INTERACTIONS OF PLANT GROWTH REGULATORS OR ADDITIVES ON ABSORPTION AND TRANSLOCATION OF HERBICIDES

By

PETER BOHDAN CHYKALIUK

Bachelor of Science
Rutgers University
New Brunswick, New Jersey
1977

Master of Science
Texas Tech University
Lubbock, Texas
1979

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
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Thesis Approved:

T. F. Peeper
Thesis Adviser

J. F. Stritzke

Eddie Basler

Paul Lachlan Lantz

Paul E. Richardson

Norman N. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Field bindweed is of European origin (27). It is also known as wild morningglory, European bindweed, creeping jenny, creeping charlie and Russian creeper (4, 8). Infestations of field bindweed can spread through seasonal root growth, seeds, and root fragments carried by farm equipment (27). The tap root may branch at a depth of 2 feet or less in a high water table area, while in other locations, it may penetrate to a depth of 10 feet or more before branching profusely (8, 45). From lateral roots, rhizomes are produced which penetrate the soil surface forming new crowns (45). Rhizomes may vary in length from a few inches to several feet.

Economic losses due to field bindweed infestations in many crops are attributed to competition for light, nutrients, and moisture, however, this weed is also a host for disease, insects, and other pests (28). Field bindweed hinders harvesting equipment by becoming tangled in moving parts and adds moisture content to grain (32). This weed has been a major problem in the midwest and western United States for many years (39) and has been increasing its presence throughout North America.

Control programs for field bindweed emphasize postemergence topical applications (32). Therefore, the leaves and stems serve as primary intercepting and absorbing organs, and the applied chemical must

penetrate into plant tissue before a biological response can be induced. Aerial plant parts are covered by a cuticle, which serves as the primary barrier to penetration of materials, particular polar substances, into plants (10).

Cutin, which is the chief structural component of the cuticle, consists of a highly concentrated layer of wax (10). The thickness of epicuticular wax on leaf surfaces varies in different species (3) and with environmental conditions (33). Several studies have shown that quantity, composition, and orientation of the waxy covering can vary with leaf age and environmental conditions and consequently these factors influence chemical absorption (23, 54, 46, 47).

The use of herbicides such as glyphosate, dicamba, and the phenoxys to control deep-rooted perennial plants such as field bindweed in many cases has either been too expensive or too inconsistent for practical control programs (34, 36). Control of field bindweed could be improved by enchancing absorption of the herbicides presently used for control.

Another major factor which provides for suboptimal efficiency of field bindweed control appears to be related to insufficient basipetal translocation of herbicide to root zones. For example, hedge bindweed (Convolvulus sopium L), Canada thistle (Circium arvense (L.) Scop.) and wild buckwheat (Polygonum convolvulus L.) translocated approximately 22,8 and 5% of applied glyphosate from the treated area, respectively, while in field bindweed only 3.5% moved from the treated area and only half of that was expected to reach the root zone (36). Studies have also shown that translocation of herbicides in deep rooted perennial weeds was associated with phytotoxicity (9, 13, 38). Thus, chemical agents which could enhance basipetal translocation of herbicides would

appear to be of practical value since they could provide increased distribution of herbicides into extensive root systems which are commonly found in perennial weeds such as field bindweed, and possibly decrease the amount of herbicide necessary for optimum control.

The objective of these studies was to evaluate effects of selected plant growth regulators and other potential synergistic additives on the uptake and translocation of various herbicides.

CHAPTER II

LITERATURE REVIEW

Surfactants can significantly enhance the phytotoxic response to herbicides such as glyphosate (17, 38), 2,4-D (13) and dicamba (26). Use of 0.1% v/v surfactant has been found to increase the toxicity of glyphosate to soybeans (30).

The primary effect of surfactants is a lowering of surface tension of the spray solution (18). Other effects of surfactants include solubilization of waxes (14), increased retention on the leaf surface, and increased drying time.

Inorganic ions such as ammonium sulfate (19), iron, aluminum (21), nitrogen (35), calcium (36), and other inorganic salts (48, 49) have either enhanced or depressed herbicidal action. Phytoxicity may be directly related to the additive's effect on herbicide penetration (17, 20). Many phosphate esters are synergistic when mixed with glyphosate or certain other water soluble foliarly applied herbicides (42). In other studies, synergistic effects apparently followed disruptions of leaf surfaces with additives (40). However, many phosphate adjuvants do not visibly injure leaves and probably act differently. Several acids or complexing agents which enhance the effects of glyphosate are citric, tartaric and lactic acids (41). Other acids which are not complexing agents had little or no effect. It was suggested that activation was due to interactions with calcium or other metallic ions, which would otherwise immobilize the herbicides (41).

