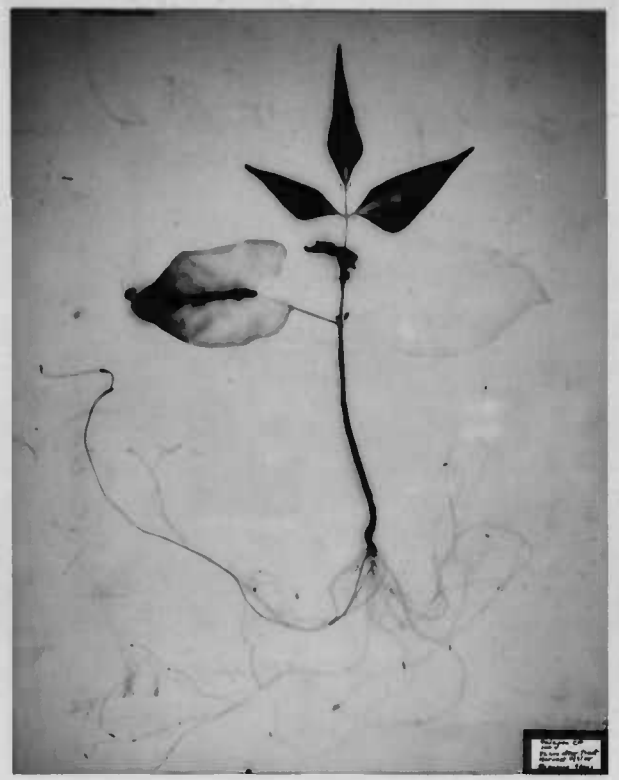
B

Plate 5. Radioautographs of bean plants harvested (A) two hours and (B) one day after the application of 100 μg. DPA* to one primary leaf blade when the first trifoliate leaf was unfolding.

* C^{14}-Labeled



A



B

Plate 6. Radioautographs of bean plants harvested (A) two days and (B) three days after the application of 100 μg. DPA* to one primary leaf blade when the first trifoliate leaf was unfolding.

A

B

Plate 7. Radioautographs of bean plants harvested (A) five days and (B) seven days after the application of 100 μg. DPA* to one primary leaf blade when the first trifoliate leaf was unfolding.

Table 1

Accumulation of Radioactivity in Bean Plants Harvested at Different Times After Application of 100 μg C^{14} Labeled Sodium 2,2-dichloropropionate to One Primary Leaf Blade

Plant Part	Total Activity of Plant Material Counts/Min x 10^3						Translocation and Accumulation of C^{14} %					
	2 hours	1 day	2 days	3 days	5 days	7 days	2 hours	1 day	2 days	3 days	5 days	7 days
Treated Primary Blade	366.4	231.6	131.9	100.6	58.4	30.8	84.9	53.7	32.2	23.3	13.5	7.2
Treated Primary Petiole	0.9	3.8	1.8	1.3	1.1	0.7	0.2	0.9	0.4	0.3	0.3	0.2
Untreated Primary Blade	2.2	3.3	3.2	2.1	2.3	3.1	0.5	0.8	0.8	0.5	0.5	0.7
Untreated Primary Petiole	0.3	0.7	0.3	0.4	0.4	0.3	0.1	0.2	0.1	0.1	0.1	0.1
Growing Tip	3.9	71.5	142.9	238.4	80.5	28.3	0.9	16.6	33.1	55.2	18.7	6.5
Stem	5.8	49.8	49.8	46.3	29.0	34.3	1.3	11.6	11.5	10.7	6.7	7.9
Root	2.1	22.9	20.9	24.3	6.9	7.6	0.5	5.3	4.8	5.6	1.6	1.8
1st Trifoliate Blade					9.4	3.2					2.2	0.7
1st Trifoliate Petiole					2.4	0.9					0.6	0.2
2nd Trifoliate Blade						6.4						1.5
2nd Trifoliate Petiole						0.7						0.2
Total Exclusive of Treated Leaf	14.3	148.2	217.1	311.5	130.9	84.8	3.3	34.5	50.3	72.1	30.4	19.6
Total	381.6	383.6	350.8	413.4	190.4	116.3	88.4	89.1	82.9	95.7	44.2	27.0
Total Activity Applied	431.6	431.6	431.6	431.6	431.6	431.6						

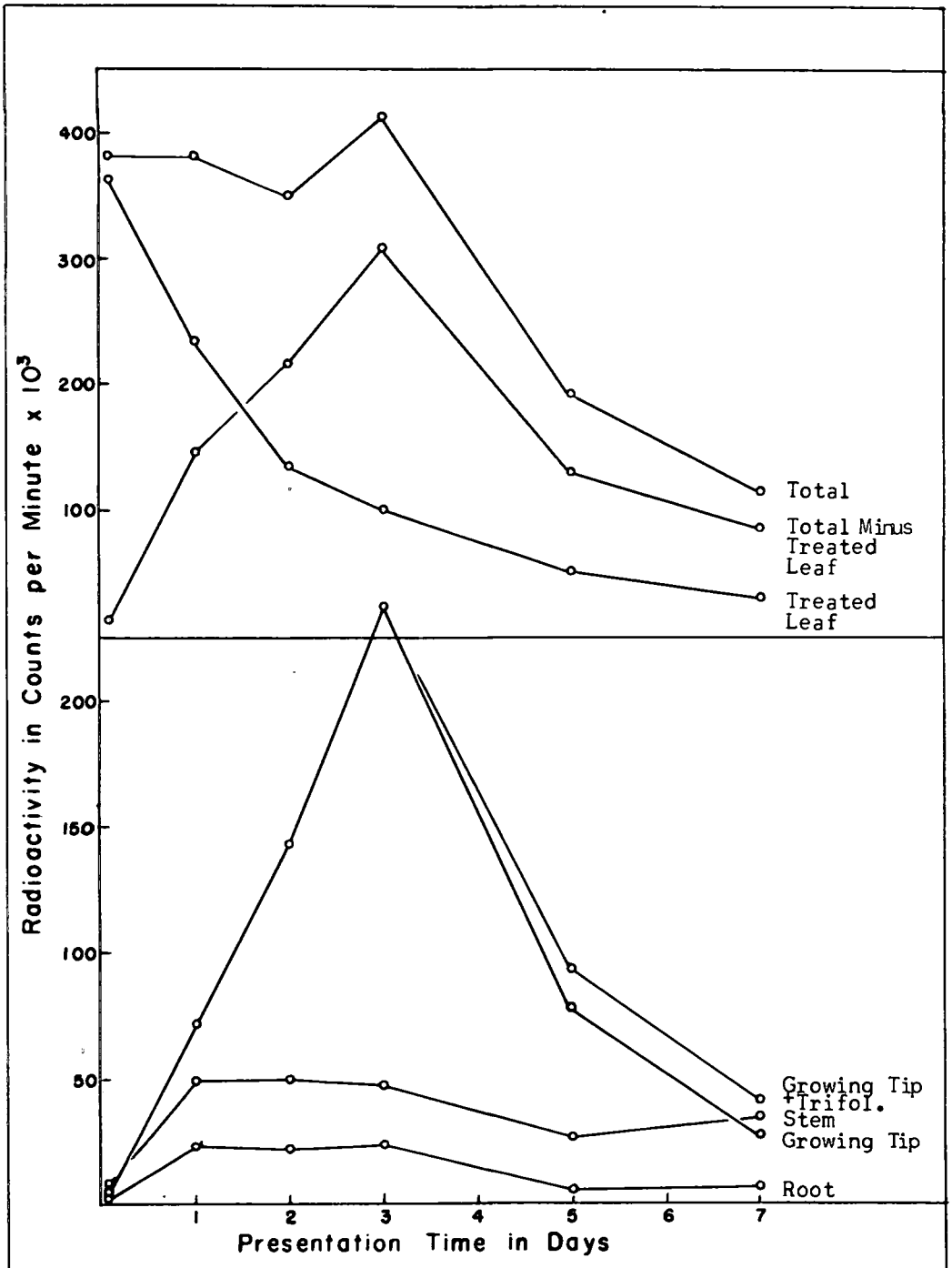


Figure 1. Accumulation of radioactivity in bean plants harvested at different times after treatment with 100 μg. of C^{14} labeled sodium 2,2-dichloropropionate.

2. Absorption and Translocation in Plants Treated with Various Amounts of Chemical. Table 2 reveals that of the various plant parts, aside from the treated leaf, only the root and to a much less extent the untreated leaf continued to accumulate greater quantities of C^{14} as the amount of DPA-2-C^{14} applied to the plant was increased from 50 to 300 µgm. The same tabular data and Figure 2 show that radioactive carbon in the stem and growing tip reached a maximum after the 200 and 150 µgm. treatments respectively. The total of the plant parts exclusive of the treated leaf showed an increase in C^{14} accumulation only through the 200 µgm. treatment, and the increase due to the change from a 150 to a 200 µgm. of DPA-2-C^{14} was very slight. On the other hand, the recoverable radioactivity in the entire plant, and the C^{14} found in the treated leaf increased in an almost direct proportion to the amount of DPA-2-C^{14} applied as the rate of application was raised from 50 to 300 µgm. Thus it is readily apparent that the application of this chemical in excess of 200 µgm. (perhaps in excess of 150 µgm.) to one leaf blade resulted in no increased translocation of C^{14} from the treated leaf blade to the other parts of the young bean plants during the twenty-four hour presentation period.

3. Absorption and Translocation Influenced by Plant Stage of Growth. Within twenty-four hours after treatment with DPA-2-C^{14} radioactive carbon had been translocated throughout bean plants regardless of the stage of growth at which the application was made (plate 8). Although the C^{14} moved to all of the plant parts making active

Table 2

Accumulation of Radioactivity in Bean Plants Treated on One Primary Leaf Blade with Various Rates of C^{14} Labeled Sodium 2,2-dichloropropionate. Plants Harvested Twenty-four Hours after Treatment

Plant Part	Total Activity of Plant Material Counts/Min x 10^3					Translocation and Accumulation of C^{14} %				
	50 µg	100 µg	150 µg	200 µg	300 µg	50 µg	100 µg	150 µg	200 µg	300 µg
Treated Primary Blade	81.0	231.6	387.4	542.2	825.7	37.5	53.7	59.8	62.8	63.8
Treated Primary Petiole	2.6	3.8	5.4	5.6	5.7	1.2	0.9	0.8	0.7	0.5
Untreated Primary Blade	1.9	3.3	2.4	3.9	5.2	0.9	0.8	0.4	0.5	0.4
Untreated Primary Petiole	0.4	0.7	0.6	0.8	2.1	0.2	0.2	0.1	0.1	0.2
Growing Tip	61.0	71.5	150.4	143.5	132.7	28.3	16.6	23.2	16.6	10.3
Stem	42.0	49.8	64.5	81.9	71.3	19.4	11.6	10.0	9.5	5.6
Root	14.9	22.9	21.4	28.2	31.8	6.9	5.3	3.3	3.3	2.5
Total Exclusive of Treated Leaf	120.2	148.2	239.3	258.3	243.1	55.7	34.5	37.0	30.0	19.0
Total	203.8	383.6	632.1	806.1	1074.5	94.4	89.1	97.6	93.5	83.3
Total Activity Applied	215.8	431.6	647.4	863.2	1294.8					

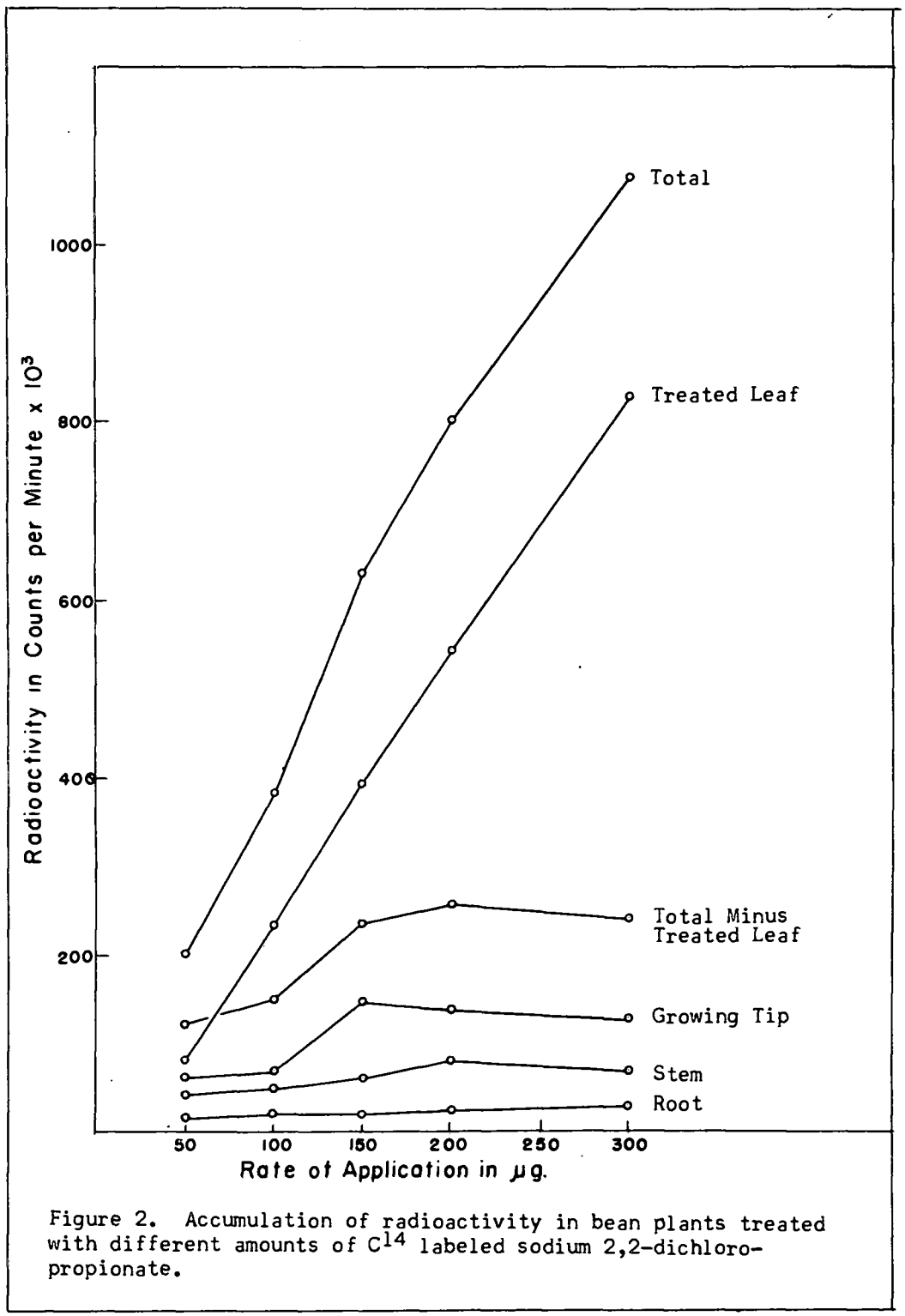


Figure 2. Accumulation of radioactivity in bean plants treated with different amounts of C^{14} labeled sodium 2,2-dichloropropionate.

growth, very little radioactivity could be detected in the more mature untreated primary leaf.

The data in Table 3 shows that the accumulation of radioactivity in the stem and root was increased when successively older plants were treated. More C^{14} was translocated to the growing tip of plants treated at the second than at the first growth stage, but those treated at the third stage contained relatively little activity in this region. Even when the C^{14} in the trifoliate leaves was added to that in the growing tip, the total was still quite low. Of interest is the greater accumulation of C^{14} in the second trifoliate leaf than in the first trifoliate leaf of the plants treated at the third stage of growth.

The amount of radioactivity in the entire plant showed a tendency toward reduction as older plants were treated.

Absorption of TPA-2-C^{14} and Translocation of C^{14} in Bean Plants.

1. Rate of Absorption and Translocation. The radioautographs in Plates 9-11 show that TPA-2-C^{14} was absorbed into the primary leaf blade to which it had been applied, and that C^{14} was rapidly translocated from this leaf to the other portions of the bean plant. Although the small amount of radioactive carbon in the untreated primary leaf is not distinguishable in the radioautographs, the data in Table 4 indicate that C^{14} had moved to all plant parts only two hours after TPA-2-C^{14} was applied. Within twenty-four hours radioactivity could be located in varying quantities throughout the plant - including the root tips. The C^{14} was readily translocated

A

B

Plate 8. Radioautographs of bean plants treated with 100 μg. DPA* on one primary leaf blade when (A) second trifoliate leaf was unfolding and (B) when third trifoliate leaf was unfolding. Harvested one day after treatment.

Table 3

Accumulation of Radioactivity in Bean Plants Treated with 100 μg of Radioactive Sodium 2,2-dichloropropionate at Three Stages of Growth. Plants Harvested Twenty-four Hours after Treatment

Plant Part	Total Activity of Plant Material Counts/Min x 10^3			Accumulation and Translocation of C^{14} %		
	1st Trifol. Unfolding	2nd Trifol. Unfolding	3rd Trifol. Unfolding	1st Trifol. Unfolding	2nd Trifol. Unfolding	3rd Trifol. Unfolding
Treated Primary Blade	231.6	147.9	176.4	53.7	34.3	41.0
Treated Primary Petiole	3.8	3.3	4.2	0.9	0.8	1.0
Untreated Primary Blade	3.3	3.2	3.4	0.8	0.7	0.8
Untreated Primary Petiole	0.7	0.6	0.6	0.2	0.1	0.1
Growing Tip	71.5	100.4	13.0	16.6	23.3	3.0
Stem	49.8	85.4	100.6	11.6	19.8	23.3
Root	22.9	33.3	38.2	5.3	7.7	8.8
1st Trifoliate Blade		4.5	2.0		1.0	0.5
1st Trifoliate Petiole		1.7	0.5		0.4	0.1
2nd Trifoliate Blade			8.3			1.9
2nd Trifoliate Petiole			2.7			0.6
Total Exclusive of Treated Leaf	148.2	229.1	169.3	34.5	53.0	39.1
Total	383.6	380.3	349.9	89.1	88.1	81.1
Total Activity Applied	431.6	431.6	431.6			

A

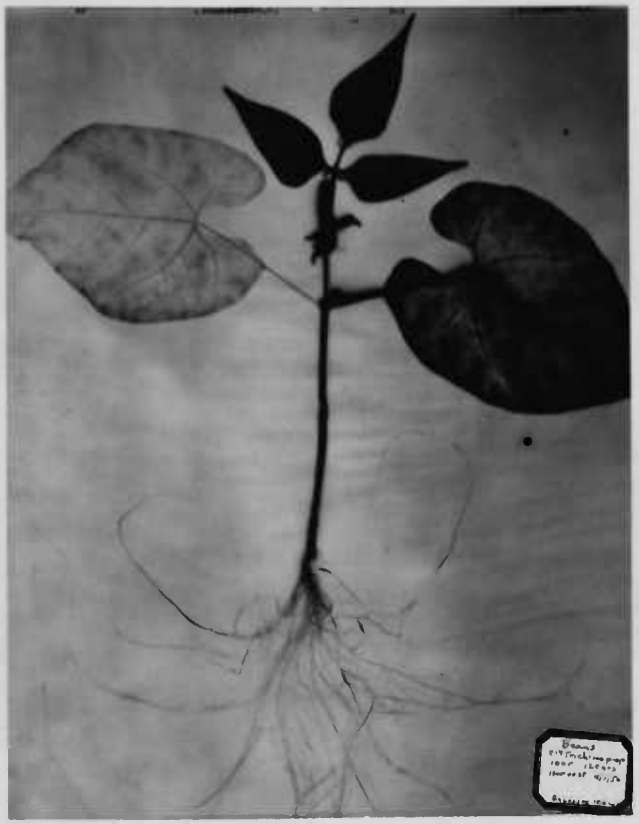
B

Plate 9. Radioautographs of bean plants harvested (A) two hours and (B) one day after the application of 100 μg. TPA * to one primary leaf blade when the first trifoliate leaf was just unfolding.