Numerous chemicals and growth regulators have been shown to influence translocation of herbicides, particularly the phenoxys. However, very few compounds have increased basipetal translocation. Most effects have been either basipetal translocation inhibition or acropetal translocation enhancement.

Basler (7) found that GA_3 treatments enhanced acropetal translocation and inhibited basipetal translocation in beans. In the same study, ABA treatment inhibited acropetal translocation and caused a short-lived enhancement of basipetal translocation. However, as treatment time increased, ABA inhibited both acropetal and basipetal auxin translocation. Basler also found in this study that ancymidole (∝-cyclopropyl-∝(4-methoxyphenyl)-4-pyrimidine-methanol) inhibited acropetal translocation and had very little effect on basipetal translocation of 2,4,5-T in intact bean seedlings. In the same study DPX 1840 [3, 3a-dihydro-2-(p-methoxyphenyl)-8H-pyrazolo(5,1-a)isoindol-8-one] and morphactins greatly increased acropetal translocation to young shoots and primary leaves and severely decreased translocation of 2,4,5-T to roots.

Basler and McBride (6) found that pretreatments with coumarin in beans inhibited 2,4,5-T translocation to young shoots and primary leaves but had very little effect on translocation to roots. Juglone enhanced acropetal translocation of 2,4,5,-T and inhibited basipetal translocation.

Ethephon substantially increased basipetal translocation of dicamba in wild garlic (Allium canadense L.) (9). The authors suggested that ethylene released from ethephon degradation may have altered the metabolic "sink source" relationship within wild garlic plants allowing increased basipetal translocation.

Researchers have found that GAF 141, an experimental ethylene-releasing agent, produced a ten fold increase of 2,4,5-T accumulation in bean seedling roots following injections into the cotyledonary node (17). GAF 141 was postulated as a compound influencing "sink source" relationships within bean plants in a similar fashion as ethephon. The mechanism of action for ethephon and GAF 141 were not identified.

Yang (50) has stated that treating field grown plants with ethylene gas is not practical because it dissipates too rapidly. However, the product ethephon exerts its effect by gradually releasing ethylene as a decomposition product close to the site of action in plant tissue. Its effects are similar to those exerted by ethylene.

Ethylene has been reported to inhibit phospholipid metabolism (24), increase membrane permeability (1), induce epinasty (20) and enhance senescence (12). Ethylene also causes loss of chlorophyll (20, 37) enchances yellowing (11), inhibits cell division and expansion (11), reduces DNA synthesis (11), and increases cellulose activity in abscission zones (22). Ethephon has been found to induce swelling of leaf bases and initiates bulbing in onion during a noninductive day length (29). Normally, day lengths of 12 to 16 hours are required for bulb initiation.

Morgan et al. (31) reported that combination sprays containing picloram (4-amino-3,5,6-trichloropicolinic acid) and ethylene-releasing agents were more effective in killing honey mesquite [Prosopis glandulosa (Torr.) var. glandulosa] than picloram alone. The same researchers also found that combinations of ethephon and 2,4,5-T significantly increase mesquite mortality over those treatments with either compound alone.

Basler (5) found that GAF 141 was effective in altering 2,4,5-T translocation in beans. This growth regulator applied at 500, 1000 and 2000 ppm as a foliar spray one day before treatment with 2,4,5,-T inhibited 2,4,5-T translocation to young shoots and primary leaves of beans. On the other hand, basipetal translocation to roots was greatly enhanced. Addition of GA_3, which stimulates acropetal translocation, reversed the effects of GAF 141.

Previous work showed that GAF 141 enhanced basipetal translocation of ^{14}C-acifluorfen to roots, and inhibited acropetal translocation to younger shoots (15). Acifluorfen is effective primarily as a postemergence herbicide, but due to a lack of basipetal translocation is thought to have little effect on roots (43). Therefore, tank mixtures with GAF 141 or similar acting plant growth regulators might prove to be beneficial synergists with acifluorfen in the control of deep rooted perennial weeds.

CHAPTER III

MATERIALS AND METHODS

Effect of SA-77 on Herbicide Absorption by Field Bindweed

Experiments were conducted to evaluate effects of SA-77, leaf age and frost on ^{14}C-2, 4-D, ^{14}C-glyphosate and ^{14}C-dicamba absorption by field bindweed leaves. Field bindweed leaves were collected from established plants growing at the Agronomy Research Station in Stillwater, Oklahoma. Experiment 1 (prefrost) was conducted with leaves collected August 28, 1980, and Experiment 2 (postfrost) with leaves collected on November 5, 1980. Field bindweed plants in Experiment 1 were exposed to 60 days of hot and dry weather conditions prior to collection during which time only 4.4 cm of rainfall occurred. Leaf samples for Experiment 2 were taken from field bindweed plants that were subjected to a total of 8 hours of -1 to 0°C temperatures during the two consecutive days, prior to sampling. Between collections 5.1 cm of rainfall was recorded. Field bindweed plants were still physiologically active when leaf samples were taken.

Immature and mature leaves were collected for both experiments. They were selected according to size and healthy appearance (green and no visual physical damage). Dry weights for immature and mature leaves averaged 45 ± 5 mg and 460 ± 60 mg, respectively. Following excision, leaf petioles were immediately embedded into water saturated tissue

paper. The leaves were then arranged in rectangular flats, covered with perforated transparent cellophane, and placed into a growth chamber under constant light (5.5 Klux), with 30% RH and 25°C.

Herbicide treatments (10 µl aliquots) per leaf sample contained total molar concentrations of 0.161mM for ^{14}C-2,4-D (specific activity = 10.1 µc/µM), 0.094mM for ^{14}C-dicamba (specific activity = 17.06 µC/µM) and 0.11mM for ^{14}C-glyphosate (specific activity = 1.95 µC/uM). The spray additive SA-77 was added to herbicide stock solutions to formulate a 5% v/v solution of SA-77. Each treatment was spotted directly to the adaxial surface of each leaf in five 2 ul drops. After treatment, the flats were again covered with clear cellophane and kept under the same growing conditions.

After 2 or 24 hours leaf surfaces were rinsed with 95% ethanol for about 10 seconds followed by a 20 second agitation in distilled water to remove herbicide, then blotted dry. The leaves were then freeze dried, weighed and combusted in a Harvey Biological Material Oxidizer. The $^{14}CO_2$ was trapped for ^{14}C analysis in $^{14}CO_2$ UNT Sorb and quantified into disintegrations per minute (DPM) using a liquid scintillation spectrophotometer. Treatments were arranged in a randomized complete block design with eight replications.

Scanning electron micrographs (SEM) of adaxial surfaces of mature and immature leaves (before frost samples) were taken to view SA-77 effects on epicuticular wax. Leaves of each age were treated with 5% v/v SA-77 by spotting 2 µl droplets on one half of the adaxial surface, leaving the other side untreated. After 24 hours, the leaves were rinsed with distilled water, dehydrated to approximately 50% moisture content under vacuum and then plated with a 200 A° layer of gold/palladium in a Hummer II apparatus.

Effects of Plant Growth Regulators or Additives on Herbicide Translocation in Beans and Field Bindweed

Modification of Herbicide Translocation in Beans

Bean seeds were germinated in a perlite medium which was moistened with half-strength Hoagland's nutrient solution (16) for 5 days at 32°C under continuous flourescent light (5.5 klux). Seedlings were then transplanted to amber jars containing 400 ml of aerated, half strength Hoagland's nutrient solution and grown for 4 days in a growth chamber with 14 hour, 33°C, 22 klux days, and 10 hour 29°C nights and 20 to 30%, relative humidity.

In all experiments the herbicide treatments consisted of either 8.7 ug glyphosate (1.95 mCi/ mMole, methyl ^{14}C), 1 ug dicamba (17.06 mCi/ mMole, ring-UL), 6.0 ug acifluorfen (3.22 mCi/mMole, ring-UL), 0.5 ug 2,4,5-T (54 mCi/mMole, 1-^{14}C-acetic acid) or 1 ug 2,4,-D (57 mCi/mMole, 1-^{14}C-carboxyl). Radiochemical purity of the herbicides as indicated by thin layer chromatography was 97 to 99%. Glyphosate was formulated into the isopropylamine salt by adding 4.35 mg ^{14}C-glyphosate plus MON 0818 (nonionic surfactant) at 15.2% v/v to an equal molar ratio of isopropylamine prior to use. This was then made up to 0.5 ml total volume with distilled water (54.3% v/v). Dicamba, acifluorfen, 2,4-D and 2,4,5-T were dissolved in 95% ethanol. Plants were treated with ^{14}C labeled herbicides by inserting a 1 ul syringe needle into the cotyledonary node and down the center of the stem about 1 cm below the point of insertion where chemicals the were deposited.