A

B

Plate 10. Radioautographs of bean plants harvested (A) two days and (B) three days after the application of 100 μg. TPA* to one primary leaf blade when the first trifoliate leaf was unfolding.



A

B

Plate 11.
Radioautographs of bean plants harvested (A) five days and (B) seven days after the application of 100 μg. TPA* to one primary leaf blade when the first trifoliate leaf was unfolding.

into new tissue as the plant developed, but very little seemed to enter the more mature untreated primary leaf even after seven days presentation time.

The graphs in Figure 3, describing the more pertinent data contained in Table 4, indicate that the stem contained most of the C^{14} which had been translocated out of the treated leaf during the first twenty-four hours following the TPA-2-C^{14} application. The amount of radioactivity in the stem increased only negligibly during the succeeding twenty-four hours, while the radioactive carbon in the growing tip and the root (in much less quantity) continued to increase through the first three days of the experiment. As the presentation time progressed further, all three of these plant parts gradually lost C^{14}. However, if the radioactivity contained in the trifoliate leaves is considered along with that found in the growing tip, it is apparent that translocation and accumulation of C^{14} in the rapidly growing tissue of TPA-2-C^{14} treated plants continued through the seven day experimental period. At the conclusion of the trial the growing tip plus the trifoliate leaves contained over 60 percent of the radioactivity originally applied to the plant.

The radioactive carbon in the treated leaf was lost at a fairly constant rate over the seven day presentation period. During the first five days of the experiment there was a corresponding increase of C^{14} in the rest of the plant. Since the total recoverable radioactivity remained fairly constant at a relatively high level through these same five days it is assumed that the loss of

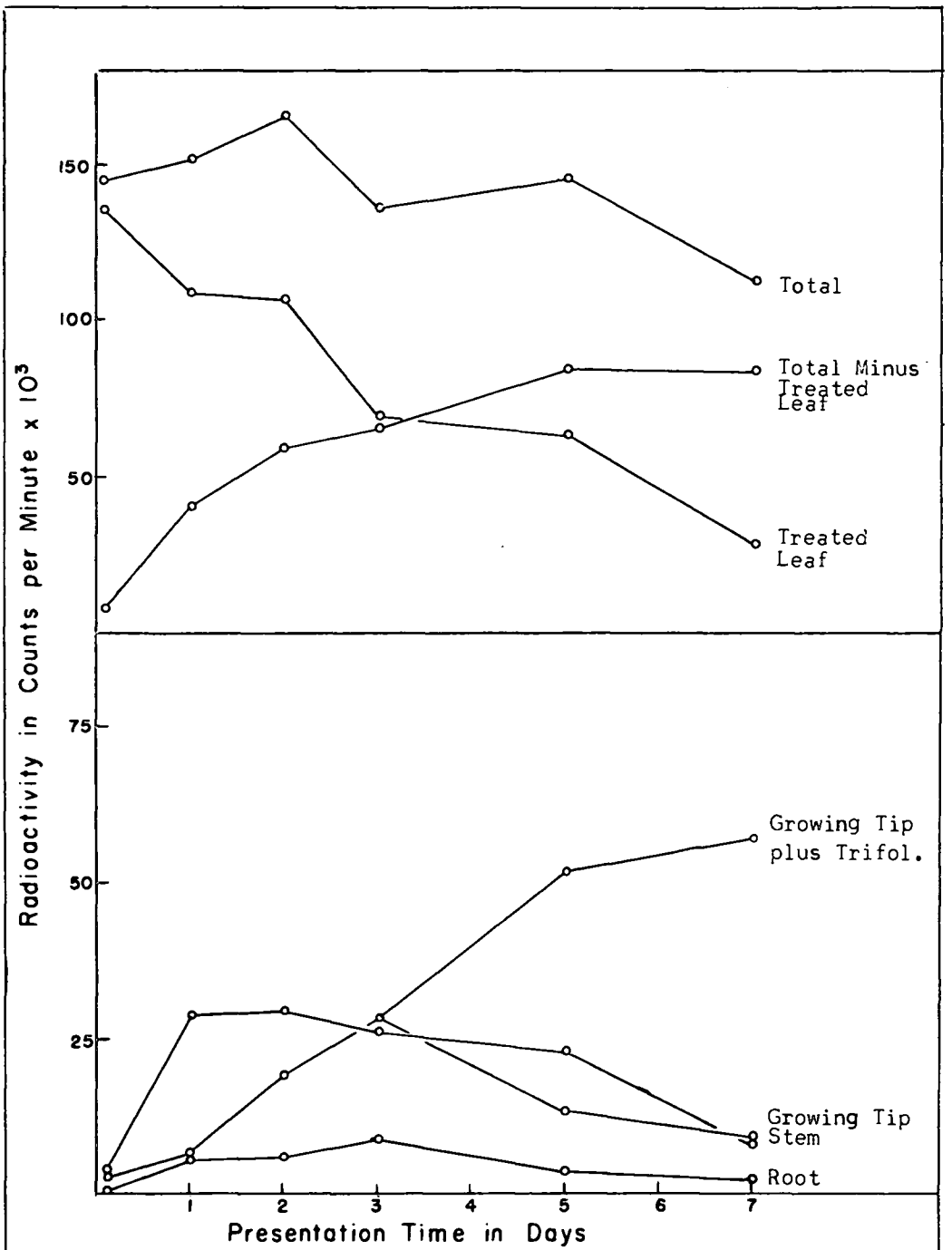


Figure 3. Accumulation of radioactivity in bean plants harvested at different times after treatment with 100 μg. of C^{14} labeled sodium 2,2,3-trichloropropionate.

Table 4

Accumulation of Radioactivity in Bean Plants Harvested at Different Times After Application of 100 μg C^{14} Labeled Sodium 2,2,3-trichloropropionate to One Primary Leaf Blade

Plant Part	Total Activity of Plant Material Counts/Min x 10^3						Translocation and Accumulation of C^{14} %					
	2 hours	1 day	2 days	3 days	5 days	7 days	2 hours	1 day	2 days	3 days	5 days	7 days
Treated Primary Blade	128.3	103.3	105.2	65.8	59.7	28.6	73.7	59.3	60.4	37.8	34.3	16.4
Treated Primary Petiole	7.6	6.6	1.7	4.2	3.1	0.8	4.4	3.8	1.0	2.4	1.8	0.5
Untreated Primary Blade	0.6	1.1	1.8	2.4	3.2	3.9	0.3	0.6	1.0	1.4	1.8	2.2
Untreated Primary Petiole	0.3	0.1	1.9	0.2	0.2	0.1	0.2	0.1	1.1	0.1	0.1	0.1
Growing Tip	3.0	6.3	19.7	28.4	13.0	9.5	1.7	3.6	11.3	16.3	7.5	5.5
Stem	4.4	28.3	29.7	26.5	23.6	8.0	2.5	16.3	17.1	15.2	13.6	4.6
Root	0.3	5.1	6.1	9.0	4.1	2.6	0.2	2.9	3.5	5.2	2.4	1.5
1st Trifoliate Blade					37.9	43.4					21.8	24.9
1st Trifoliate Petiole					1.1	0.6					0.6	0.3
2nd Trifoliate Blade						13.8						7.9
2nd Trifoliate Petiole						0.8						0.5
Total Minus Treated Blade and Petiole	8.6	40.9	59.2	66.5	83.1	82.7	4.9	23.5	34.0	38.2	47.8	47.5
Total	144.5	150.8	166.1	136.5	145.9	112.1	83.0	86.6	95.4	78.4	83.9	64.4
Total Theoretically Applied	174.1	174.1	174.1	174.1	174.1	174.1						

radioactivity from the treated leaf represented translocation to the other plant parts. The decrease in the total C^{14} recovered from the fifth to the seventh day after the experiment was initiated suggests that during this period TPA-2-C^{14} was being broken down by the bean plant.

2. Absorption and Translocation in Plants Treated with Various Amounts of Chemical. The data presented in Table 5 and in Figure 4 indicate that the accumulation of radioactivity in the growing tip, root, and stem increased as the amount of TPA-2-C^{14} applied to the plant was increased from 50 to 200 µgm. Treatment with 300 µgm., however, resulted in a decrease in the amount of C^{14} found in the stem, and only a negligible increase in the root and growing tip. Thus, the total of the plant parts, exclusive of the treated leaf, showed a maximum C^{14} accumulation after the application of 200 µgm. of TPA-2-C^{14}. Conversely, the total recoverable radioactivity, and the amount of C^{14} in the treated leaf continued to increase as the rate of application of TPA-2-C^{14} was increased from 50 through 300 µgm. This would indicate that regardless of the amount of chemical absorbed by the treated leaf, only a limited quantity of C^{14} was translocated to the other portions of the young bean plant during the first twenty-four hours following treatment.

Following treatment at all rates of application, the major portion of C^{14} in TPA-2-C^{14} treated plants (aside from that in the treated leaf) accumulated in the stem during the twenty-four hour presentation time (Figure 4). In DPA-2-C^{14} treated plants, the

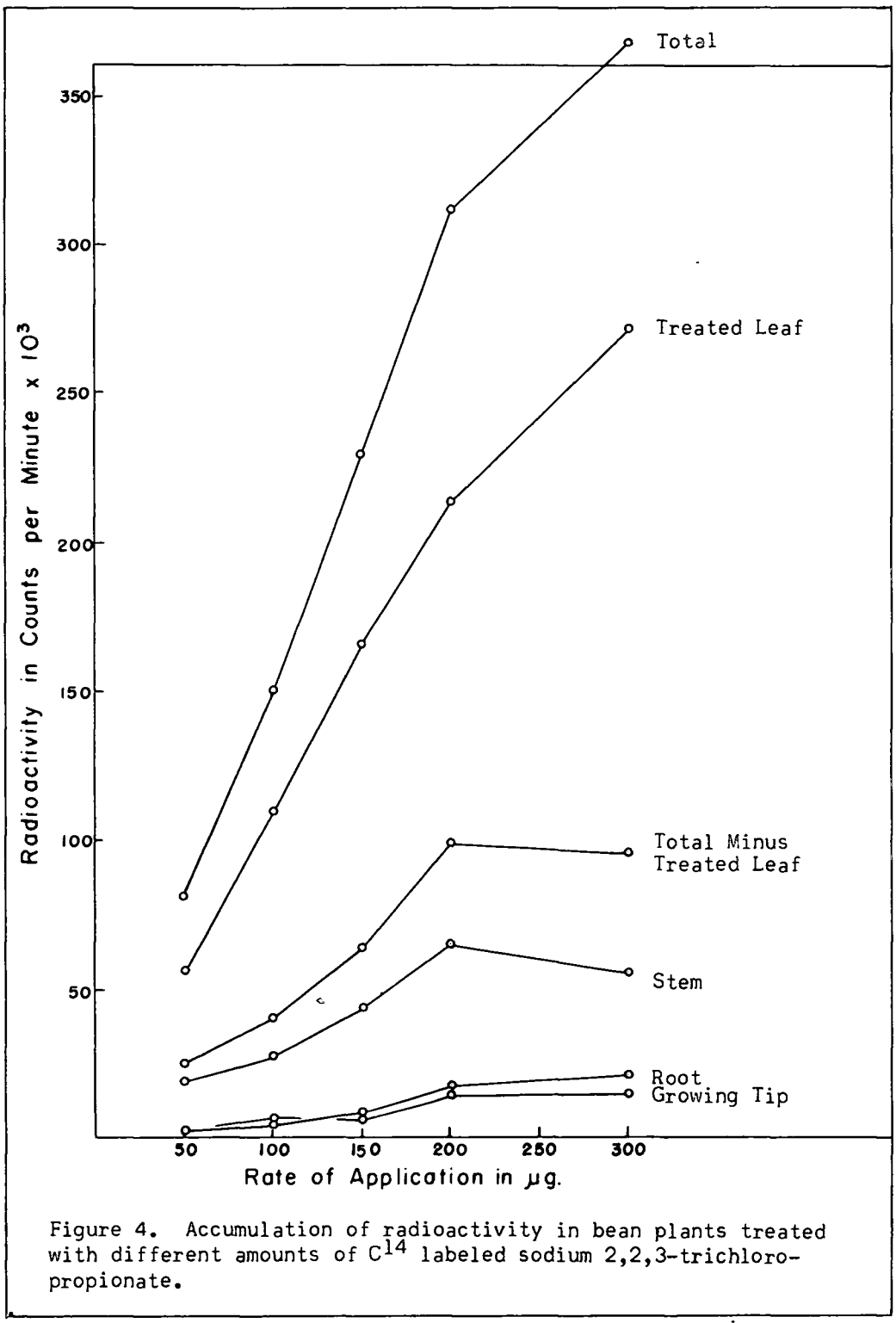


Figure 4. Accumulation of radioactivity in bean plants treated with different amounts of C^{14} labeled sodium 2,2,3-trichloro-propionate.

Table 5

Accumulation of Radioactivity in Bean Plants Treated on One Primary Leaf Blade with Various Rates of C^{14} Labeled Sodium 2,2,3-trichloropropionate. Plants Harvested Twenty-four Hours After Treatment

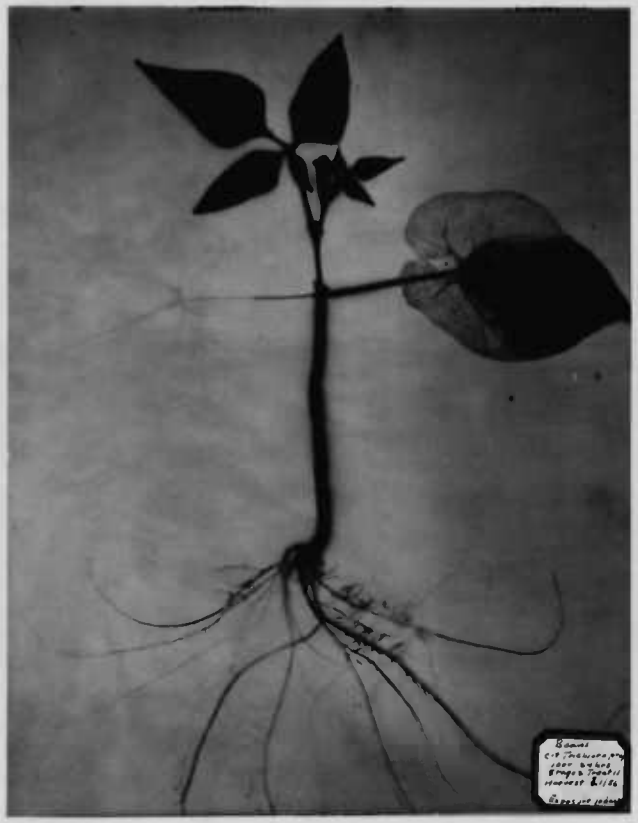
Plant Part	Total Activity of Plant Material Counts/Min x 10^3					Translocation and Accumulation of C^{14} %				
	50 µg	100 µg	150 µg	200 µg	300 µg	50 µg	100 µg	150 µg	200 µg	300 µg
Treated Primary Blade	55.6	103.3	163.5	200.1	252.7	63.8	59.3	62.6	57.5	48.4
Treated Primary Petiole	1.2	6.6	2.0	13.1	18.1	1.4	3.8	0.8	3.8	3.5
Untreated Primary Blade	0.0	1.1	2.3	0.0	2.1	0.0	0.6	0.9	0.0	0.4
Untreated Primary Petiole	0.5	0.1	0.2	0.5	0.6	0.6	0.1	0.1	0.1	0.1
Growing Tip	2.5	6.3	8.6	14.9	15.2	2.9	3.6	3.3	4.3	2.9
Stem	19.7	28.3	43.2	65.1	57.2	22.6	16.3	16.5	18.7	10.9
Root	2.3	5.1	9.6	18.3	21.1	2.6	2.9	3.7	5.3	4.0
Total Exclusive of Treated Blade and Petiole	25.0	40.9	63.9	98.8	96.2	28.7	23.5	24.5	28.4	18.3
Total	81.8	150.8	229.4	312.0	367.0	93.9	86.6	87.9	89.7	70.2
Total Theoretically Applied	87.1	174.1	261.2	348.2	522.3					

growing tip accumulated considerably more C^{14} than the stem (Figure 2). These observations suggest that C^{14} is translocated more rapidly in bean plants treated with DPA-2-C^{14} than with TPA-2-C^{14}.

3. Absorption and Translocation Influenced by Plant Stage of Growth. Radioautographs (Plate 12) indicate that within one day after treatment radioactivity could be located in all parts of the bean plants treated with TPA-2-C^{14} at all three stages of growth, however, measurements of radioactivity (Table 6) show that no C^{14} could be detected in the roots of plants treated at the third stage of growth. It is also apparent from the radioautographs that fairly large quantities of radioactive carbon accumulated in the trifoliate leaves of the older plants, but that very little radioactive carbon accumulated in the untreated primary leaf of plants treated at any stage of growth.

The data in Table 6 indicate that plants to which TPA-2-C^{14} was applied at the second and third stages of growth accumulated a relatively high percentage of the total recoverable radioactivity in the trifoliate leaves. In plants treated at the first stage of growth the majority of the C^{14}, aside from that in the treated leaf, was found in the stem. The radioactive carbon in the stem, the root, and the growing tip decreased as progressively older bean plants were treated.

The recovery of radioactivity from the entire plant, and from the treated leaf appeared to increase as plants of the second and third growth stages were treated. As previously indicated, the



A

B

Plate 12. Radioautographs of bean plants treated with 100 μg. TPA* on one primary leaf blade when (A) second trifoliate leaf was unfolding and (B) third trifoliate leaf was unfolding. Harvested one day after treatment.

Table 6

Accumulation of Radioactivity in Bean Plants Treated with 100 μg of Radioactive Sodium 2,2,3-trichloropropionate at Three Stages of Growth. Plants Harvested Twenty-four Hours after Treatment

Plant Part	Total Activity of Plant Material Counts/Min x 10^3			Accumulation and Translocation of C^{14} %		
	1st Trifol. Unfolding	2nd Trifol. Unfolding	3rd Trifol. Unfolding	1st Trifol. Unfolding	2nd Trifol. Unfolding	3rd Trifol. Unfolding
Treated Primary Blade	103.3	98.6	117.3	59.3	56.6	67.4
Treated Primary Petiole	6.6	3.6	5.4	3.8	2.1	3.1
Untreated Primary Blade	1.1	0.2	0.4	0.6	0.1	0.2
Untreated Primary Petiole	0.1	0.1	0.1	0.1	0.1	0.1
Growing Tip	6.3	6.9	1.6	3.6	4.0	0.9
Stem	28.3	25.9	17.7	16.3	14.9	10.2
Root	5.1	4.0	0.0	2.9	2.3	0.0
1st Trifoliate Blade		22.3	13.8		12.8	7.9
1st Trifoliate Petiole		1.4	0.5		0.8	0.3
2nd Trifoliate Blade			11.5			6.6
2nd Trifoliate Petiole			1.0			0.6
Total Minus Treated Blade and Petiole	40.9	60.8	46.6	23.5	35.0	26.8
Total	150.8	163.0	169.3	86.6	93.7	97.3
Total Theoretically Applied	174.1	174.1	174.1			

opposite trend was noticeable in bean plants treated with DPA-2-C^{14} at different stages of development.