GAF 141 or ethephon was applied to completely wet the tops of bean seedlings with a distilled water solution containing, 0, 250, 500, 1000,

1500 ppm of these materials plus 0.1% v/v Triton AG-98 or 0.1% v/v Triton X-100 (both are nonionic sufactants). GAF 141 or ethephon was applied simultaneously (0 hours), 4 hours or 24 hours prior to ^{14}C-2, 4-D, ^{14}C-glyphosate, ^{14}C-2,4,5-T, ^{14}C-acifluorfen or ^{14}C-dicamba treatments. Treated plants were harvested 4, 24, 48 and/or 72 hours following ^{14}C-herbicide injection in various experiments.

Herbex treatments were foliarly applied to beans at 1500 ppm, with no surfactant added, simultaneously with ^{14}C-2,4-D. Plants were harvested 24 hours following treatment.

Ammonium metavanadte treatments at concentrations of 1, 2 or 4 µg per plant were stem injected into the cotyledonary node along with 1.0 ug ^{14}C-2,4,5-T. Plants were harvested 24 hours following treatments.

Similar harvesting procedures were used for all of the bean translocation experiments. At harvest, the plants were separated into young shoots (including all tissue above the primary leaves), primary leaves (including petioles), epicotyl (including all tissue 0.5 cm above the cotyledonary node up to the primary leaf node), treated area (including all stem tissue 0.5 cm above the cotyledonary node down to 2.5 cm below the cotyledonary node), hypocotyl (including the remainder of the stem down to the roots) and roots. Treatments were replicated 8 times and bean seedlings were arranged in a randomized block design within the growth chambers. Plant parts were freeze-dried and combusted similarly to the method used in the absorption studies. At harvest, 10 ml aliquots of the nutrient solution were freeze-dried, and assayed for ^{14}C-activity along with the plant parts and quantified by liquid scintillation counting. Statistical analysis of the data was conducted using standard F tests and Duncan's New Multiple Range Test ($p<.05$).

Modification of Herbicide Translocation in Field Bindweed

Field bindweed plants were grown from 10 ± 1 cm root sections taken from an established stand in the field. Plants were grown in 400 ml half-strength Hoaglands nutrient solution until there were 5 to 7 fully expanded leaves on each plant. At this stage field bindweed plants were treated by submerging plant tops in a 2000 ppm GAF 141 solution containing 0.05% Triton B-1956 (nonionic surfactant) as a wetting agent. Simultaneously with the GAF 141 treatment four 2.5 µl drops of ethanol containing a total of 1 µg of ^{14}C-dicamba or 8.7 µg of ^{14}C-glyphosate were applied to one mature leaf. Treatments were replicated 6 times and harvested 24 hours after treatment.

At harvest, plants were separated into upper foliage and stems minus the treated leaf, original root piece, upper 6 cm of root from the original root piece, and the remaining lower root portion. A 10 ml aliquot from the nutrient solution was taken to measure any ^{14}C which may have leaked from the roots. The ^{14}C was combusted, quantified and analyzed statistically utilizing the same methodology as in the bean experiments.

CHAPTER IV

RESULTS AND DISCUSSION

Effects of SA-77 on Herbicide Absorption by Field Bindweed

Absorption of ^{14}C-2,4-D, ^{14}C-dicamba, and ^{14}C-glyphosate increased with longer treatment exposure at both the prefrost and postfrost dates (Table I). A 2 to 3 fold increase in absorption was observed for each herbicide 24 hours following treatment compared to the 2 hour exposure. These observations are consistent with past studies that have compared absorption over time (10, 13, 17, 25).

The effects of leaf maturity on absorption have a practical significance in understanding or developing a control program for field bindweed. Significantly more % ^{14}C was absorped by mature leaves than immature leaves with all herbicides (Table I). A 3 fold increase in ^{14}C-2,4-D and ^{14}C-dicamba absorption was observed in mature leaves compared to immature leaves collected prefrost. A 4 fold increase in ^{14}C-glyphosate absorption was observed in mature field bindweed leaves over immature leaves collected prefrost. Postfrost collected mature leaves also absorbed more of each herbicide than immature leaves collected postfrost. However, considering only mature leaves, the effect of frost increased the uptake of ^{14}C-2,4,-D but not ^{14}C-dicamba or ^{14}C-glyphosate. With all three herbicides the effect of frost was greater on immature leaves. Leaf surface waxes in mature leaves may

TABLE I

EFFECTS OF TREATMENT EXPOSURE, LEAF MATURITY, AND ADDITIVE ON HERBICIDE ABSORPTION OF FIELD BINDWEED[1] LEAVES HARVESTED AT TWO COLLECTION DATES

Treatment	^{14}C-2,4-D[2]		^{14}C-Dicamba		^{14}C-Glyphosate	
	Pre	Post	Pre	Post	Pre	Post
	% ^{14}C of Total Applied					
Exposure						
2 hours	4.1 c	13.4 b	12.7 b	12.2 b	15.0 d	25.7 c
24 hours	12.2 b	29.7 a	35.9 a	41.6 a	33.1 b	42.6 a
Leaf Maturity						
Immature	4.1 c	12.6 b	11.7 c	20.8 b	9.2 c	29.0 b
Mature	12.2 b	30.5 a	37.0 a	33.1 a	38.9 a	39.4 a
Additive						
0.0% v/v SA-77	7.6 b	19.8 a	18.2 b	19.7 b	16.1 d	24.2 c
5.0% v/v SA-77	8.8 b	23.3 a	30.4 a	34.2 a	32.0 b	44.2 a
Collection Date	8.2 b	21.5 a	24.3 a	26.9 a	24.0 b	34.2 a

[1] Percent means for each treatment comparison (exposure, leaf maturity, additive and collection date) under each herbicide followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[2] The pre column is for samples collected before frost and the post column is for samples collected after frost.

have been disrupted through some mechanism similar to that occurring in leaves exposed to freezing temperatures (23). This may explain the decrease in significant differences in % ^{14}C absorption between the mature and immature leaves for the postfrost date (Table I). Scanning electron micrographs (SEMs) of immature adaxial leaf surfaces (Figures 1 and 5) compared to mature adaxial leaf surfaces (Figures 2 and 6) show a pronounced irregularity of cells with greater ridging of waxes on the mature leaf surface than on immature leaf surfaces. This may indicate that mature leaf surfaces may have disruptions which offered decreased resistance to herbicide penetration. These surface disruptions may be indicative of regions with thinner wax deposition.

Additions of SA-77 to ^{14}C-2,4,-D did not increase ^{14}C-2,4-D absorption either before or after frost. With ^{14}C-dicamba and ^{14}C-glyphosate increased absorption by field bindweed leaves was observed at both collection dates by adding SA-77 (5%v/v) to the carrier solution. SEMs indicate that SA-77 solutions increased ridging and surface disruptions in both young (Figures 1, 3, 5, 7) and old (Figures 2, 4 6, 8) field bindweed adaxial leaf surfaces. Apparently, SA-77 causes the epicuticular wax to form into ridges through an undetermined mechanism or causes excretion of new wax in ridge-like formations. Barring additional deposition of new wax onto the leaf surface, thinner areas of wax would exist which should be less of a physical barrier to herbicide penetration.

Combining main effects (treatment exposure, leaf maturity, and additive) provided greater % absorption (Table I) at the postfrost date than at the prefrost date for ^{14}C-2,4,-D and ^{14}C-glyphosate but not

Figure 1. Scanning Electron Micrograph of an Immature Field Bindweed Adaxial Leaf Surface Untreated. 20x

Figure 2. Scanning Electron Micrograph of a Mature Field Bindweed Adaxial Leaf Surface Untreated. 20x