Absorption of DPA-2-C^{14} and Translocation of C^{14} in Sweet Corn Plants.

1. Rate of Absorption and Translocation. It is apparent from the data in Table 7 and from Plate 13 that DPA-2-C^{14} was absorbed into the treated tip of the second leaf and that small quantities of C^{14} were translocated to all other portions of the sweet corn plant within two hours after treatment. Twenty-four hours were necessary for the radioactive carbon to be distinguishable throughout the entire plant. Plates 13-15 indicate that there was a gradual increase of radioactivity in the plant parts other than the treated leaf, and that as the experimental period progressed, C^{14} quite readily moved into newly developing plant tissue.

The graph in Figure 5, prepared from data presented in Table 7, clearly shows the pattern of C^{14} translocation in sweet corn plants treated with DPA-2-C^{14}. Twenty-four hours after treatment the second leaf (minus treated tip) and the root contained a large proportion of the radioactive carbon which had moved out of the treated tip of the second leaf blade. The quantity of C^{14} in the second leaf (minus treated tip) increased through the third day, after which more than one-half of its radioactivity was lost in the ensuing four days. The C^{14} in the root decreased in amount during the second twenty-four hours of the experiment and then remained at a fairly constant level. The third leaf increased in C^{14} accumulation through the first two days following application, lost radioactivity during the

A

B

Plate 13. Radioautographs of sweet corn plants harvested (A) two hours and (B) one day after the application of 100 μg. DPA* to the distal 1 to 2 inches of the second leaf at the time the fourth leaf was emerging.

A

B

Plate 14. Radioautographs of sweet corn plants harvested (A) two days and (B) three days after the application of 100 μg. DPA* to the distal 1 to 2 inches of the second leaf at the time the fourth leaf was emerging.

A

B

Plate 15. Radioautographs of sweet corn plants harvested (A) five days and (B) seven days after the application of 100 μg. DPA* to the distal 1 to 2 inches of the second leaf at the time the fourth leaf was emerging.

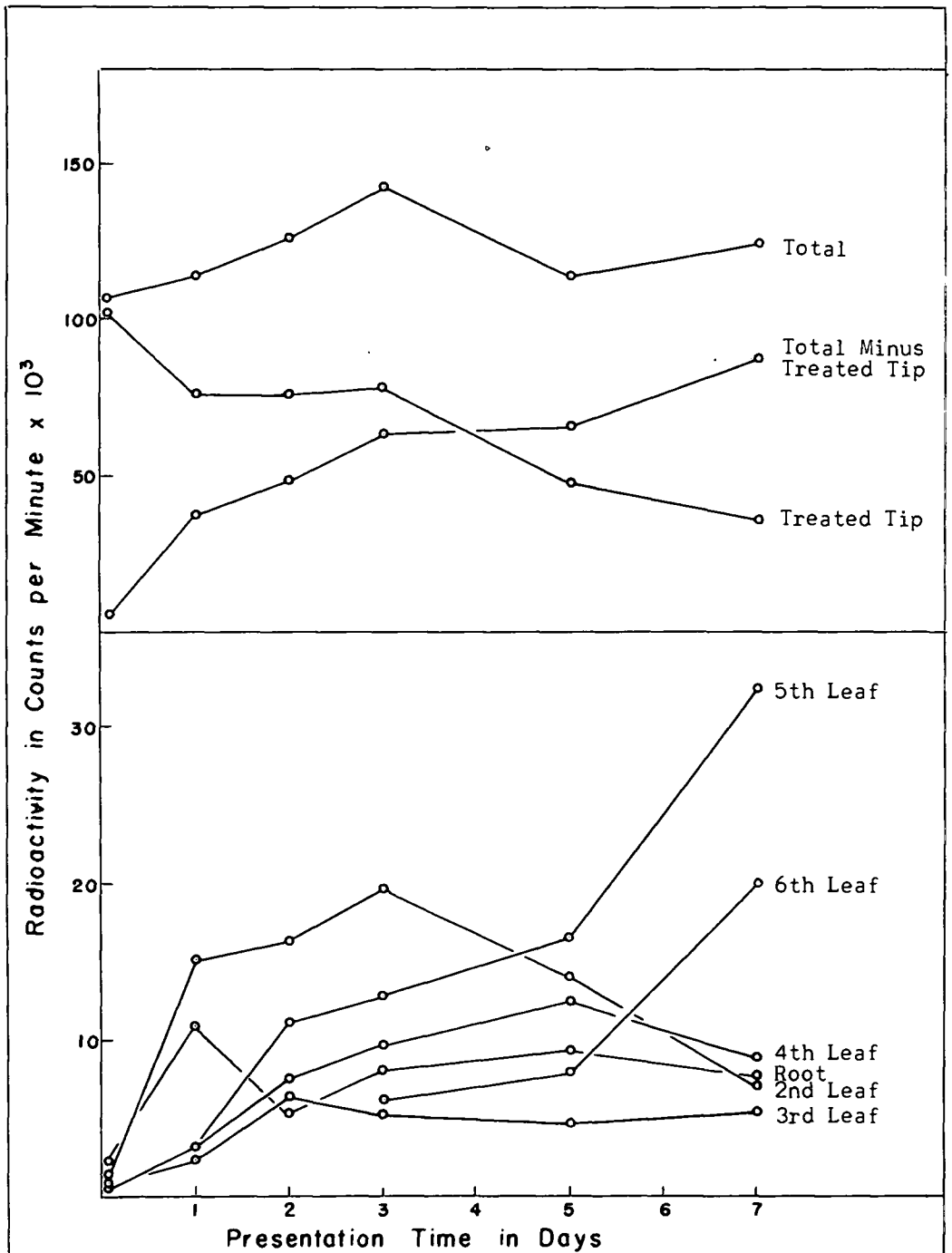


Figure 5. Accumulation of radioactivity in sweet corn plants harvested at different times after treatment with 100 μg. of C^{14} labeled sodium 2,2-dichloropropionate.

Table 7

Accumulation of Radioactivity in Corn Plants Harvested at Different Times After Application of 100 μg C^{14} Labeled Sodium 2,2-dichloropropionate to the Distal Two Inches of the Second Leaf Blade

Plant Part	Total Activity of Plant Material Counts/Min x 10^3						Translocation and Accumulation of C^{14} %					
	2 hours	1 day	2 days	3 days	5 days	7 days	2 hours	1 day	2 days	3 days	5 days	7 days
1st Blade	0.9	0.6	0.5	0.1	0.2	0.4	0.8	0.3	0.2	0.1	0.1	0.2
1st Sheath	0.3	2.0	1.2	0.5	0.4	0.4	0.1	0.9	0.5	0.2	0.2	0.2
2nd Blade Minus Tip	1.9	10.7	10.3	13.1	8.6	4.5	0.4	4.6	4.4	5.6	3.7	1.9
2nd Sheath	0.4	4.5	6.0	6.6	3.4	2.6	0.2	1.9	2.6	2.8	1.5	1.1
3rd Blade	0.4	2.0	4.1	3.8	3.6	3.3	0.2	0.9	1.8	1.6	1.6	1.4
3rd Sheath	0.1	0.6	2.5	1.8	1.1	2.2	0.1	0.3	1.1	0.8	0.5	0.9
4th Leaf	0.3	3.1	7.8	9.9	12.4		0.1	1.3	3.4	4.3	5.3	
4th Blade						5.5						2.4
4th Sheath						3.2						1.4
5th Leaf		3.0	11.1	12.8	18.4	32.3		1.3	4.8	5.5	7.9	13.9
6th Leaf				6.2	8.0	20.0				2.7	3.4	8.6
7th Leaf						5.6						2.4
Root	2.1	10.9	5.6	8.1	9.2	7.8	0.9	5.7	2.4	3.5	4.0	3.4
Treated Tip-2nd Blade	101.4	76.2	76.9	78.3	47.9	36.1	43.8	32.8	33.2	33.8	20.7	15.6
Total Minus Treated Tip	6.4	37.4	49.1	62.9	65.3	87.8	2.8	16.2	21.2	27.1	28.2	37.8
Total	107.8	113.6	126.0	141.2	113.2	123.9	46.6	49.0	54.4	60.9	48.9	53.4
Total Theoretically Applied	231.9	231.9	231.9	231.9	231.9	231.9						

next twenty-four hours, and then did not change through the rest of the experimental period. The accumulation of radioactivity in the rapidly developing fourth, fifth, and sixth leaves increased gradually through five days after which the fourth leaf lost C^{14}, and the gain of radioactive carbon in the fifth and sixth leaves was very marked. The quantity of C^{14} detected in the first leaf was quite small at all stages of the experiment, but in contrast to the other leaves, the larger proportion of activity was found in the leaf sheath instead of in the leaf blade.

The consistent increase in amount of radioactive carbon in the portion of the plant exclusive of the treated tip corresponds quite well with a rather consistent loss of C^{14} from the treated tip. Throughout the experimental period the total recoverable radioactivity remained rather constant, suggesting that DPA-2-C^{14} was not broken down in sweet corn plants during the seven days following treatment.

2. Absorption and Translocation in Plants Treated with Various Amounts of Chemical. The data in Table 8, shown graphically in Figure 6, indicate that except for the second leaf, all parts of the sweet corn plant increased in C^{14} accumulation as the rate of application of DPA-2-C^{14} was raised from 50 to 300 µgm. However, although the total recoverable radioactivity and the C^{14} in the treated tip increased almost in direct proportion to the rate applied, the percentage of translocation from the treated leaf to the other parts of the plant decreased as higher rates of application were used. It would appear that treatment with more than 200 µgm. of DPA-2-C^{14}

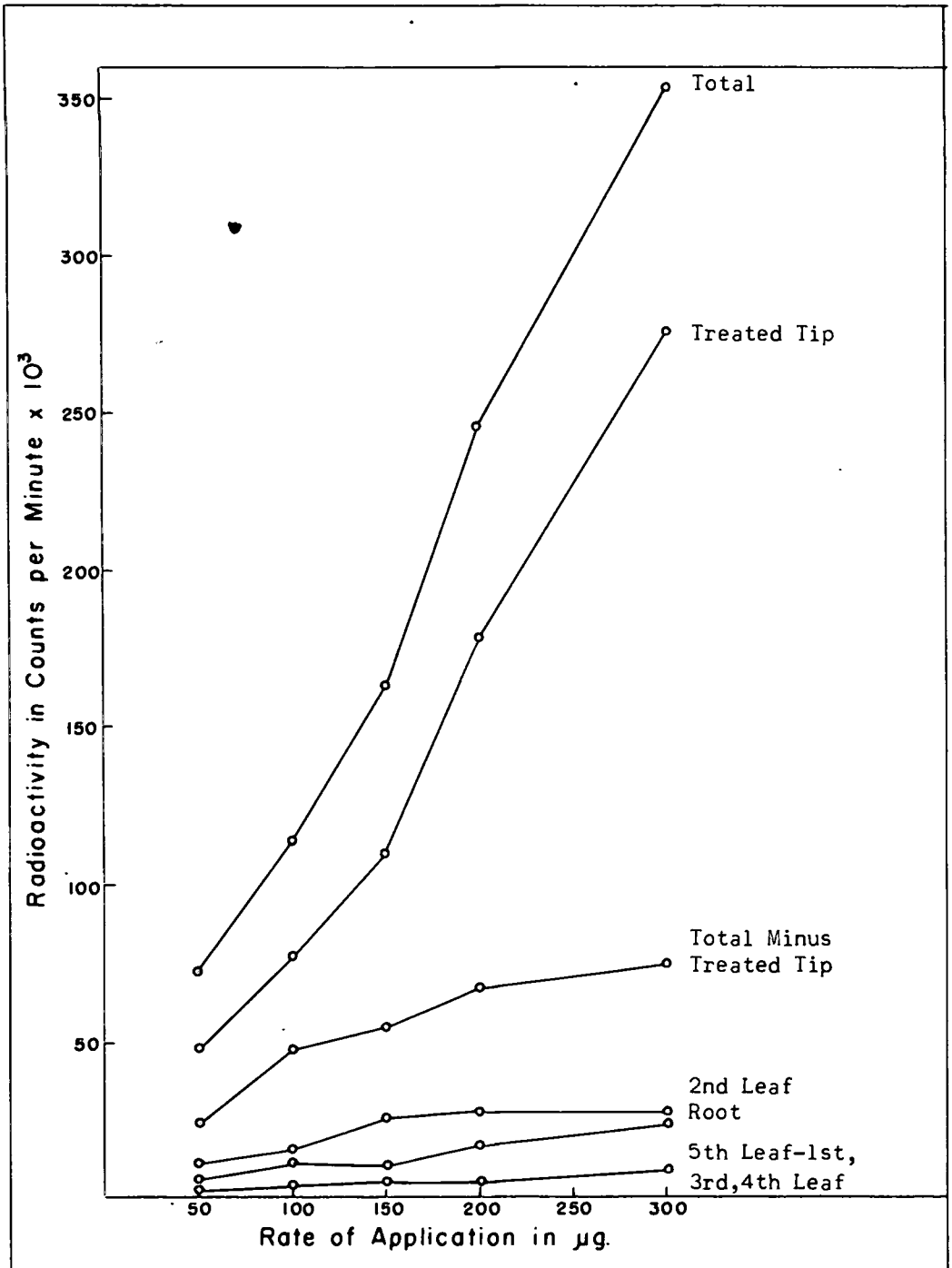


Figure 6. Accumulation of radioactivity in sweet corn plants treated with different amounts of C^{14} labeled sodium 2,2-dichloropropionate.

Table 8

Accumulation of Radioactivity in Corn Plants Treated on the Distal Two Inches of the Second Leaf Blade with Various Rates of C^{14} Labeled Sodium 2,2-dichloropropionate. Plants Harvested Twenty-four Hours after Treatment

Plant Part	Total Activity of Plant Material Counts/Min x 10^3					Translocation and Accumulation of C^{14} %				
	50 µg	100 µg	150 µg	200 µg	300 µg	50 µg	100 µg	150 µg	200 µg	300 µg
1st Blade	0.3	0.6	0.4	1.9	1.1	0.3	0.3	0.1	0.4	0.2
1st Sheath	0.3	2.0	2.3	4.8	3.8	0.3	0.9	0.7	1.0	0.5
2nd Blade-Minus Tip	7.5	10.7	18.2	20.3	16.5	6.5	4.6	5.2	4.4	2.4
2nd Sheath	3.2	4.5	7.2	6.9	10.6	2.8	1.9	2.1	1.5	1.5
3rd Blade	1.5	2.0	3.7	3.9	4.2	1.3	0.9	1.1	0.8	0.6
3rd Sheath	0.6	0.6	1.1	1.2	1.6	0.5	0.3	0.3	0.3	0.2
4th Leaf	2.9	3.1	4.8	4.9	6.4	2.5	1.3	1.4	1.1	0.9
5th Leaf	2.8	3.0	4.8	5.1	9.2	2.4	1.3	1.4	1.1	1.3
Root	4.8	10.9	10.6	17.9	23.1	4.1	5.7	3.0	3.9	3.3
Treated Tip	48.6	76.2	109.5	177.8	275.9	41.9	32.8	31.5	38.3	39.6
Total Minus Treated Tip	23.9	37.4	53.1	66.9	76.5	20.7	16.2	15.3	14.5	10.9
Total	72.5	113.6	162.6	244.7	352.4	62.6	49.0	46.8	52.8	50.5
Total Theoretically Applied	116.0	231.9	347.9	463.8	695.6					

resulted in only a negligible increase in the amount of C^{14} being accumulated in the plant parts aside from the treated leaf during a twenty-four hour presentation period.

3. Absorption and Translocation Influenced by Plant Stage of Growth. The radioautographs presented in Plate 16 show that radioactive carbon was translocated throughout sweet corn plants at three stages of growth within twenty-four hours after treatment with DPA-2-C^{14}. The majority of the radioactivity appeared to be accumulated in the treated tip and the remainder of the second leaf blade and sheath after only a one day presentation period.

Data contained in Table 9 indicate that total recoverable radioactivity, and the amount of C^{14} in the total plant, exclusive of the treated tip, tended to increase as successively older plants were treated. There was much more radioactive carbon found in the treated tips of plants treated at the second than at the first growth stage, and slightly more at the second than at the third stage of growth. The increased translocation out of the treated tip of the progressively older plants appears to have been primarily to the rapidly developing leaves since the amount of radioactivity in the root, the first, the second (minus treated tip), and the third leaves did not vary greatly in the plants treated at the different stages of growth.

Absorption of TPA-2-C^{14} and Translocation of C^{14} in Sweet Corn Plants.

1. Rate of Absorption and Translocation. Plates 17-19 and the data in Table 10 show that within two hours after the application of

A

B

Plate 16. Radioautographs of sweet corn plants treated with 100 μg. DPA* on the distal 1 to 2 inches of the second leaf at the time (A) the fifth leaf was emerging and (B) the sixth leaf was emerging. Harvested one day after treatment.

Table 9

Accumulation of Radioactivity in Corn Plants Treated on the Distal Two Inches of the 2nd Leaf Blade with 100 μg of C^{14} Labeled Sodium 2,2-dichloropropionate at Three Stages of Growth. Plants Harvested Twenty-four Hours after Treatment

Plant Parts	Total Activity in Plant Material Counts/Min x 10^3			Translocation and Accumulation of C^{14} %		
	4th Leaf Emerging	5th Leaf Emerging	6th Leaf Emerging	4th Leaf Emerging	5th Leaf Emerging	6th Leaf Emerging
1st Blade	0.6	1.6	3.8	0.3	0.7	1.6
1st Sheath	2.0	0.3	0.2	0.9	0.1	0.1
2nd Blade-Minus Tip	10.7	8.5	9.4	4.6	3.7	4.1
2nd Sheath	4.5	3.8	3.9	1.9	1.6	1.7
3rd Blade	2.0	1.9	1.3	0.9	0.8	0.6
3rd Sheath	0.6	1.1	0.8	0.3	0.5	0.3
4th Leaf	3.1	5.7		1.3	2.5	
4th Blade			11.5			5.0
4th Sheath			0.9			0.4
5th Leaf	3.0	8.6	7.3	1.3	3.7	3.1
6th Leaf		8.7	4.7		3.8	2.0
7th Leaf			1.8			0.8
Root	10.9	5.6	11.3	5.7	2.4	4.9
Treated Tip-2nd Blade	76.2	133.7	125.7	32.8	57.7	54.2
Total Minus Treated Tip	37.4	45.8	56.9	16.2	19.8	24.6
Total	113.6	179.5	182.6	49.0	77.5	78.8
Total Theoretically Applied	231.9	231.9	231.9			

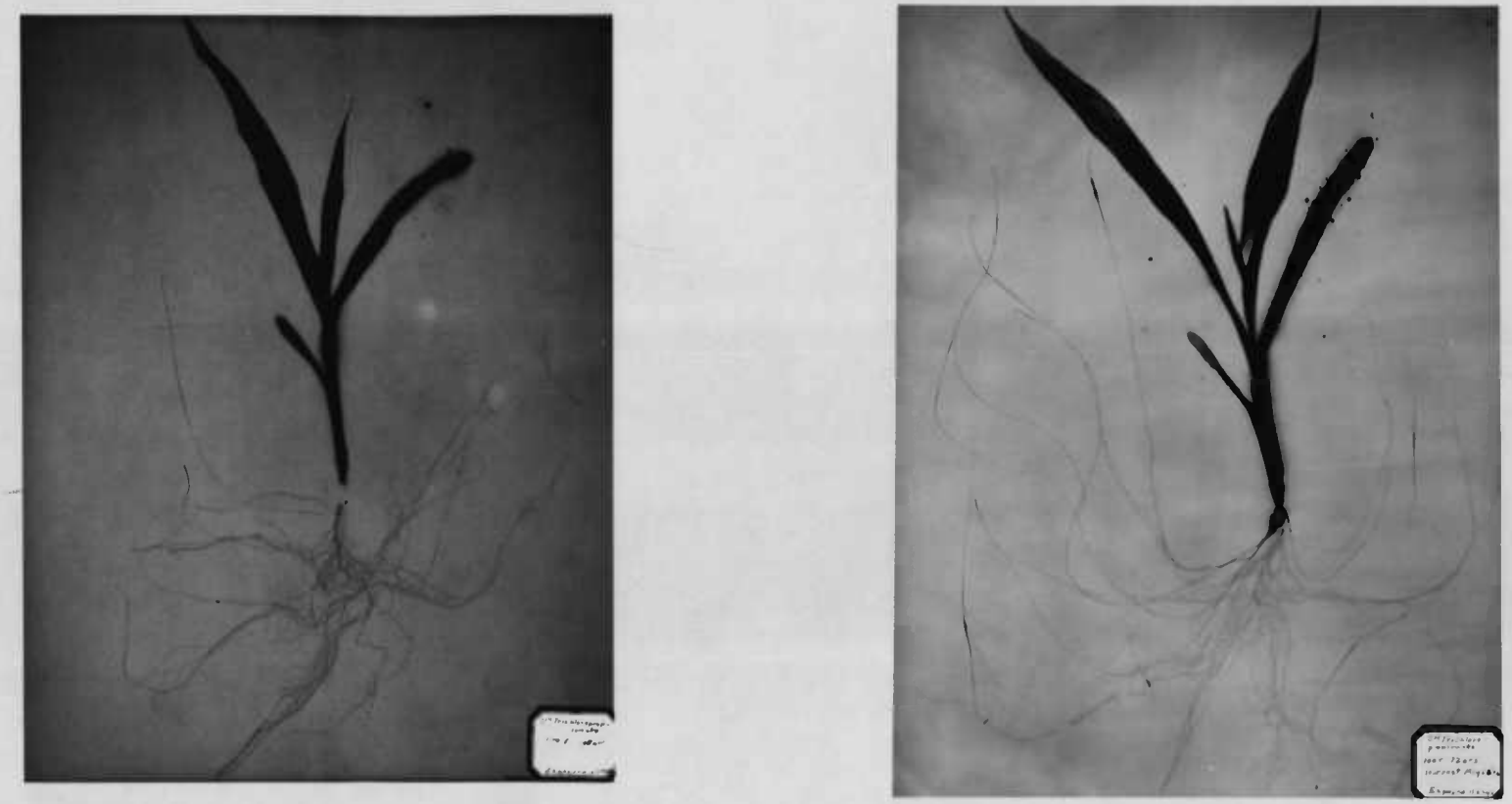
TPA-2-C^{14} to sweet corn plants C^{14} had moved to all parts of the plant although the majority of the radioactive carbon was still found in the second leaf. Twenty-four hours after treatment sufficient amounts of C^{14} had been translocated throughout the plant to show all plant sections clearly in radioautographs. As the sweet corn plants developed new tissue the C^{14} was translocated into these rapidly growing plant parts.

Figure 7 illustrates the more pertinent data contained in Table 10 and shows that throughout the seven day experimental period most of the radioactivity, aside from that in the treated tip, was in the second leaf (minus treated tip). The accumulation of C^{14} in the second leaf (minus treated tip) was very high in relation to the other untreated plant parts through the first two days following treatment with TPA-2-C^{14}, after which this leaf lost some C^{14} in the ensuing five days. All of the other plant parts except the treated tip increased in the amount of C^{14} accumulation throughout the seven day presentation period. The quantity of radioactive carbon in these plant sections was quite low at all times as indicated by the curve depicting the total activity minus that in the treated tip. The maximum amount of radioactivity translocated out of the treated tip was only 29 percent of the total amount of C^{14} applied to the plant and though the treated tip did lose C^{14} throughout the trial, the minimum quantity found in this section was 28 percent of the original application, or over one-half of the total amount found in the entire plant. The radioactive carbon from TPA-2-C^{14} apparently was not translocated out of the growing tip to the other parts of the

A

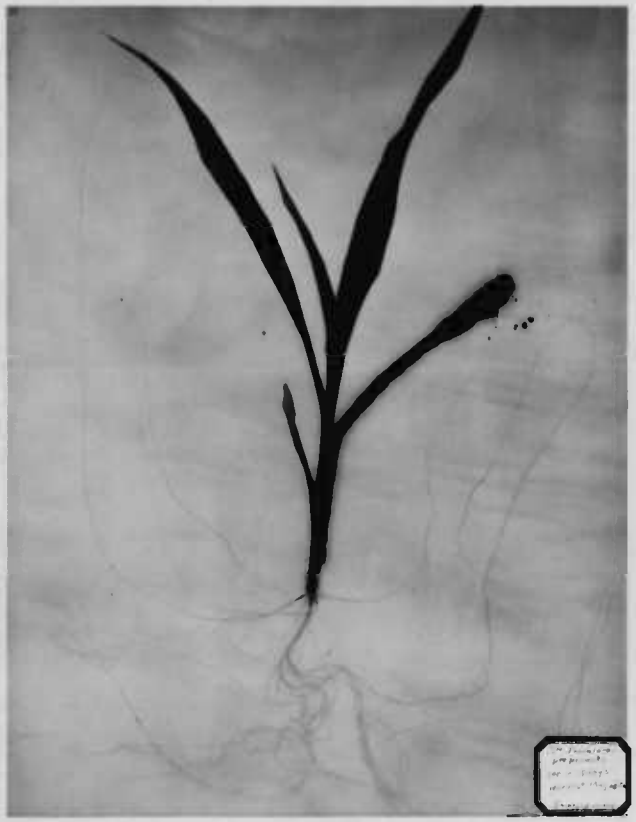
B

Plate 17. Radioautographs of sweet corn plants harvested (A) two hours and (B) one day after the application of 100μg. TPA* to the distal 1 to 2 inches of the second leaf at the time the fourth leaf was emerging.



A B

Plate 18. Radioautographs of sweet corn plants harvested (A) two days and (B) three days after the application of 100 μg. TPA* to the distal 1 to 2 inches of the second leaf at the time the fourth leaf was emerging.



A

B

Plate 19. Radioautographs of sweet corn plants harvested (A) five days and (B) seven days after the application of 100 μg. TPA* to the distal 1 to 2 inches of the second leaf at the time the fourth leaf was emerging.

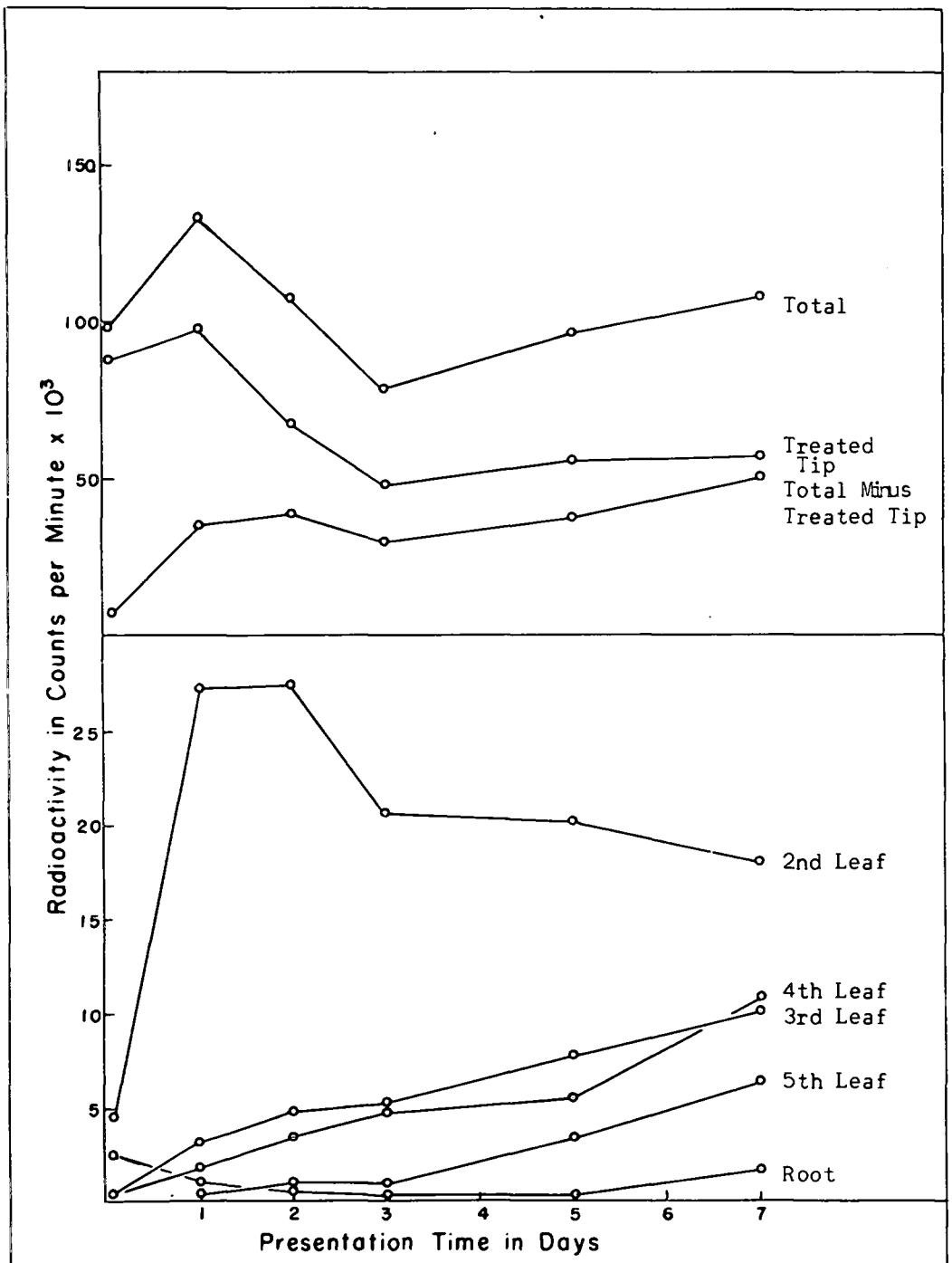


Figure 7. Accumulation of radioactivity in sweet corn plants harvested at different times after treatment with 100 μg. of C^{14} labeled sodium 2,2,3-trichloropropionate.

Table 10

Accumulation of Radioactivity in Corn Plants Harvested at Different Times After Application of 100 μg C^{14} Labeled Sodium 2,2,3-trichloropropionate to the Distal Two Inches of the Second Leaf Blade

Plant Part	Total Activity of Plant Material Counts/Min x 10^3						Translocation and Accumulation of C^{14} %					
	2 hours	1 day	2 days	3 days	5 days	7 days	2 hours	1 day	2 days	3 days	5 days	7 days
1st Blade	0.4	0.5	0.9	0.9	0.6	0.6	0.2	0.3	0.5	0.5	0.3	0.3
1st Sheath	0.4	0.8	1.3	1.0	0.6	0.8	0.2	0.5	0.7	0.6	0.3	0.5
2nd Blade Minus Tip	3.0	16.8	16.6	13.3	10.8	7.9	1.7	9.5	9.4	7.5	6.1	4.5
2nd Sheath	1.4	10.4	10.7	7.2	9.3	10.2	0.8	5.9	6.1	4.1	5.2	5.8
3rd Blade	0.2	2.9	4.5	4.6	5.8	7.3	0.1	1.6	2.5	2.6	3.3	4.1
3rd Sheath		0.4	0.4	0.7	1.9	2.8		0.2	0.2	0.4	1.1	1.6
4th Leaf	0.3	1.9	3.6	4.8	5.5		0.2	1.1	2.0	0.5	3.1	
4th Blade						10.1						5.7
4th Sheath						0.8						0.5
5th Leaf		0.4	0.9	1.1	3.6	6.5		0.2	0.5	0.6	2.0	3.7
6th Leaf					0.6	1.4					0.3	0.8
7th Leaf						0.6						0.3
Root	2.3	0.8	0.5	0.2	0.2	1.9	1.3	0.5	0.3	0.1	0.1	1.1
Treated Tip-2nd Blade	89.4	98.5	69.1	49.3	56.8	57.9	50.6	55.7	39.1	27.9	32.1	32.7
Total Minus Treated Tip	8.0	34.9	39.4	29.8	38.9	50.9	4.5	19.7	22.4	16.9	21.8	28.9
Total	97.4	133.4	108.5	79.1	95.7	108.8	55.1	75.4	61.3	44.8	53.9	61.6
Total Applied	176.8	176.8	176.8	176.8	176.8	176.8						

sweet corn plant as rapidly as was the C^{14} from DPA-2-C^{14}.

Although the total recoverable radioactivity did vary considerably it appears that this variation was approximately equally distributed around the average of the points on the curve. This suggests that within seven days after treatment TPA-2-C^{14} was not broken down in sweet corn plants.

2. Absorption and Translocation in Plants Treated with Various Amounts of Chemical. The data in Table 11, summarized in graphic form in Figure 8, show that accumulation of C^{14} increased in all parts of corn plants as the rate of application was increased from 50 to 300 µgm. Although the total recoverable radioactivity and the radioactive carbon in the treated tip increased almost in direct proportion to the quantity of TPA-2-C^{14} applied, the amount of C^{14} in the rest of the plant increased only slightly as the rate of chemical application was increased. Regardless of the amount of TPA-2-C^{14} applied to the plants, the second leaf (minus treated tip) contained over one half of the radioactive carbon which accumulated in the untreated parts of the plant during the twenty-four hour presentation time. Of the other plant parts, the third leaf, the fourth leaf, the root, and the fifth leaf contained small quantities of radioactivity in the order listed. This again would indicate that TPA-2-C^{14} treated plants did not translocate C^{14} as quickly as those treated with DPA-2-C^{14}

3. Absorption and Translocation Influenced by Plant Stage of Growth. Radioautographs (Plate 20) indicate that within twenty-four hours

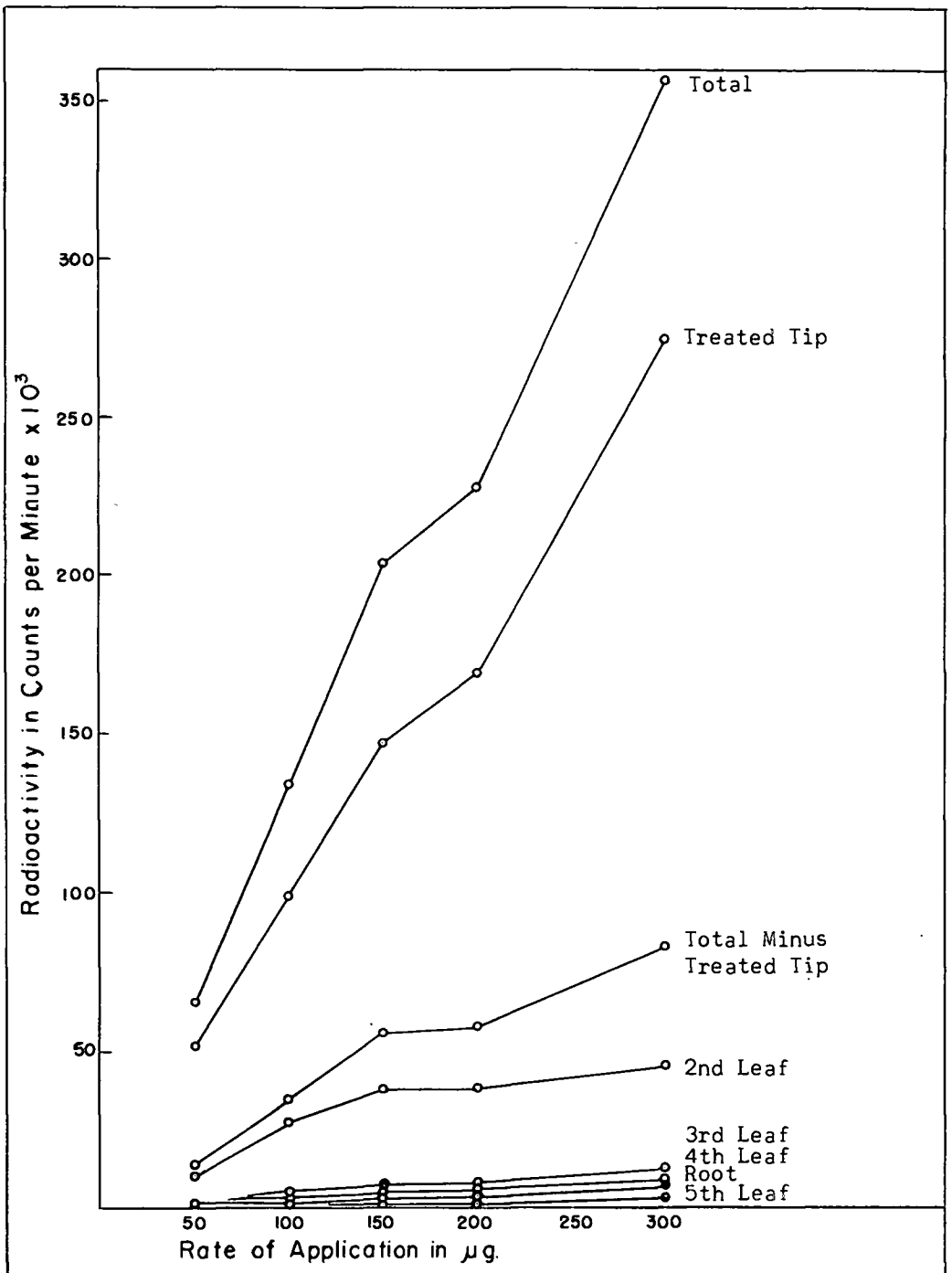


Figure 8. Accumulation of radioactivity in sweet corn plants treated with different amounts of C^{14} labeled sodium 2,2,3-trichloropropionate.