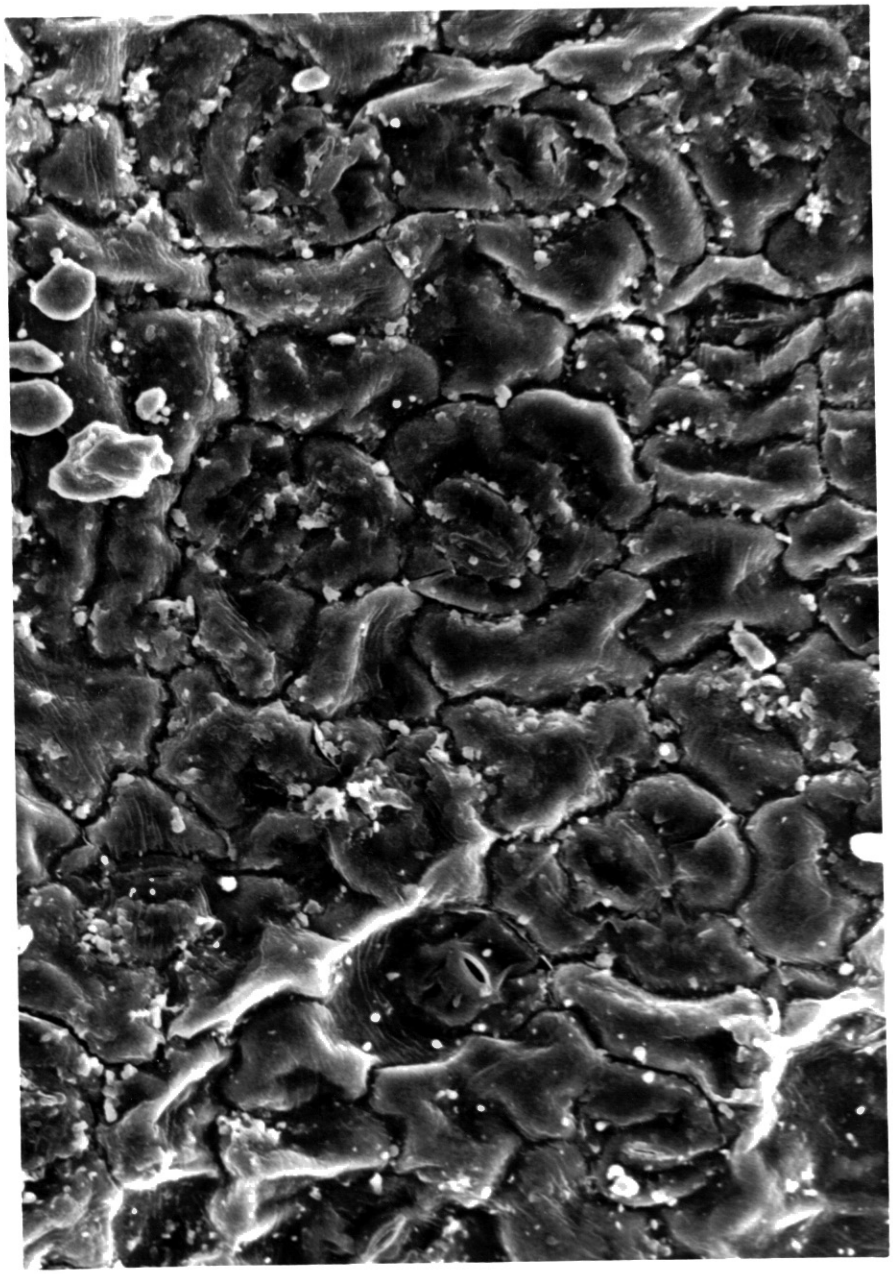


Figure 3. Scanning Electron Micrograph of Immature Field Bindweed Adaxial Leaf Surface 24 Hours After Treatment with SA-77 at 5% v/v. 20x

Figure 4. Scanning Electron Micrograph of a Mature Field Bindweed Adaxial Leaf Surface 24 hours After Treatment with SA-77 at 5% v/v. 20x

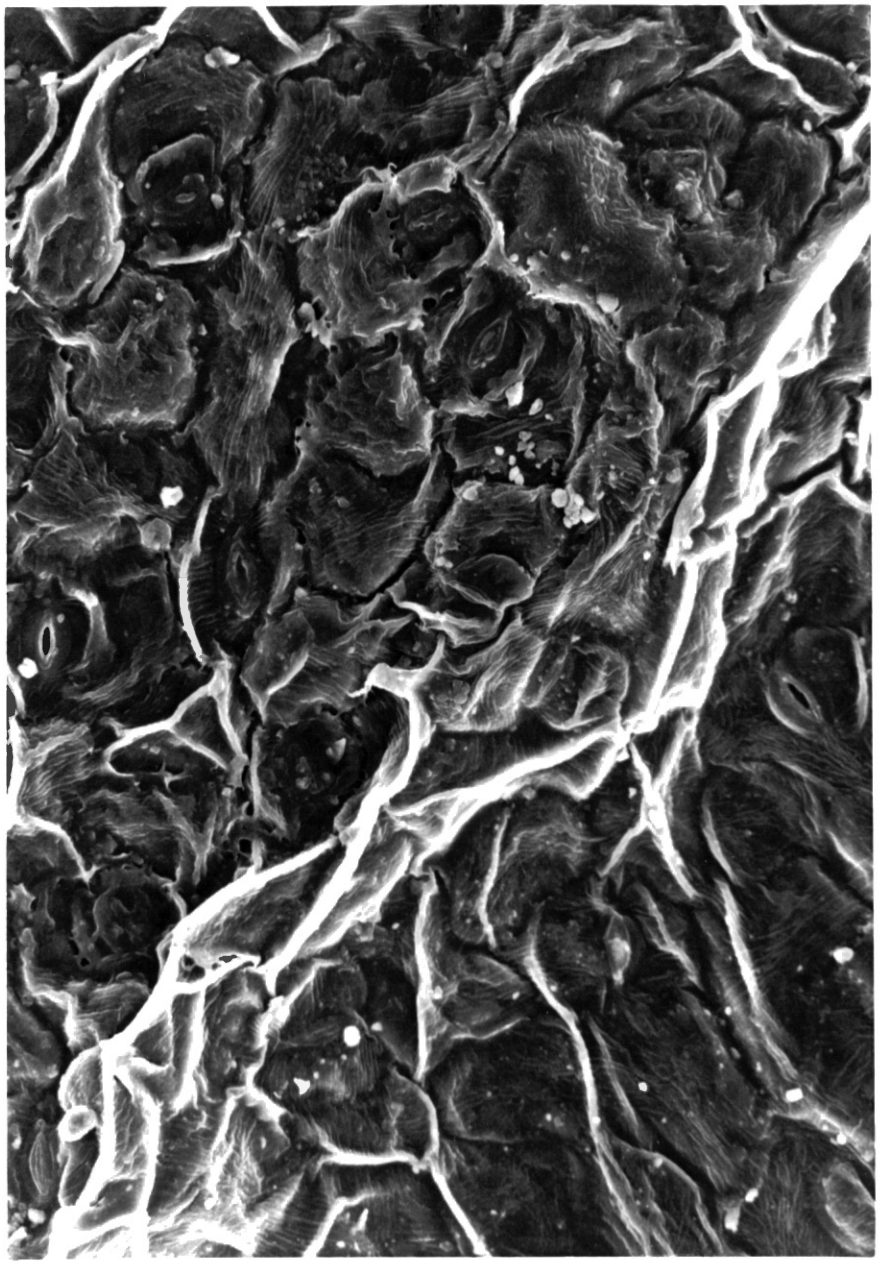


Figure 5. Scanning Electron Micrograph of an Immature Field Bindweed Adaxial Leaf Surface Untreated. 1300x