Table 11

Accumulation of Radioactivity in Corn Plants Treated on the Distal Two Inches of the Second Leaf Blade with Various Rates of Sodium 2,2,3-trichloropropionate.* Plants Harvested Twenty-four Hours after Treatment

Plant Part	Total Activity of Plant Material Counts/Min x 10^3					Translocation and Accumulation of C^{14} %				
	50 µg	100 µg	150 µg	200 µg	300 µg	50 µg	100 µg	150 µg	200 µg	300 µg
1st Blade	0.4	0.5	1.2	1.7	2.4	0.5	0.3	0.5	0.5	0.5
1st Sheath	0.3	0.8	1.4	1.5	2.2	0.3	0.5	0.5	0.4	0.4
2nd Blade-Minus Tip	6.0	16.8	24.5	25.2	27.3	6.8	9.5	9.2	7.1	5.1
2nd Sheath	4.5	10.4	14.3	12.8	18.1	5.1	5.9	5.4	3.6	3.4
3rd Blade	1.0	2.9	6.4	6.7	11.6	1.1	1.6	2.4	1.9	2.2
3rd Sheath	0.1	0.4	0.4	0.5	0.4	0.1	0.2	0.2	0.1	0.1
4th Leaf	0.4	1.9	4.5	5.4	9.3	0.5	1.1	1.7	1.5	1.8
5th Leaf	0.2	0.4	0.9	1.0	3.8	0.2	0.2	0.3	0.3	0.7
Root	0.7	0.8	2.6	2.9	7.0	0.8	0.5	1.0	0.8	1.3
Treated Tip-2nd Blade	50.9	98.5	146.9	169.9	275.0	57.5	55.7	55.3	48.0	51.8
Total Minus Treated Tip	13.6	34.9	56.2	57.7	82.1	15.4	19.7	21.2	16.2	15.5
Total	64.5	133.4	203.1	227.6	357.1	72.9	75.4	76.5	64.2	67.3
Total Theoretically Applied	88.4	176.8	265.2	353.6	530.4					

* C^{14} Labeled

after the application of TPA-2-C^{14}, radioactive carbon was translocated to all parts of sweet corn plants treated at three successive stages of growth. At the time of harvest the greatest concentration of radioactivity appeared to be in the second leaf. The data presented in Table 12 show that of the C^{14} translocated out of the treated tip, more than one-half was found in the untreated portion of the second leaf of plants treated at all three growth stages. The stage of growth at which sweet corn plants were treated did not appear to greatly influence the amount of radioactivity accumulated in the root or in the first, second (minus treated tip), and third leaf. The accumulation of C^{14} in the fourth leaf, however, increased markedly after treatment of plants at the third stage of growth as compared to younger plants treated with TPA-2-C^{14}.

There was too great a variation in the total recoverable radioactivity and in the amount of C^{14} found in the treated tip to suggest a definite trend or pattern of accumulation.

Absorption and Translocation as a Basis for Selective Toxicity

The radioautographs presented in Plate 21 show that DPA-2-C^{14} and TPA-2-C^{14} were absorbed by the leaves of Birdsfoot trefoil plants, and that C^{14} was translocated to other parts of the plants. It would appear that C^{14} from DPA-2-C^{14} treatments was translocated faster and in greater quantity than was C^{14} from TPA-2-C^{14} treatments. Very little radioactivity is apparent in the root system of the plants treated with TPA-2-C^{14}.

The difference in the apparent amount of radioactivity on the

A

B

Plate 20. Radioautographs of sweet corn plants treated with 100 μg. TPA* on the distal 1 to 2 inches of the second leaf at the time (A) the fifth leaf was emerging and (B) the sixth leaf was emerging. Harvested one day after treatment.

Table 12

Accumulation of Radioactivity in Corn Plants Treated on the Distal Two Inches of the Second Leaf Blade with 100 μg C^{14} Labeled Sodium 2,2,3-trichloropropionate at Three Stages of Growth. Plants Harvested Twenty-four Hours After Treatment

Plant Part	Total Activity in Plant Material Counts/Min x 10^3			Translocation and Accumulation of C^{14} %		
	4th Leaf Emerging	5th Leaf Emerging	6th Leaf Emerging	4th Leaf Emerging	5th Leaf Emerging	6th Leaf Emerging
1st Blade	0.5	0.2	0.3	0.3	0.1	0.2
1st Sheath	0.8	0.5	0.2	0.5	0.3	0.1
2nd Blade - Minus Tip	16.8	7.3	14.5	9.5	4.1	8.2
2nd Sheath	10.4	5.1	9.4	5.9	2.9	5.3
3rd Blade	2.9	1.0	0.8	1.6	0.6	0.5
3rd Sheath	0.4	0.5	0.2	0.2	0.3	0.1
4th Leaf	1.9	0.9		1.1	0.5	
4th Blade			18.2			10.6
4th Sheath			1.9			0.9
5th Leaf	0.4	0.5	0.3	0.2	0.3	0.2
6th Leaf		0.2	1.1		0.1	0.6
7th Leaf			0.1			0.1
Root	0.8	0.7	0.9	0.5	0.4	0.5
Treated Tip - 2nd Blade	98.5	72.0	84.6	55.7	40.7	47.9
Total Minus Treated Tip	34.9	16.9	47.9	19.7	9.6	27.2
Total	133.4	88.9	132.5	75.4	50.3	75.1
Total Theoretically Applied	176.8	176.8	176.8			

A

B

Plate 21. Radioautographs of lotus plants harvested one day after the application of 30 μg. of (A) DPA* and (B) TPA* to one leaflet (darkest spot). Plants were seedlings about four months old.

treated leaves of the birdsfoot trefoil plants is probably due to lack of uniformity in the preparation of the radioautographs.

Loss of Radioactivity

1. Loss of C^{14} Through Respiration by Bean and Sweet Corn Plants. During three days following the application of DPA-2-C^{14} essentially no radioactivity could be detected in the carbon dioxide evolved by either bean or sweet corn plants. Of the amount of radioactivity theoretically applied to the plant leaves, 94.7 percent was accounted for in the tissue of bean plants, and 83.8 percent was accounted for in the tissue of sweet corn plants.

2. Measurement of Radioactivity by Direct Plating of Plant Extract. The data in Table 13 show that the total recoverable radioactivity in DPA-2-C^{14} treated sweet corn plants varied from about 90 percent one day after treatment to approximately 75 percent in plants harvested seven days after treatment. This would indicate that by the direct plating method higher recovery percentages of radioactivity in sweet corn plants was realized.

The amount of radioactivity in the treated leaf decreased during the seven day experimental period in what appeared to be a direct proportion to the increase in the amount of C^{14} accumulated in the rest of the plant. It is interesting to note that although the total recovery of C^{14} was higher, apparently less C^{14} was translocated out of the treated leaf in this experiment than in the previous experiment concerned with the absorption of DPA-2-C^{14} and translocation of C^{14} in sweet corn plants.

Table 13

Accumulation of Radioactivity in Sweet Corn Plants Harvested at Different Times after Application of 100 μgm. of C^{14} Labeled Sodium 2,2-dichloropropionate to the Distal Two Inches of the Second Leaf

Plant Part	Time After Treatment	Total Activity x 10^3	Accumulation of C^{14} in %
Treated Leaf	2 hours	127.0	87.6
Untreated*		2.3	1.6
Treated Leaf	1 day	119.7	82.6
Untreated		11.9	8.2
Treated Leaf	3 days	94.3	65.0
Untreated		22.7	15.7
Treated Leaf	5 days	89.4	61.7
Untreated		21.5	14.8
Treated Leaf	7 days	85.7	59.1
Untreated		22.7	15.7

*Includes all portions of the plant aside from the treated leaf.

Residual Activity in Soil

Table 14 presents a summary of the dry and fresh weight, height at three and six weeks after planting, number of plants per pot displaying morphological responses, and the number of plants per pot surviving six weeks after planting as measurements of the responses of sweet corn plants seeded immediately after DPA and TPA soil treatments. These data indicate that at comparable rates of application the toxicity of DPA and TPA did not generally differ significantly, but that TPA was consistently more toxic to sweet corn plants than was DPA. The degree of toxicity of each herbicide apparently was dependent on the amount of the chemical applied, and on the type of soil which was treated. The growth of sweet corn plants was inhibited to a much greater extent by both chemicals in the lighter textured, lower organic matter loam soil than in the heavier clay loam soil containing a higher percentage of organic matter.

The difference in growth of the non-treated (control) plants in the diverse soils is believed to be due to differences in the environment at the time the three experiments were conducted rather than to soil differences.

Residual Activity of DPA and TPA in Chehalis Clay Loam Soil

Tables 15 to 20 show the influence of time and temperature on the residual activity of DPA and TPA in Chehalis clay loam soil as measured by various responses of sweet corn plants seeded at several intervals after DPA and TPA applications to the soil.

The data indicate that, within the limits of this study, time

Table 14

The Toxicity of Soil Applications of DPA and TPA to Sweet Corn Plants Grown for Six Weeks in Three Soils

	Clay Loam	Loam	Sterilized Loam	Clay Loam	Loam	Sterilized Loam
	Dry Weight per Plant in Grams			Fresh Weight per Plant in Grams		
TPA at 10 ppm.	0.207	0.139	0.192	2.67	1.26	2.28
TPA at 50 ppm.	0.070	0		0.87	0	
DPA at 10 ppm.	0.260	0.206	0.421	3.54	2.01	5.64
DPA at 50 ppm.	0.142	0.015		2.13	0.19	
Control	0.386	0.814	1.377	4.61	5.34	13.04
	Height of Plants in Inches Three Weeks After Planting			Height of Plants in Inches Six Weeks After Planting		
TPA at 10 ppm.	7.67	2.00	2.75	10.75	2.25	5.13
TPA at 50 ppm.	3.75	0.36		5.42	0	
DPA at 10 ppm.	8.34	4.25	8.13	15.58	4.25	9.25
DPA at 50 ppm.	5.29	1.50		13.42	0.50	
Control	10.09	13.75	11.25	18.92	17.92	25.38
	Number of Plants per Pot Displaying Morphological Responses			Number of Plants Surviving Six Weeks After Planting		
TPA at 10 ppm.	2.33	5.00	5.00	4.33	1.42	5.00
TPA at 50 ppm.	4.50	5.00		2.58	0	
DPA at 10 ppm.	0.33	5.00	5.00	4.50	4.67	5.00
DPA at 50 ppm.	0.83	5.00		4.17	0.33	
Control	0	0	0	4.33	4.92	4.88

Note: These figures are averages of the data under "0 Weeks Storage" in Tables 15 to 32.

of storage did not exert as much influence as did temperature of storage on the residual activity of DPA and TPA in the clay loam soil. Although after three weeks of storage at any of the three temperatures there was no significant difference in the growth of sweet corn plants seeded in soil treated with DPA at 50 ppm. and of sweet corn plants seeded in untreated soil, as the 32 to 40° F. storage period lengthened residual toxicity due to the 50 ppm. DPA treatment became apparent. The data in Table 18 indicate that soil stored from six through fifteen weeks at 32 to 40° F. contained sufficient DPA to result in reduced plant height measurements six weeks after planting. Fresh weight and three-week plant height determinations (Tables 16 and 17) show that the 50 ppm. DPA concentration was effective in reducing plant growth in soil stored at 32 to 40° F. from nine through twelve and fifteen weeks, respectively. After twelve and fifteen weeks of 32 to 40° F. storage the growth of sweet corn plants in soil treated with DPA at 50 ppm. was reduced in comparison to plants grown in untreated soil (Table 15).

Increasing the storage temperature to 55 to 60° F. and to 72° F. resulted in the detoxication of the 50 ppm. DPA concentration within three weeks after application to the soil (Tables 15 to 20). Morphological responses, typical of those induced in sweet corn by DPA and TPA, provided some evidence of herbicidal activity resulting from 50 ppm. DPA treatments through nine and twelve weeks of storage at 55 to 60° F. and at 72° F., respectively, but at no time did more than one plant per pot display these abnormalities (Table 19).

Table 15

Dry Weight of Sweet Corn Plants as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Clay Loam Soil

		Dry Weight per Plant in Grams					Dry Weight per Plant in Grams		
		32-40°F	55-60°F	72°F			32-40°F	55-60°F	72°F
0 Weeks Storage					9 Weeks Storage				
TPA at 10 ppm.		.232	.179	.211	TPA at 10 ppm.		.392	.508	.695
TPA at 50 ppm.		.078	.063	.068	TPA at 50 ppm.		.064	.277	.409
DPA at 10 ppm.		.282	.262	.235	DPA at 10 ppm.		.389	.662	.685
DPA at 50 ppm.		.132	.161	.134	DPA at 50 ppm.		.392	.668	.673
Control		.330	.439	.388	Control		.753	.671	.733
	LSD 0.01	.118	.193	.136		LSD 0.01	-	.290	-
	0.05	.085	.138	.097		0.05	-	.207	-
3 Weeks Storage					12 Weeks Storage				
TPA at 10 ppm.		.385	.307	.397	TPA at 10 ppm.		.794	.968	1.086
TPA at 50 ppm.		.092	.094	.112	TPA at 50 ppm.		.106	.457	.598
DPA at 10 ppm.		.302	.340	.396	DPA at 10 ppm.		.803	1.285	1.235
DPA at 50 ppm.		.184	.341	.300	DPA at 50 ppm.		.815	1.223	1.218
Control		.292	.377	.387	Control		1.154	1.022	1.114
	LSD 0.01	.193	.136	.245		LSD 0.01	.348	-	.715
	0.05	.138	.097	.175		0.05	.248	-	.511
6 Weeks Storage					15 Weeks Storage				
TPA at 10 ppm.		.279	.539	.693	TPA at 10 ppm.		.658	.947	1.092
TPA at 50 ppm.		.066	.178	.196	TPA at 50 ppm.		.054	.360	.500
DPA at 10 ppm.		.542	.548	.666	DPA at 10 ppm.		.746	.973	.996
DPA at 50 ppm.		.444	.529	.519	DPA at 50 ppm.		.524	.915	1.202
Control		.536	.555	.756	Control		.786	.927	1.155
	LSD 0.01	.226	.162	.348		LSD 0.01	.193	.264	-
	0.05	.162	.119	.248		0.05	.138	.189	-

Table 16

Fresh Weight of Sweet Corn Plants as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Clay Loam Soil

		Fresh Weight per Plant in Grams					Fresh Weight per Plant in Grams		
		32-40°F	55-60°F	72°F			32-40°F	55-60°F	72°F
0 Weeks Storage					9 Weeks Storage				
TPA at 10 ppm.		2.85	2.34	2.83	TPA at 10 ppm.		3.50	4.98	6.87
TPA at 50 ppm.		0.93	0.88	0.81	TPA at 50 ppm.		0.89	3.25	3.32
DPA at 10 ppm.		3.89	3.51	3.21	DPA at 10 ppm.		3.93	6.05	6.79
DPA at 50 ppm.		2.21	2.32	1.87	DPA at 50 ppm.		3.74	7.07	6.90
Control		4.04	5.38	4.41	Control		7.69	6.42	7.37
	LSD 0.01	2.08	1.71	1.41		LSD 0.01	2.06	3.24	2.38
	0.05	1.49	1.22	1.00		0.05	1.47	2.32	1.70
3 Weeks Storage					12 Weeks Storage				
TPA at 10 ppm.		4.00	3.38	4.16	TPA at 10 ppm.		8.04	9.68	11.34
TPA at 50 ppm.		1.20	1.16	1.38	TPA at 50 ppm.		1.43	6.29	6.78
DPA at 10 ppm.		3.44	3.83	4.21	DPA at 10 ppm.		8.82	13.56	13.40
DPA at 50 ppm.		2.19	3.79	3.61	DPA at 50 ppm.		8.99	11.51	12.25
Control		3.14	4.11	4.28	Control		12.24	10.87	9.38
	LSD 0.01	1.75	1.53	2.19		LSD 0.01	4.25	-	7.13
	0.05	1.25	1.09	1.57			3.04	-	5.10
6 Weeks Storage					15 Weeks Storage				
TPA at 10 ppm.		3.18	5.38	7.79	TPA at 10 ppm.		5.95	8.60	10.58
TPA at 50 ppm.		0.55	1.99	2.17	TPA at 50 ppm.		0.73	3.92	5.59
DPA at 10 ppm.		5.84	5.91	6.89	DPA at 10 ppm.		7.89	8.84	9.37
DPA at 50 ppm.		5.13	5.87	6.20	DPA at 50 ppm.		5.65	7.49	10.75
Control		4.71	5.29	6.46	Control		6.36	8.12	10.74
	LSD 0.01	2.13	2.06	3.26		LSD 0.01	2.34	3.24	3.00
	0.05	1.52	1.47	2.33		0.05	1.67	2.32	2.14

Table 17

Height of Sweet Corn Plants Three Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Clay Loam Soil

		Height in Inches		
		32-40°F	55-60°F	72°F
0 Weeks Storage				
TPA at 10 ppm.		8.25	7.38	7.38
TPA at 50 ppm.		3.63	3.75	3.88
DPA at 10 ppm.		8.63	8.63	7.75
DPA at 50 ppm.		5.25	5.50	5.13
Control		10.38	8.88	11.00
	LSD 0.01	2.09	2.06	2.43
	0.05	1.49	1.47	1.74
3 Weeks Storage				
TPA at 10 ppm.		8.00	6.25	7.00
TPA at 50 ppm.		3.75	4.88	4.88
DPA at 10 ppm.		6.50	7.25	8.25
DPA at 50 ppm.		5.00	7.50	6.13
Control		6.75	6.75	7.38
	LSD 0.01	3.08	2.28	3.30
	0.05	2.20	1.63	2.36
6 Weeks Storage				
TPA at 10 ppm.		6.25	8.00	7.88
TPA at 50 ppm.		3.38	5.25	4.50
DPA at 10 ppm.		7.00	7.38	9.13
DPA at 50 ppm.		7.25	8.00	6.13
Control		7.75	7.25	6.75
	LSD 0.01	1.48	2.16	3.91
	0.05	1.06	1.55	2.79
9 Weeks Storage				
TPA at 10 ppm.		6.13	6.25	6.88
TPA at 50 ppm.		3.25	4.50	4.50
DPA at 10 ppm.		6.00	7.00	6.13
DPA at 50 ppm.		5.00	5.38	7.13
Control		7.13	7.13	6.75
	LSD 0.01	1.96	1.79	2.17
	0.05	1.40	1.28	1.55
12 Weeks Storage				
TPA at 10 ppm.		10.50	10.50	9.50
TPA at 50 ppm.		3.00	6.25	7.25
DPA at 10 ppm.		8.75	11.50	10.00
DPA at 50 ppm.		7.00	10.00	10.00
Control		10.00	7.75	10.75
	LSD 0.01	2.90	3.30	-
	0.05	2.07	2.36	3.10
15 Weeks Storage				
TPA at 10 ppm.		11.00	12.50	8.38
TPA at 50 ppm.		2.63	7.25	8.00
DPA at 10 ppm.		9.63	11.75	11.38
DPA at 50 ppm.		6.75	12.50	12.00
Control		11.75	11.25	12.25
	LSD 0.01	2.19	3.10	2.67
	0.05	1.57	2.21	1.89

Table 18

Height of Sweet Corn Plants Six Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Effect of DPA and TPA in Clay Loam Soil

		Height in Inches		
		32-40°F	55-60°F	72°F
0 Weeks Storage				
TPA at 10 ppm.		8.25	10.25	13.75
TPA at 50 ppm.		5.50	5.50	5.25
DPA at 10 ppm.		12.75	17.50	16.50
DPA at 50 ppm.		13.50	13.75	13.00
Control		18.25	18.50	20.00
	LSD 0.01	3.64	3.30	5.10
	0.05	2.48	2.38	3.72
3 Weeks Storage				
TPA at 10 ppm.		16.00	14.25	17.25
TPA at 50 ppm.		6.25	6.00	6.75
DPA at 10 ppm.		16.75	18.00	18.00
DPA at 50 ppm.		13.25	17.50	16.75
Control		16.75	17.75	18.00
	LSD 0.01	3.84	5.00	6.42
	0.05	2.75	3.57	4.58
6 Weeks Storage				
TPA at 10 ppm.		10.50	17.50	17.75
TPA at 50 ppm.		3.25	6.00	7.00
DPA at 10 ppm.		16.25	17.00	17.75
DPA at 50 ppm.		16.00	17.25	14.00
Control		15.50	17.00	17.75
	LSD 0.01	2.63	3.21	6.90
	0.05	1.79	2.30	4.94
9 Weeks Storage				
TPA at 10 ppm.		15.25	18.50	20.75
TPA at 50 ppm.		3.75	9.25	8.75
DPA at 10 ppm.		16.25	18.75	21.00
DPA at 50 ppm.		15.00	18.25	21.25
Control		21.25	19.75	20.75
	LSD 0.01	3.00	4.77	3.58
	0.05	2.14	3.41	2.56
12 Weeks Storage				
TPA at 10 ppm.		18.00	18.50	20.00
TPA at 50 ppm.		4.50	10.50	11.75
DPA at 10 ppm.		18.50	21.00	20.25
DPA at 50 ppm.		18.50	19.75	20.75
Control		21.25	19.25	19.75
	LSD 0.01	2.55	4.65	4.65
	0.05	1.74	3.32	3.32
15 Weeks Storage				
TPA at 10 ppm.		18.00	20.00	21.25
TPA at 50 ppm.		2.50	7.25	9.50
DPA at 10 ppm.		14.25	21.50	22.00
DPA at 50 ppm.		18.75	20.75	23.75
Control		20.00	21.25	23.00
	LSD 0.01	2.39	6.27	4.26
	0.05	1.64	4.48	3.05

Table 19

Number of Sweet Corn Plants per Pot Displaying Morphological Responses as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Clay Loam Soil

	Number of Plants per Pot Displaying Morphological Responses				Number of Plants per Pot Displaying Morphological Responses		
	32-40°	55-60°F	72°F		32-40°	55-60°F	72°F
0 Weeks Storage				9 Weeks Storage			
TPA at 10 ppm.	2.50	2.75	1.75	TPA at 10 ppm.	1.50	0.25	0
TPA at 50 ppm.	4.75	4.50	4.25	TPA at 50 ppm.	4.25	3.25	2.75
DPA at 10 ppm.	0	0.25	0.75	DPA at 10 ppm.	0.25	0	0
DPA at 50 ppm.	1.00	0.75	0.75	DPA at 50 ppm.	0	0.25	0
Control	0	0	0	Control	0	0	0
3 Weeks Storage				12 Weeks Storage			
TPA at 10 ppm.	2.25	1.25	0.75	TPA at 10 ppm.	0.50	0.25	0
TPA at 50 ppm.	4.00	4.75	4.50	TPA at 50 ppm.	4.50	4.00	4.00
DPA at 10 ppm.	0.25	0	0	DPA at 10 ppm.	0	0	0
DPA at 50 ppm.	0.75	0.25	0.25	DPA at 50 ppm.	0	0	0.25
Control	0.00	0	0	Control	0	0	0
6 Weeks Storage				15 Weeks Storage			
TPA at 10 ppm.	3.75	1.00	0.50	TPA at 10 ppm.	0.25	0	0
TPA at 50 ppm.	4.75	4.00	4.25	TPA at 50 ppm.	4.75	4.50	4.25
DPA at 10 ppm.	0.50	0	0.50	DPA at 10 ppm.	0	0	0
DPA at 50 ppm.	0.50	0.25	0.75	DPA at 50 ppm.	0	0	0
Control	0	0	0	Control	0	0	0

Table 20

Number of Sweet Corn Plants per Pot Surviving Six Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Clay Loam Soil

	Number of Living Plants				Number of Living Plants		
	32-40°F	55-60°F	72°F		32-40°F	55-60°F	72°F
0 Weeks Storage				9 Weeks Storage			
TPA at 10 ppm.	4.25	4.50	4.25	TPA at 10 ppm.	4.75	5.00	4.50
TPA at 50 ppm.	2.25	3.00	2.50	TPA at 50 ppm.	3.75	4.00	3.25
DPA at 10 ppm.	4.25	5.00	4.25	DPA at 10 ppm.	4.50	4.25	4.25
DPA at 50 ppm.	4.50	3.50	4.50	DPA at 50 ppm.	4.50	3.00	4.25
Control	4.00	4.00	5.00	Control	4.00	4.75	4.50
3 Weeks Storage				12 Weeks Storage			
TPA at 10 ppm.	3.75	4.75	4.25	TPA at 10 ppm.	4.25	4.25	4.50
TPA at 50 ppm.	2.50	4.50	4.75	TPA at 50 ppm.	2.75	4.50	4.25
DPA at 10 ppm.	3.75	4.75	4.75	DPA at 10 ppm.	4.75	4.25	4.00
DPA at 50 ppm.	4.25	4.75	3.25	DPA at 50 ppm.	3.75	4.00	4.25
Control	4.50	4.00	4.25	Control	4.00	4.25	4.25
6 Weeks Storage				15 Weeks Storage			
TPA at 10 ppm.	5.00	4.75	4.00	TPA at 10 ppm.	4.75	4.50	4.25
TPA at 50 ppm.	4.00	4.00	4.00	TPA at 50 ppm.	4.00	4.50	4.50
DPA at 10 ppm.	4.75	4.75	4.50	DPA at 10 ppm.	4.25	4.50	4.75
DPA at 50 ppm.	4.25	4.50	3.25	DPA at 50 ppm.	4.75	5.00	4.25
Control	4.75	4.75	4.25	Control	4.50	5.00	4.50

Soil treatments of DPA at 10 ppm. resulted in much the same pattern of residual activity as that of DPA at 50 ppm. In soil stored at 55 to 60° F. and at 72° F. the 10 ppm. DPA concentration apparently was detoxicated within three weeks. On the other hand, in similarly treated soil stored at 32 to 40° F. there was significant evidence of reduced plant growth from nine through fifteen weeks of storage, depending on the criteria employed. Thus, fresh weight and six week plant height measurements (Tables 16 and 18) showed reduced plant growth from nine through twelve and fifteen weeks of storage, respectively, and dry weight and three week height measurements (Tables 15 and 17) showed reduced plant growth only after twelve and fifteen weeks of storage, respectively.

As measured by all of the plant growth responses (Tables 15 to 18) as well as the number of plants per pot displaying morphological responses (Table 19), the 50 ppm. TPA treatment remained active in the clay loam soil throughout the fifteen week storage at 32 to 40° F. The activity of the TPA remaining in the soil was sufficient through twelve weeks of storage to reduce the number of plants per pot which survived the six week growing period that followed (Table 20). In contrast to the 50 ppm. DPA application, the 50 ppm. TPA application was not rendered ineffective by increased storage temperature. The six week plant height measurements, the number of plants per pot displaying morphological responses, and with the exception of the twelve week entry at 55 to 60° F. and at 72° F., the fresh weight and three week plant height measurements, show that the 50

ppm. TPA concentration had not been significantly reduced during fifteen weeks of storage at either 55 to 60° F. or 72° F. The dry weight determinations, however, indicate that some TPA was lost within nine weeks of storage at 72° F. (Table 15).

The residual activity of TPA following the application of 10 ppm. to the clay loam soil corresponds somewhat to the residual activity of DPA applied at the rate of either 10 or 50 ppm. to the clay loam soil. The 10 ppm. TPA treatment apparently remained effective in reducing sweet corn plant growth through twelve weeks of storage at 32 to 40° F., although a few isolated entries representing the different criteria for growth response were not significantly different from those obtained from plants grown in untreated soil. TPA applied at 10 ppm. apparently was decomposed within three weeks of storage at the higher temperatures.

These observations suggest that at the higher temperatures favorable to the reduction of residual activity, TPA is more stable than DPA in Chehalis clay loam soil.

Residual Activity of DPA and TPA in Chehalis Loam Soil

Tables 21 to 26 show the influence of time and temperature on the residual activity of DPA and TPA in Chehalis loam soil as measured by various responses of sweet corn plants seeded at various intervals after DPA and TPA applications to the soil.

As was observed in regard to the residual activity of DPA and TPA in clay loam soil, the data indicate that storage temperature exerted more influence than did storage time on the residual activity

Table 21

Dry Weight of Sweet Corn Plants as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Loam Soil

		Dry Weight per Plant in Grams 32-40°F	55-60°F	72°F
0 Weeks Storage				
TPA at 10 ppm.		.076	.064	.277
TPA at 50 ppm.		0	0	0
DPA at 10 ppm.		.183	.216	.218
DPA at 50 ppm.		.046	0	0
Control		.748	.879	.814
	LSD 0.01	.193	.216	.236
	0.05	.139	.154	.169
3 Weeks Storage				
TPA at 10 ppm.		.456	1.674	1.790
TPA at 50 ppm.		0	0	0
DPA at 10 ppm.		.266	1.159	1.617
DPA at 50 ppm.		.058	.830	1.945
Control		.635	1.106	1.449
	LSD 0.01	.327	-	.625
	0.05	.234	1.003	.446
6 Weeks Storage				
TPA at 10 ppm.		.322	1.383	1.559
TPA at 50 ppm.		0	0	.008
DPA at 10 ppm.		.231	1.429	1.428
DPA at 50 ppm.		.055	1.148	1.523
Control		.544	1.165	1.529
	LSD 0.01	.256	.236	.225
	0.05	.182	.169	.182
9 Weeks Storage				
TPA at 10 ppm.		.170	1.818	2.071
TPA at 50 ppm.		0	0	0
DPA at 10 ppm.		.393	1.716	2.008
DPA at 50 ppm.		.070	1.835	1.855
Control		1.023	1.638	1.810
	LSD 0.01	.289	.305	.236
	0.05	.203	.218	.169
12 Weeks Storage				
TPA at 10 ppm.		1.366	2.418	2.104
TPA at 50 ppm.		0	0	.636
DPA at 10 ppm.		1.407	2.071	2.379
DPA at 50 ppm.		.076	2.332	2.706
Control		1.708	2.255	2.566
	LSD 0.01	1.470	.796	1.429
	0.05	1.050	.568	1.020
15 Weeks Storage				
TPA at 10 ppm.		.925	2.344	3.218
TPA at 50 ppm.		0	.038	1.236
DPA at 10 ppm.		1.419	2.378	3.521
DPA at 50 ppm.		.040	2.971	3.145
Control		1.779	3.001	3.349
	LSD 0.01	-	.960	-
	0.05	-	.696	-

Table 22

Fresh Weight of Sweet Corn Plants as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Loam Soil

	Fresh Weight per Plant in Grams		
	32-40°F	55-60°F	72°F
0 Weeks Storage			
TPA at 10 ppm.	0.47	0.58	2.72
TPA at 50 ppm.	0	0	0
DPA at 10 ppm.	1.82	1.99	2.23
DPA at 50 ppm.	0.28	0.28	0
Control	5.08	5.46	5.48
LSD 0.01	1.17	1.09	1.94
0.05	0.84	0.78	1.38
3 Weeks Storage			
TPA at 10 ppm.	4.22	11.28	11.71
TPA at 50 ppm.	0	0	0
DPA at 10 ppm.	2.83	7.26	10.54
DPA at 50 ppm.	0.34	6.65	13.68
Control	6.35	7.37	9.52
LSD 0.01	3.11	-	3.67
0.05	2.24	-	2.63
6 Weeks Storage			
TPA at 10 ppm.	3.32	8.66	9.53
TPA at 50 ppm.	0	0	2.75
DPA at 10 ppm.	3.45	8.38	9.30
DPA at 50 ppm.	0.61	9.84	9.56
Control	3.89	7.49	9.51
LSD 0.01	1.75	2.04	2.46
0.05	1.25	1.44	1.76
9 Weeks Storage			
TPA at 10 ppm.	1.45	15.11	17.61
TPA at 50 ppm.	0	0	0
DPA at 10 ppm.	5.06	14.20	17.73
DPA at 50 ppm.	0.96	15.77	16.54
Control	8.05	13.32	15.93
LSD 0.01	2.60	2.87	1.78
0.05	1.86	2.05	1.27
12 Weeks Storage			
TPA at 10 ppm.	11.00	17.30	16.37
TPA at 50 ppm.	0	0	7.09
DPA at 10 ppm.	10.21	14.02	14.95
DPA at 50 ppm.	0.37	15.49	17.38
Control	11.86	15.31	17.36
LSD 0.01	10.05	9.34	-
0.05	7.49	6.67	
15 Weeks Storage			
TPA at 10 ppm.	11.98	26.35	27.72
TPA at 50 ppm.	0	0.09	14.04
DPA at 10 ppm.	15.69	25.69	34.82
DPA at 50 ppm.	0.31	26.35.	31.36
Control	16.19	27.62	30.64
LSD 0.01	11.02	9.62	-
0.05	7.27	6.87	

Table 23

Height of Sweet Corn Plants Three Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Loam Soil

		Height in Inches					Height in Inches		
		32-40°F	55-60°F	72°F			32-40°F	55-60°F	72°F
0 Weeks Storage					9 Weeks Storage				
TPA at 10 ppm.		2.00	2.00	2.00	TPA at 10 ppm.		3.00	13.25	14.00
TPA at 50 ppm.		0.63	0.19	0.25	TPA at 50 ppm.		1.00	1.25	1.00
DPA at 10 ppm.		4.00	4.50	4.25	DPA at 10 ppm.		4.88	14.75	13.50
DPA at 50 ppm.		1.13	1.63	1.75	DPA at 50 ppm.		1.75	14.50	13.50
Control		13.75	13.75	13.75	Control		12.00	11.75	14.50
	LSD 0.01	1.09	1.53	1.21		LSD 0.01	1.16	4.74	3.78
	0.05	0.78	1.09	1.79		0.05	0.83	3.38	2.70
3 Weeks Storage					12 Weeks Storage				
TPA at 10 ppm.		3.13	8.00	11.75	TPA at 10 ppm.		4.00	16.25	15.50
TPA at 50 ppm.		1.00	1.50	1.50	TPA at 50 ppm.		0.75	1.75	2.00
DPA at 10 ppm.		4.50	8.25	12.00	DPA at 10 ppm.		6.50	16.00	16.75
DPA at 50 ppm.		1.38	2.38	11.25	DPA at 50 ppm.		1.50	15.75	18.00
Control		10.25	10.75	12.25	Control		14.00	16.50	17.00
	LSD 0.01	1.53	4.21	2.51		LSD 0.01	3.88	2.35	3.30
	0.05	1.09	3.01	1.79		0.05	2.77	1.68	2.35
6 Weeks Storage					15 Weeks Storage				
TPA at 10 ppm.		4.00	12.00	13.75	TPA at 10 ppm.		7.75	30.00	29.75
TPA at 50 ppm.		1.50	1.50	1.50	TPA at 50 ppm.		0.75	2.50	3.50
DPA at 10 ppm.		5.25	14.25	14.75	DPA at 10 ppm.		11.50	26.25	27.75
DPA at 50 ppm.		1.50	14.00	15.00	DPA at 50 ppm.		2.25	26.00	27.00
Control		18.25	12.75	12.75	Control		19.50	26.50	27.75
	LSD 0.01	2.13	3.31	3.39		LSD 0.01	8.15	4.50	4.22
	0.05	1.52	2.37	2.42		0.05	5.82	3.22	3.01

Table 24

Height of Sweet Corn Plants Six Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Loam Soil

		Height in Inches					Height in Inches		
		32-40°F	55-60°F	72°F			32-40°F	55-60°F	72°F
0 Weeks Storage					9 Weeks Storage				
TPA at 10 ppm.		1.75	1.50	3.50	TPA at 10 ppm.		4.50	25.50	28.00
TPA at 50 ppm.		0	0	0	TPA at 50 ppm.		0	0	0
DPA at 10 ppm.		4.00	4.50	4.25	DPA at 10 ppm.		7.50	26.25	28.25
DPA at 50 ppm.		0.50	1.00	0	DPA at 50 ppm.		2.50	27.00	28.25
Control		18.25	17.25	18.50	Control		22.25	26.50	27.25
	LSD 0.01	1.61	2.60	0.87		LSD 0.01	4.43	4.06	1.71
	0.05	1.15	1.85	0.62		0.05	3.16	2.90	1.22
3 Weeks Storage					12 Weeks Storage				
TPA at 10 ppm.		3.25	17.25	22.75	TPA at 10 ppm.		22.50	30.75	31.50
TPA at 50 ppm.		0	0	0	TPA at 50 ppm.		0	0	7.75
DPA at 10 ppm.		4.75	20.25	23.25	DPA at 10 ppm.		19.75	29.00	32.25
DPA at 50 ppm.		1.25	5.38	23.50	DPA at 50 ppm.		1.50	30.75	31.50
Control		18.50	19.50	21.50	Control		27.75	30.00	32.50
	LSD 0.01	2.82	9.15	2.83		LSD 0.01	19.75	8.73	14.68
	0.05	2.01	6.55	2.02		0.05	14.15	6.23	10.97
6 Weeks Storage					15 Weeks Storage				
TPA at 10 ppm.		6.00	25.00	26.00	TPA at 10 ppm.		17.25	33.25	37.00
TPA at 50 ppm.		0	0	0.50	TPA at 50 ppm.		0	1.50	8.25
DPA at 10 ppm.		5.25	23.00	23.00	DPA at 10 ppm.		31.25	36.75	40.25
DPA at 50 ppm.		2.00	20.50	25.00	DPA at 50 ppm.		1.25	36.75	37.00
Control		18.25	24.00	25.50	Control		32.00	35.50	36.75
	LSD 0.01	4.68	4.32	3.42		LSD 0.01	11.75	8.00	14.90
	0.05	3.34	3.08	2.44		0.05	8.39	5.71	10.62

Table 25

Number of Sweet Corn Plants per Pot Displaying Morphological Responses as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Loam Soil

	Number of Plants per Pot Displaying Morphological Responses				Number of Plants per Pot Displaying Morphological Responses		
	32-40°F	55-60°F	72°F		32-40°F	55-60°F	72°F
0 Weeks Storage				9 Weeks Storage			
TPA at 10 ppm.	5.00	5.00	5.00	TPA at 10 ppm.	5.00	0	0
TPA at 50 ppm.	5.00	5.00	5.00	TPA at 50 ppm.	5.00	5.00	5.00
DPA at 10 ppm.	5.00	5.00	5.00	DPA at 10 ppm.	5.00	0	0
DPA at 50 ppm.	5.00	5.00	5.00	DPA at 50 ppm.	5.00	0.50	0
Control	0	0	0	Control	0	0	0
3 Weeks Storage				12 Weeks Storage			
TPA at 10 ppm.	5.00	2.50	1.00	TPA at 10 ppm.	5.00	0	0.25
TPA at 50 ppm.	5.00	5.00	5.00	TPA at 50 ppm.	5.00	5.00	4.75
DPA at 10 ppm.	5.00	3.50	0	DPA at 10 ppm.	4.00	0	0
DPA at 50 ppm.	5.00	5.00	1.00	DPA at 50 ppm.	5.00	0	0
Control	0	0	0	Control	0	0	0
6 Weeks Storage				15 Weeks Storage			
TPA at 10 ppm.	5.00	0.25	0	TPA at 10 ppm.	4.75	0.25	0.25
TPA at 50 ppm.	5.00	5.00	5.00	TPA at 50 ppm.	5.00	5.00	4.75
DPA at 10 ppm.	5.00	0	0	DPA at 10 ppm.	3.00	0	0
DPA at 50 ppm.	5.00	0.25	0	DPA at 50 ppm.	5.00	0	0
Control	0	0	0	Control	0	0	0

Table 26

Number of Sweet Corn Plants per Pot Surviving Six Weeks After Planting As a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Loam Soil

	Number of Living Plants				Number of Living Plants		
	32-40°F	55-60°F	72°F		32-40°F	55-60°F	72°F
0 Weeks Storage				9 Weeks Storage			
TPA at 10 ppm.	1.75	1.00	1.50	TPA at 10 ppm.	3.50	5.00	5.00
TPA at 50 ppm.	0	0	0	TPA at 50 ppm.	0	0	0
DPA at 10 ppm.	5.00	4.75	4.25	DPA at 10 ppm.	5.00	4.25	5.00
DPA at 50 ppm.	0.25	0.75	0	DPA at 50 ppm.	2.00	4.50	5.00
Control	4.75	5.00	5.00	Control	4.75	5.00	5.00
3 Weeks Storage				12 Weeks Storage			
TPA at 10 ppm.	3.50	3.75	4.50	TPA at 10 ppm.	4.00	5.00	5.00
TPA at 50 ppm.	0	0	0	TPA at 50 ppm.	0	0	0.75
DPA at 10 ppm.	4.75	5.00	5.00	DPA at 10 ppm.	4.75	5.00	5.00
DPA at 50 ppm.	1.00	1.75	4.50	DPA at 50 ppm.	2.25	5.00	5.00
Control	4.75	5.00	5.00	Control	5.00	5.00	5.00
6 Weeks Storage				15 Weeks Storage			
TPA at 10 ppm.	3.50	4.75	5.00	TPA at 10 ppm.	3.75	4.50	5.00
TPA at 50 ppm.	0	0	0.25	TPA at 50 ppm.	0	0.50	1.00
DPA at 10 ppm.	4.50	5.00	4.75	DPA at 10 ppm.	4.50	5.00	5.00
DPA at 50 ppm.	2.25	4.50	5.00	DPA at 50 ppm.	1.25	5.00	5.00
Control	5.00	5.00	4.50	Control	5.00	5.00	4.75

of DPA and TPA incorporated into the loam soil. Dry weight, fresh weight, and three and six week plant height measurements, as well as the number of plants per pot displaying morphological responses, all showed that in comparison to sweet corn plants grown in untreated soil, the growth of sweet corn plants was significantly reduced in loam soil treated with 50 ppm. of DPA and stored from three to fifteen weeks (Tables 21-25). The number of plants per pot still alive six weeks after planting serves as an indication that a toxic amount of DPA still remained in the loam soil fifteen weeks after the application of DPA at 50 ppm. to soil subsequently stored at 32 to 40° F. Morphological responses of sweet corn plants suggested that the 10 ppm. concentration of TPA was active through fifteen weeks of storage at 32 to 40° F. (Table 25). However, all other plant growth measurements showed a significant reduction of sweet corn plant growth due to the 10 ppm. DPA treatment through only nine weeks of 32 to 40° F. storage (Tables 21-24).

In contrast to the relative stability of DPA in loam soil kept at low temperature, DPA at 50 ppm. was detoxicated within six and three weeks, respectively, at temperatures of 55 to 60° F. and 72° F., and DPA at 10 ppm. was decomposed within three weeks at either of the two higher temperatures (Tables 21-24). The number of plants per pot displaying morphological responses or abnormalities suggested that some activity still remained of the 10 ppm. DPA treatment through the three week storage at 55 to 60° F. (Table 25), but the number of plants per pot surviving six weeks after planting indicated that no

effect of the 10 ppm. DPA treatment could be detected three weeks after application to the soil regardless of the storage temperature (Table 26).

TPA concentrations of 50 ppm. remained toxic to sweet corn plants throughout the fifteen week storage period at all three temperatures (Tables 21-26). Although some plants germinated and made limited early growth it was not until after fifteen weeks of storage at 55 to 60° F. or six weeks at 72° F. that any sweet corn plants survived the six week growing period, and at that time only one plant per pot was alive for harvest (Table 26). Those sweet corn plants which did survive this treatment made good growth as evidenced by the dry and fresh weight data given in Tables 21 and 22, which suggest that some TPA was being broken down after twelve to fifteen weeks at 72° F.

Plant height three weeks after planting, the number of plants per pot displaying morphological responses, and the number of plants per pot surviving six weeks after planting (Tables 23, 25, 26, respectively) showed that in comparison to untreated soil significant toxicity remained in loam soil throughout fifteen weeks of storage at 32 to 40° F. following the 10 ppm. TPA application to the soil. Dry and fresh weights as well as plant height six weeks after planting (Tables 21, 22, 24) showed that this lower concentration of TPA remained active in the soil for only nine weeks of storage at 32 to 40° F. At temperatures of 55 to 60° F. and of 72° F., TPA applied at 10 ppm. apparently was decomposed within three weeks.

These observations suggest that within the limitations of this

study, under high temperatures favorable to the loss of residual activity, TPA is more stable than DPA in Chehalis loam soil, and DPA and TPA are more stable in Chehalis loam than in Chehalis clay loam soil.

Residual Activity of DPA and TPA in Sterilized Chehalis Loam Soil

Tables 27 to 32 show the influence of time and temperature on the residual activity of DPA and TPA in sterilized Chehalis loam soil as measured by various responses of sweet corn plants seeded at several intervals after DPA and TPA application to the soil.

The data indicate that neither time nor temperature of storage influenced the residual activity of DPA and TPA incorporated into sterilized soil (Tables 27-32). Little if any breakdown of either DPA or TPA occurred at either storage temperature through fifteen weeks following chemical application.

Dry weight, fresh weight, three and six week plant height measurements of plants seeded after each period of storage (Tables 27 to 32) showed a distinct relationship to the same measurements of sweet corn plants seeded in the clay loam soil and in the loam soil immediately after treatment with DPA and TPA (Table 14). TPA appeared to be more toxic than DPA to sweet corn plants.

Table 27

Dry Weight of Sweet Corn Plants as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Sterilized Loam Soil

	Dry Weight in Grams	
	32-40°F	72°F
0 Weeks Storage		
TPA at 10 ppm.	.199	.184
DPA at 10 ppm.	.499	.343
Control	1.329	1.425
3 Weeks Storage		
TPA at 10 ppm.	.125	.083
DPA at 10 ppm.	.275	.308
Control	1.124	1.310
6 Weeks Storage		
TPA at 10 ppm.	.071	.078
DPA at 10 ppm.	.319	.295
Control	.945	1.073
9 Weeks Storage		
TPA at 10 ppm.	.081	.075
DPA at 10 ppm.	.256	.236
Control	.588	.584
15 Weeks Storage		
TPA at 10 ppm.	.087	.083
DPA at 10 ppm.	.460	.604
Control	1.149	1.156

Table 28

Fresh Weight of Sweet Corn Plants as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Sterilized Loam Soil

	Fresh Weight in Grams	
	32-40°F	72°F
0 Weeks Storage		
TPA at 10 ppm.	2.43	2.13
DPA at 10 ppm.	6.70	4.57
Control	12.50	13.57
3 Weeks Storage		
TPA at 10 ppm.	1.35	0.80
DPA at 10 ppm.	3.69	4.02
Control	13.44	14.94
6 Weeks Storage		
TPA at 10 ppm.	1.07	0.82
DPA at 10 ppm.	5.00	4.60
Control	13.93	15.41
9 Weeks Storage		
TPA at 10 ppm.	0.93	0.79
DPA at 10 ppm.	3.30	3.23
Control	7.52	8.17
15 Weeks Storage		
TPA at 10 ppm.	0.94	0.89
DPA at 10 ppm.	6.44	8.86
Control	14.86	15.42

Table 29

Height of Sweet Corn Plants Three Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Sterilized Loam Soil

	Height in Inches	
	32-40°F	72°F
0 Weeks Storage		
TPA at 10 ppm.	4.75	3.50
DPA at 10 ppm.	9.00	7.25
Control	10.75	11.75
3 Weeks Storage		
TPA at 10 ppm.	3.75	2.50
DPA at 10 ppm.	5.75	7.75
Control	9.50	9.25
6 Weeks Storage		
TPA at 10 ppm.	3.75	2.75
DPA at 10 ppm.	6.00	6.25
Control	9.00	9.25
9 Weeks Storage		
TPA at 10 ppm.	3.75	2.50
DPA at 10 ppm.	6.50	6.50
Control	9.00	9.00
15 Weeks Storage		
TPA at 10 ppm.	2.25	2.50
DPA at 10 ppm.	6.00	6.00
Control	8.00	7.25

Table 30

Height of Sweet Corn Plants Six Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Sterilized Loam Soil

	Height in Inches	
	32-40°F	72°F
0 Weeks Storage		
TPA at 10 ppm.	5.75	4.50
DPA at 10 ppm.	10.25	8.25
Control	25.25	25.50
3 Weeks Storage		
TPA at 10 ppm.	5.50	3.50
DPA at 10 ppm.	8.75	9.00
Control	23.25	24.75
6 Weeks Storage		
TPA at 10 ppm.	4.00	3.75
DPA at 10 ppm.	8.00	8.75
Control	25.25	21.75
9 Weeks Storage		
TPA at 10 ppm.	3.50	2.50
DPA at 10 ppm.	8.50	10.25
Control	23.75	23.25
15 Weeks Storage		
TPA at 10 ppm.	3.75	4.25
DPA at 10 ppm.	10.25	13.50
Control	21.75	22.25

Table 31

Number of Sweet Corn Plants per Pot Displaying Morphological Responses as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Sterilized Loam Soil

	Number of Plants per Pot Displaying Morphological Responses	
	32-40°F	72°F
0 Weeks Storage		
TPA at 10 ppm.	5	5
DPA at 10 ppm.	5	5
Control	0	0
3 Weeks Storage		
TPA at 10 ppm.	5	5
DPA at 10 ppm.	5	5
Control	0	0
6 Weeks Storage		
TPA at 10 ppm.	5	5
DPA at 10 ppm.	5	5
Control	0	0
9 Weeks Storage		
TPA at 10 ppm.	5	5
DPA at 10 ppm.	5	5
Control	0	0
15 Weeks Storage		
TPA at 10 ppm.	5	5
DPA at 10 ppm.	5	5
Control	0	0

Table 32

Number of Sweet Corn Plants per Pot Surviving Six Weeks After Planting as a Measure of the Effect of Time and Temperature on the Residual Activity of DPA and TPA in Sterilized Loam Soil

	Number of Living Plants per Pot	
	32-40°F	72°F
0 Weeks Storage		
TPA at 10 ppm.	5.00	5.00
DPA at 10 ppm.	5.00	5.00
Control	5.00	4.75
3 Weeks Storage		
TPA at 10 ppm.	4.50	2.75
DPA at 10 ppm.	5.00	4.75
Control	5.00	5.00
6 Weeks Storage		
TPA at 10 ppm.	4.25	3.00
DPA at 10 ppm.	5.00	5.00
Control	5.00	5.00
9 Weeks Storage		
TPA at 10 ppm.	2.50	1.00
DPA at 10 ppm.	5.00	5.00
Control	5.00	5.00
15 Weeks Storage		
TPA at 10 ppm.	3.50	3.75
DPA at 10 ppm.	5.00	5.00
Control	5.00	5.00

DISCUSSION

Absorption and Translocation

This study of the absorption of DPA-2-C^{14} and TPA-2-C^{14} by the leaves of bean and sweet corn plants, and the subsequent translocation of C^{14} to the other plant parts suggests that these two chemicals exhibit a pattern of absorption and translocation in plants similar to that of other growth regulators.

Absorption of DPA-2-C^{14} and TPA-2-C^{14}

Rate of Absorption. None of the experiments constituting the basis of this investigation were designed to provide a measure of the speed or amount of DPA-2-C^{14} or TPA-2-C^{14} absorbed into the plant foliage. However, the loss of radioactivity experiments may provide an indirect means of arriving at certain conclusions regarding the absorption of DPA-2-C^{14} and TPA-2-C^{14} by the leaves of bean and sweet corn plants. It was found that a much higher percentage of recovery of radioactivity could be realized by measuring the amount of C^{14} in fresh plant extract than by measuring the amount of C^{14} in barium carbonate samples prepared after oxidizing plant tissue which had been dried in a vacuum oven immediately after harvest. Baldwin, et al. (4, pp. 429-430) obtained similar results when they utilized these two techniques of radioactivity measurement during a study of the absorption and translocation of radioactive IPC by corn and oat plants. These workers concluded that drying the newly harvested plants in the vacuum oven resulted in vaporization of the unabsorbed

IPC-C^{14} remaining on the leaf surface. If true, this would provide an indication of the amount of chemical which had been absorbed into the leaf. However, it should be recognized that the vacuum drying may also have caused vaporization of DPA-2-C^{14} and TPA-2-C^{14} which had been absorbed into the leaves. Possibly only that portion of the DPA-2-C^{14} and TPA-2-C^{14} which had become associated with other compounds within the plant were retained in the leaf tissue after drying.

On the assumption that vacuum drying the treated leaves removed the unabsorbed chemical remaining on the leaf surface, the results of these experiments indicate that as much DPA-2-C^{14} and TPA-2-C^{14} was absorbed by the leaves of bean and sweet corn plants within two hours after treatment as was absorbed during seven days. This observation is in agreement with that of Santlemann and Willard (42, pp. 26-27) who reported that within thirty minutes after the application of DPA to one of two quackgrass shoots arising from the same rhizome sufficient DPA had been absorbed to eventually kill both the treated and the untreated shoot. In 2,4-D absorption studies, Weaver and DeRose (50, pp. 510-520) observed that a six hour presentation was necessary to attain the maximum absorption of 2,4-D by bean plant leaves, and Rice (44, pp. 301-314) found that 2,4-D absorption did not continue after four hours following treatment unless a surface active agent had been added to the treatment solution. The use of a surface active agent appeared to lengthen the period of 2,4-D absorption to seventy-two hours.

The apparently faster rate of absorption of DPA and TPA than of 2,4-D by bean plant leaves could in part be due to differences in molecular weights of the compounds. DPA and TPA respectively have molecular weights only 65 and 80 percent as large as that of 2,4-D. This would suggest that DPA should be absorbed more rapidly than TPA, and that 2,4-D should be absorbed more rapidly than 2,4,5-T, since on the molecular weight basis DPA is 80 percent the size of TPA, and 2,4-D is 86 percent the size of 2,4,5-T. Although several workers (12, p. 293; 21; and 34, p. 630) have observed that 2,4-D was absorbed by plant foliage at a faster rate than 2,4,5-T, no differences in the rate of absorption of DPA-2-C^{14} and TPA-2-C^{14} by plant leaves was revealed in this study. It is possible that harvests at closer intervals after treatment would detect some differential absorption of DPA-2-C^{14} and TPA-2-C^{14}. Another factor which might be worthy of consideration in discussing the rate of absorption of a chemical by a plant leaf would be the general structure of the chemical compound. It would appear reasonable to expect that the smaller, more compact DPA or TPA molecule might move through the cuticle and the semipermeable membrane of the epidermal cells of the plant leaf more readily than the larger 2,4-D molecule. This line of reasoning, however, would not account for the observed differences in foliar absorption of 2,4-D and 2,4,5-T. Other factors or combinations of factors probably enter into the problem.

Amount of Absorption. In these experiments both DPA-2-C^{14} and TPA-2-C^{14} were absorbed in greater quantity by the leaves of bean

plants than of sweet corn plants. Using procedures similar to those employed in this study, Fang and Butts (22, pp. 2-3) observed that bean plant leaves absorbed more carboxyl-C^{14}-labeled 2,4-D than did the leaves of corn or wheat plants. This differential absorption of the chemicals by the leaves of bean and corn plants could be due to differences of leaf structure of the two plants, and to the placement of the treatment solution on the leaf surface. Based on Craft's experiments (12; pp. 297, 323) the radioactive compounds were placed along the mid-vein of the primary leaf of bean plants which results in very rapid and complete absorption of 2,4-D. The sweet corn plants were treated by spreading the herbicidal solution over the distal one and one-half inches of the second leaf. This would allow only a relatively small amount of the chemical to have direct access to the small (in relation to the midvein of bean plants) parallel veins near the sweet corn leaf tip. It would appear that there was less opportunity for the absorption of the herbicides by the leaves of sweet corn plants than of bean plants.

Translocation of DPA and TPA

Distribution of C^{14}. During the seven day experimental period C^{14} in DPA-2-C^{14} and TPA-2-C^{14} treated bean and sweet corn plants appeared to move out of the treated area to the adjacent plant parts, and then toward the rapidly developing tissues. In general the maximum concentration of radioactivity in the plant parts nearest the treated area, the stem of bean plants, and the second leaf (minus the treated tip) of sweet corn plants, was attained within one day after

treatment. As the presentation time lengthened the amount of radioactive carbon in these plant parts, and in the roots, tended to remain fairly constant or to decline. In comparison, there was a consistent tendency for the growing tips and trifoliate leaves of bean plants, and the fourth, fifth, and sixth leaves of sweet corn plants to increase C^{14} accumulation as the experimental period progressed. On the other hand, the more mature plant parts such as the untreated primary bean leaf and the first sweet corn leaf exhibited very little C^{14} accumulation at any time. The same general pattern of radioactivity distribution in bean and sweet corn plants treated with C^{14} labeled 2,4-D was noted by Fang et al. (23, pp. 251-252) and Fang and Butts (22, pp. 2-3). Mitchell and Linder (36, pp. 54-55) found that after the application of 2,4-D-5-I^{131} to bean plants, I^{131} was translocated primarily to the growing tip and upper stem within three days. Holley et al. (29, pp. 145-146), however, felt that the C^{14} from radioactive 2,4-D applied to one primary leaf of bean plants moved principally toward the root, while smaller quantities were transported to the upper plant parts. They proposed that the C^{14} then moved from the roots to the foliage along with the transpirational stream. It is possible that Holley and his group did not realize that the vascular strands from the primary leaf of bean plants do not connect with the main vertical vascular system until they extend back down the stem to the cotyledonary nodes. Thus, the movement of C^{14} a certain distance down the stem to the cotyledonary node may have been misinterpreted as translocation toward the root system.

The apparent similarity of the pattern of translocation of C^{14} from the leaves of DPA-2-C^{14} and TPA-2-C^{14} treated plants to the pattern of translocation of radioactive tracers from the leaves of radioactive 2,4-D treated plants (36, pp. 54-55; 37, pp. 21-25; 29, pp. 145-146; and 23, pp. 249-255) suggests that the active agents of DPA and TPA move through plants in the manner proposed for the translocation of the active agent of 2,4-D and other growth regulator type herbicides - that is, primarily through the phloem in conjunction with the products of photosynthesis. The results obtained by Santlemann and Willard (47, pp. 25-26) in their study of DPA translocation in quack grass support this suggestion. It is quite possible that some of the C^{14} which was translocated to the roots of DPA-2-C^{14} and TPA-2-C^{14} treated bean and sweet corn plants was subsequently transported in the transpirational stream to the rapidly developing tissues of the foliage. In an exploratory experiment (not reported in this manuscript) it was indicated that both DPA-2-C^{14} and TPA-2-C^{14} were taken up by the roots of sweet corn plants, and that within twenty-four hours after treatment radioactivity could be detected throughout the plants by means of radioautographs.

Rate of Translocation. As has been previously indicated C^{14} was translocated from the treated area to the other plant parts at a more rapid rate after DPA-2-C^{14} applications than after TPA-2-C^{14} applications to bean and sweet corn plants, but that regardless of the chemical treatment C^{14} was transported more rapidly in bean plants than in sweet corn plants. Following DPA-2-C^{14} treatments to

the bean plants approximately thirty-six hours were required for the amount of C^{14} in the untreated portion of the plant (total plant minus treated leaf) to equal the amount of C^{14} in the treated leaf, whereas slightly more than seventy-two hours were necessary to attain a similar radioactive carbon distribution in TPA-2-C^{14} treated bean plants. Ninety-six hours after the application of DPA-2-C^{14} the untreated parts of sweet corn plants finally contained as much C^{14} as the treated tip, but in TPA-2-C^{14} treated sweet corn plants the treated tip still retained more C^{14} than the untreated parts had accumulated after seven days presentation time.

Again, differences in the results obtained with DPA and TPA appear to correspond to differences in the behavior of 2,4-D and 2,4,5-T. Several investigators (12, p. 293; 21; and 34, p. 630) have found that 2,4-D was translocated from the foliage to the other parts of treated plants more rapidly than was 2,4,5-T. Crafts (12, p. 293) suggested that "theoretically the chlorine substitutions in these molecules are lipophylic, and the third chlorine may hinder the partition of the molecule from the lipid phase of the leaf or cell surface into the aqueous medium of the living cell". On this basis the TPA and 2,4,5-T molecules containing three chlorine atom substitutions would be absorbed and translocated by plant leaves at a slower rate than the molecules with two chlorine substitutions (DPA and 2,4-D). Other factors concerning the properties of these herbicides which might enter into this discussion have been explored in relation to the differential absorption of di- and

trichloro- compounds by plant leaves.

In addition to the results of this study which indicate that C^{14} was translocated faster from the leaves of bean plants than of sweet corn plants treated with either DPA-2-C^{14} or TPA-2-C^{14}, others have found that after foliar applications of DPA-Cl^{36} (52, pp. 81-95), and 2,4-D-C^{14} (23, pp. 251-252 and 22, pp. 2-3), translocation of the radioactive tracer to other plant parts was more rapid in dicotyledonous than in monocotyledonous plants. It has been suggested (22, pp. 2-3) that the intercalary meristem of grass plants may in some way impede translocation from treated leaves to other portions of the plant. This might appear to be somewhat inconsistent with the supposition that the active agents of these herbicides move through plants in conjunction with the products of photosynthesis. This apparent inconsistency might be resolved by a consideration of some factors concerning the test plants. In all of the examples mentioned, as well as in this study, plants in early growth stages were utilized. It is not until monocotyledonous plant leaves have almost fully elongated that secondary xylem and phloem become well developed in the intercalary meristem. This lack of an efficient vascular system connecting various leaves of young monocotyledonous plants could result in a reduced rate of translocation from one leaf to another.

Translocation Influenced by Amount of Chemical Applied. The results of the experiments in which various amounts of DPA-2-C^{14} and TPA-2-C^{14} were applied to bean and sweet corn plants compare quite well with those of Fang et al.(23, pp. 251-252) who applied increasing

quantities of 2,4-D-C^{14} to the leaves of bean plants. As the rate of chemical application was increased there was a decrease in the percentage of C^{14} translocated from the treated area to other parts of the plants. These observations would tend to support the generally accepted suggestion that applications of excessive quantities of 2,4-D to perennial plants results in the disruption of the vascular system before sufficient quantities of herbicide could be translocated to all parts of the plant and thereby attain maximum effectiveness. Since the active agent of DPA and TPA apparently was translocated from the treated leaves of bean and sweet corn plants at a slower rate as the amount of chemical applied was increased, it might follow that toxic concentrations could be accumulated in the treated leaf before lethal quantities could be translocated to the root system and other parts of the plant.

Translocation Influenced by Plant Growth Stage. General field usage of 2,4-D and other growth regulator type herbicides has indicated that as plants develop from seedlings to maturity they become more tolerant to herbicides. Fang et al. (23, pp. 252-253) pointed out that after treatment at three stages of growth the rate of absorption of 2,4-D-C^{14} was greatest in the youngest bean plants which had been treated. This was interpreted as one reason for the greater effectiveness of 2,4-D when applied to younger plants as compared to the relative low effectiveness on older plants. The data reported herein indicate that the absorption of DPA-2-C^{14} and TPA-2-C^{14} and subsequent C^{14} translocation as influenced by plant stage of growth

are rather inconsistent. Absorption of DPA-2-C^{14} apparently was greater in younger bean plants than in older bean plants, but TPA-2-C^{14} absorption appeared to be slightly greater as older bean plants were treated. In older sweet corn plants DPA-2-C^{14} absorption apparently was increased, and TPA-2-C^{14} absorption was too inconsistent to establish a trend. Translocation of C^{14} to the various plant parts was just as inconsistent as the apparent absorption. Possibly more information could have been obtained if longer intervals between the three stages of growth to be tested had been established. It is also possible that more definite trends would have developed if plants at more than three stages of growth had been studied.

Absorption and Translocation as a Basis for Selective Toxicity

The demonstration that the absorption of DPA-2-C^{14} and TPA-2-C^{14} and the translocation of C^{14} in birds foot trefoil (resistant to DPA) and in bean and sweet corn plants (sensitive to DPA and TPA) was rather similar suggests that absorption and translocation are not factors involved in the selective toxicity of DPA and TPA. This observation is in agreement with those of Fang and Butts (22, pp. 2-3) and Rogers (46, p. 8) who have indicated that absorption and translocation apparently are not involved in the differential phytotoxicity exhibited by 2,4-D or ATZ.

On the basis of the amount of radioactivity found in entire plants at various intervals after treatment, it is suggested that in bean plants DPA was broken down and metabolized faster than TPA, and that both DPA and TPA were broken down and metabolized more rapidly

in bean plants than in sweet corn plants. The total recovery of radioactivity from DPA-2-C^{14} treated bean plants was reduced markedly after remaining fairly constant during the first three days following treatment whereas it was not until after five days had elapsed that the recovery of radioactivity in TPA-2-C^{14} treated plants decreased to any extent. In sweet corn plants no consistent decrease in total recovery of radioactivity was noted during the seven day experimental period.

The sharp reduction in the amount of radioactivity in the growing tip of DPA-2-C^{14} treated bean plants corresponding to the loss in total radioactivity during the final four days of the experiment suggests that the breakdown and metabolism of DPA may occur primarily in the trifoliate leaves since it was at this stage of the experiment that the trifoliate leaves began to expand. Possibly experiments conducted over a longer period of time would provide more information concerning the biological half-life of these compounds in the different plants. It is also likely that measurements of the amount of C^{14} lost as $C^{14}O_2$ over a longer period than the three day trial of this study would be of help in determining how rapidly DPA and TPA are detoxified in plants.

It would appear that a study of the metabolism of DPA and TPA in different plant species would be of value. As yet there has been no indication as to whether DPA and TPA or some complex containing the active agent of these herbicides is translocated through sensitive and tolerant plants. Neither is there information available to

indicate where in the plant - morphological or physiological - that DPA and TPA exert their toxic properties. The answers to such questions as these would undoubtedly help in the evaluation of the many potential herbicides that are discovered each year.

Residual Activity in Soil

The growth responses of sweet corn plants seeded in DPA and TPA treated soils indicated that although the two chemicals exhibited similar phytotoxicity, TPA consistently was more effective in inhibiting the growth of sweet corn plants. Had other plant species been used as test plants it is quite possible that DPA might have appeared to be the more toxic of the two herbicides. It has been recognized for sometime that 2,4-D and 2,4,5-T are generally toxic to broadleaf weeds; however, 2,4-D is more toxic than 2,4,5-T to Canada thistle (Cirsium arvense), and 2,4,5-T is more toxic to wild blackberry (Ribes spp.) than 2,4-D. Advantage has been taken of this differential specificity by mixing 2,4-D and 2,4,5-T for applications to an area containing a variety of plant species. The mixture provides better control of all species present than either 2,4-D or 2,4,5-T alone.

The higher degree of growth inhibition of sweet corn plants by DPA and TPA in corporated into loam soil as compared to clay loam soil is consistent with well established principles concerning soil applications of herbicides. It has been noted over the years that most soil active herbicides are reduced in effectiveness in soils high in clay and organic matter content. As previously indicated in the Review of Literature, Weaver (49, pp. 74-78) reported that 2,4-D

and 2,4,5-T were both adsorbed in considerable quantity on both anion and cation exchangers, and that the adsorbed 2,4-D was not available to plant roots. Aldrich (1, pp. 258-259) in reviewing herbicide residues in soil indicated that adsorption of the herbicide on clay and organic colloids represented one manner in which the effectiveness of many herbicides can be reduced following soil applications.

The results of the experiments designed to study the influence of time and temperature on the residual activity of DPA and TPA in different soils are in agreement with the results obtained by other workers (48, pp. 2-4; 30, pp. 209-214; 35, pp. 323-324; 25, pp. 50-56; 3, p. 171; 8, pp. 317-318; and 18, pp. 223-225) studying the decomposition of various organic soil active herbicides. The data reported in this study indicate that increased temperature of storage and possibly the higher soil organic matter content of the clay loam soil, both of which would contribute to the development of soil microorganism populations, hastened the decomposition of DPA and TPA incorporated into soil. Conversely, the removal of the microorganism influence by autoclaving resulted in little if any loss of DPA or TPA toxicity in moist soil over a period of fifteen weeks of storage at either 32 to 40° F. or 72° F. Thiegs (48, pp. 2-4) and Holstun and Loomis (30, pp. 209-214) studying DPA, Loustalat and Ferrer (35, pp. 323-324) working with TCA, Freed (25, pp. 50-56) testing IPC, and others (3, p. 171; 8, pp. 317-318; and 18, pp. 223-225) investigating 2,4-D and 2,4,5-T, have reported that such factors as increased

temperature, increased moisture, high soil organic matter, and high lime content all favored soil microorganism populations and increased the rate of herbicide breakdown in soil, and that soil sterilization to prevent the development of soil microorganisms resulted in very slow deactivation of the soil active herbicides. Audus (2, p. 356) has isolated a bacteria which is capable of breaking down 2,4-D, but as yet there have been no reports of specific microorganisms responsible for the detoxication of the other herbicides studied.

Although it was generally true that higher temperatures increased the rate of DPA and TPA decomposition, certain exceptions to this observation exist. As was indicated in the presentation of results, after three weeks of storage at any of the three temperatures there was no significant difference in the growth of sweet corn plants seeded in clay loam soil treated with 50 ppm. of DPA and of sweet corn plants seeded in untreated soil. Also, it was not until after twelve weeks of storage at 32 to 40° F. that all of the plant growth responses were reduced by the 50 ppm. DPA treatment. It would appear that the DPA became more toxic as the 32 to 40° F. storage period progressed. However, the results of the sterilization experiment indicate that such an assumption would be erroneous. One possibility for the lack of evident toxicity in the 50 ppm. treated soil stored for only three to nine weeks at 32 to 40° F. involves the time of year during which that particular experiment was conducted. The

chemical treatments to the soil were made during late December. Thus, the tests for residual activity in the clay loam soil at three, six, and nine weeks after treatment were conducted during a period of short daylength and low light intensity, conditions that are quite unfavorable for plant growth. Thus, the effects of the treatments imposed were probably obscured by the limiting effects of poor light conditions. As the storage period progressed both intensity and duration of light increased so that plants seeded to untreated soil representing twelve and fifteen weeks of storage grew normally, and inhibition of the plants in treated soil became evident.

When incorporated into the same type of soil stored at identical temperatures DPA and TPA at 10 ppm. concentrations were detoxicated in approximately equal lengths of time. DPA and TPA applied at 50 ppm. to either soil type and then stored at 32 to 40° F. also revealed no differences in regard to their persistence in soil. However, in clay loam soil and in loam soil kept at 55 to 60° F. or at 72° F., TPA remained active for a considerably longer period than did DPA. Thus in the loam soil the 50 ppm. concentration of DPA was rendered inactive within six weeks at 55 to 60° F. whereas TPA was still quite toxic to sweet corn plants seeded fifteen weeks after the treatments were made. Similar studies have indicated that regardless of the inherent toxicity toward a particular plant species, following equivalent soil applications, 2,4-D was less persistent than 2,4,5-T (18, pp. 223-225), and IPC breaks down more rapidly than CIPC (25, pp. 50-56). In three groups of herbicides in which two chemicals in

each group differ in chemical sturcture by only one chlorine substitution, the compound with the extra chlorine substitution exhibits greater persistence in various soil types.

Audus (2, p. 356) has found that one of a group of very common soil bacteria known as Bacterium globiforme is capable of utilizing 2,4-D as a source of carbon. His work would suggest that only the one form of this group is responsible for the decomposition of 2,4-D, and that this particular bacterium is not present in great quantity in the normal soil. The lag phase prior to decomposition of 2,4-D in soil further suggests that proliferation of the bacteria that utilizes 2,4-D is necessary before noticeable detoxication takes place. Further studies by Audus (3, p. 170) indicate that the organism capable of utilizing 2,4-D does not decompose 2,4,5-T. Apparently the organism (or organisms) capable of breaking down 2,4,5-T were present in even less number than those which brought about the detoxication of 2,4-D. It would appear reasonable to expect that a similar situation might be responsible for the differential soil persistence of DPA and TPA.

SUMMARY

Sodium 2,2-dichloropropionate (DPA) and sodium 2,2,3-trichloropropionate (TPA), two chemicals differing in chemical structure by only one chlorine substitution, which recently have been developed as growth regulator type herbicides toxic toward grass plants were studied as follows.

(1) Absorption of sodium 2,2-dichloropropionate-2-C^{14} (DPA-2-C^{14}) and sodium 2,2,3-trichloropropionate-2-C^{14} (TPA-2-C^{14}) by the leaves of bean and sweet corn plants, and the translocation of C^{14} to other plant parts.

(2) Absorption of DPA-2-C^{14} and TPA-2-C^{14} by the leaves of a plant tolerant to the action of DPA (birdsfoot trefoil) and the translocation of C^{14} to other plant parts.

(3) Residual activity of DPA and TPA as influenced by time and temperature in two soil types, and in sterilized soil, as measured by the growth of sweet corn plants seeded at various intervals after treatment.

The data from these studies may be summarized as follows:

1. Apparently as much DPA-2-C^{14} and TPA-2-C^{14} were absorbed by leaves of bean and sweet corn plants within two hours as in seven days. DPA-2-C^{14} and TPA-2-C^{14} appeared to be absorbed in greater quantity by the leaves of bean plants than sweet corn plants. Various factors possibly involved in this differential absorption by bean and sweet corn plants was discussed.

2. Following the absorption of DPA-2-C^{14} and TPA-2-C^{14},

radioactive carbon apparently was translocated from the treated area primarily toward the rapidly developing plant tissue of bean and sweet corn plants. This suggests that the active agent of DPA and TPA moves through plants in conjunction with the products of photosynthesis.

3. The translocation of C^{14} in DPA-2-C^{14} treated plants appeared to be more rapid than in TPA-2-C^{14} treated plants, but regardless of the treatment, translocation of C^{14} in these experiments was more rapid in bean than in sweet corn plants. The possibility that the intercalary meristem in young sweet corn plants may have impeded translocation was considered.

4. Increasing the amount of DPA-2-C^{14} and TPA-2-C^{14} applied to the leaves of bean and sweet corn plants resulted in a decrease in the percentage of C^{14} translocated from the treated area to other plant parts. This may, in part at least, explain why high rates of application of plant growth regulator herbicides sometimes results in less effective weed control than moderate rates of application.

5. At the three stages of growth at which DPA-2-C^{14} and TPA-2-C^{14} were applied, no consistent differences in absorption by the leaves, nor translocation of C^{14} to other plant parts could be detected.

6. Since DPA-2-C^{14} and TPA-2-C^{14} were absorbed by the leaves of birdsfoot trefoil (tolerant to the action of DPA), and the translocation of C^{14} to other plant parts corresponded to the behavior of these chemicals applied to bean and sweet corn plants (sensitive

to the action of DPA and TPA), it is proposed that absorption and translocation are not factors concerned in the selective toxicity of DPA and TPA.

7. The growth responses of sweet corn plants indicated that although soil applications of DPA and TPA exhibited similar toxicity, TPA consistently was more toxic than DPA. Considering the differential sensitivity of various broadleaf plants to 2,4-D and 2,4,5-T, it is suggested that other grass plants may be more sensitive to DPA than to TPA.

8. Higher temperature and possibly greater soil organic matter content increased the rate of detoxication of DPA and TPA in soil. Sterilizing the soil prior to chemical treatment resulted in little or no decomposition during fifteen weeks of storage at either 32 to 40° F. or at 72° F. It is apparent that soil microorganisms were primarily responsible for the detoxication of DPA and TPA, and any modification of the environment that promoted microorganism proliferation hastened the breakdown of soil active herbicides.

9. Under conditions favoring decomposition of soil active herbicides, TPA remained toxic to sweet corn longer than did DPA.

10. Due to the more rapid rate of translocation and to the faster detoxication in soil, it is suggested that DPA would probably prove more practical than TPA for the control of perennial grass plants on agricultural cropland. If these two compounds exhibit differential specificity toward various grass species, a mixture of the two, comparable to the mixtures of 2,4-D and 2,4,5-T may find some practical use.

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APPENDIX

Appendix Table 1

Certain Properties of Chehalis Clay Loam Soil*

	Percent
Mechanical Analysis (Hydrometer) Sand	28.3
Silt	43.9
Clay	27.7
Organic Matter Content (Walkley-Black)	3.65
Moisture Equivalent	30.4
Fifteen-Atmosphere	13.4

*Determinations conducted by the Oregon State College Soils Department.

Appendix Table 2

Certain Properties of Chehalis Loam Soil

		Percent
Mechanical Analysis (Hydrometer)	Sand	47.7
	Silt	33.9
	Clay	18.7
Organic Matter Content (Walkley-Black)		1.80
Moisture Equivalent		20.9
Fifteen-Atmospheres		9.2

Appendix Table 3

Typical Analysis of Variance Used in Evaluating Residual Activity of DPA and TPA

Source of Variation	Degrees of Freedom
Total	19
Replications	3
Treatments	4
Error	12