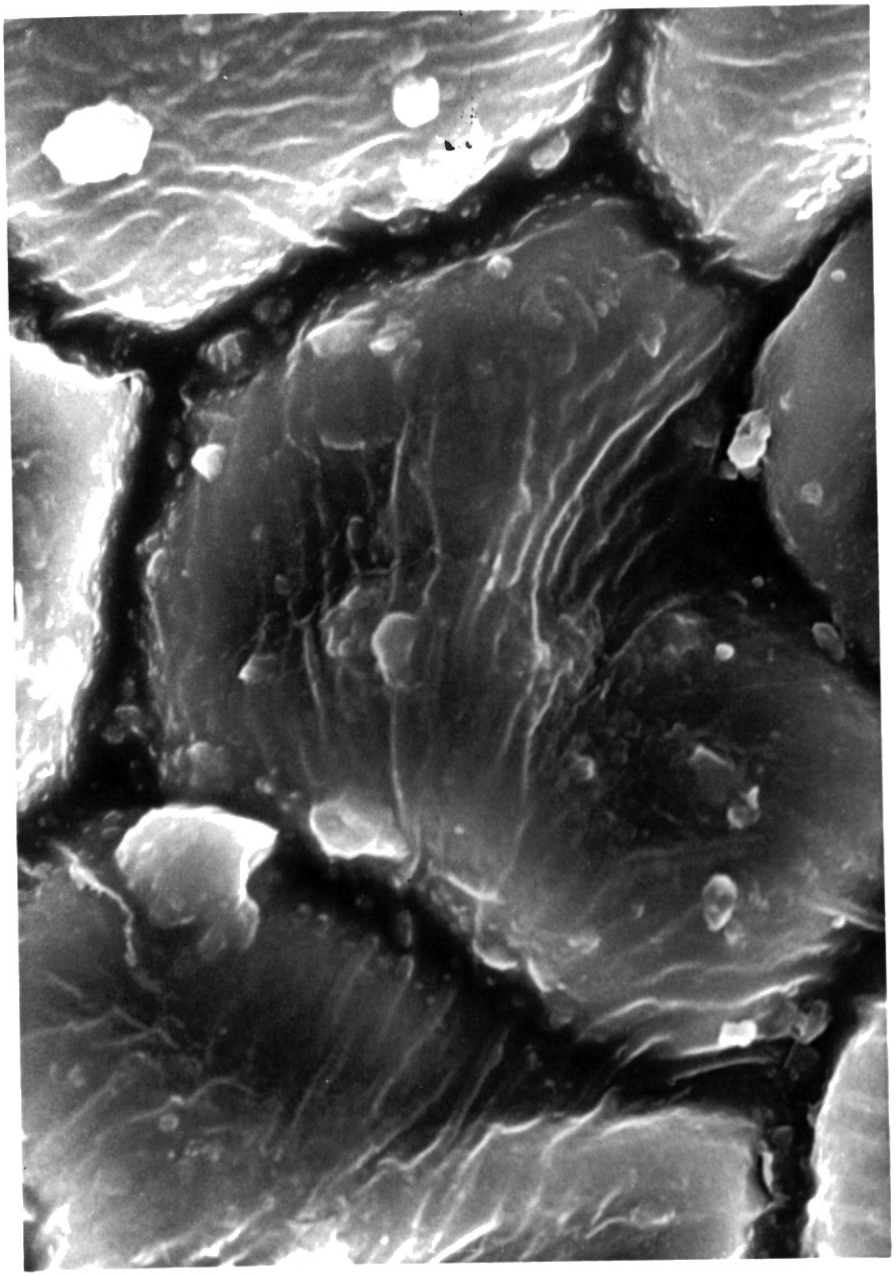


Figure 6. Scanning Electron Micrograph of a Mature Field Bindweed Adaxial Leaf Surface Untreated. 1300x

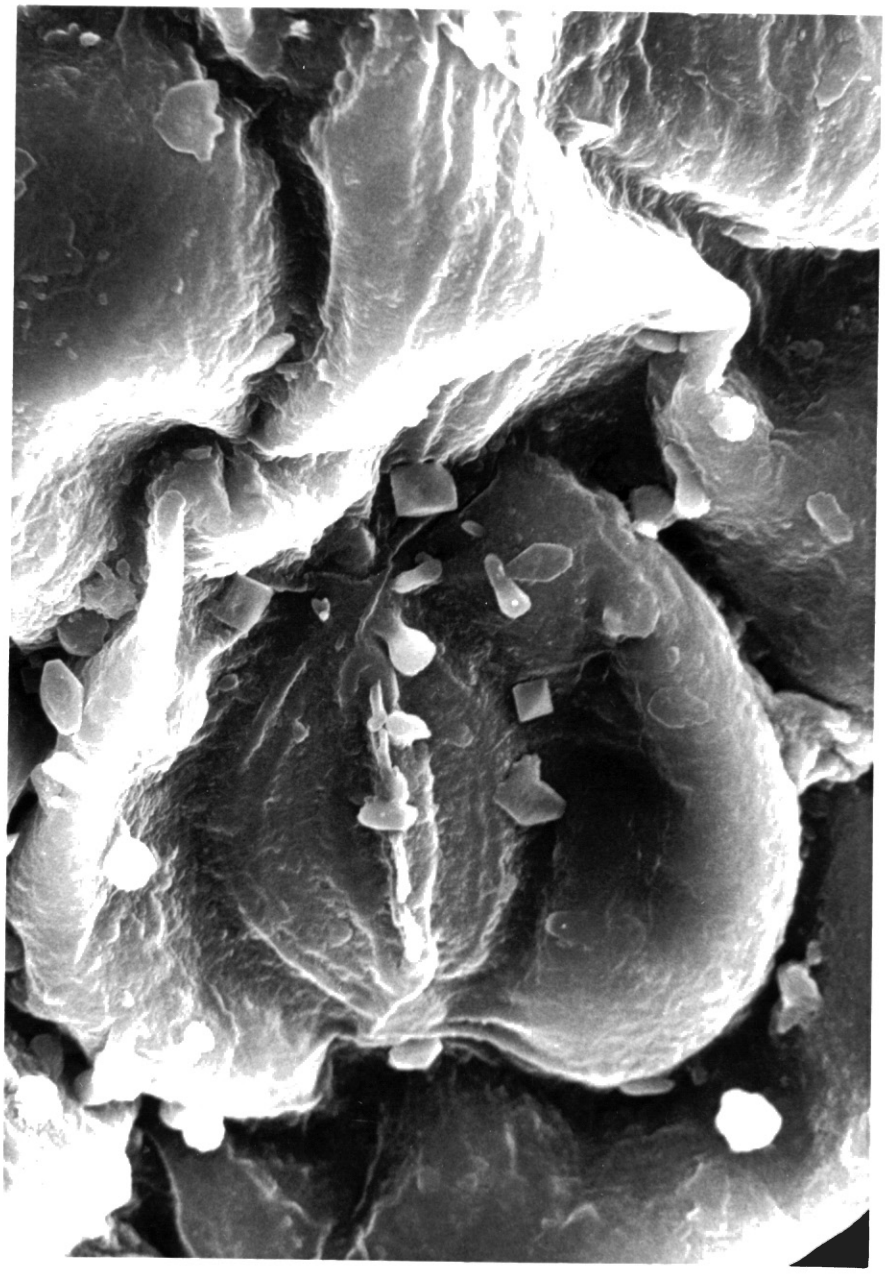


Figure 7. Scanning Electron Micrograph of an Immature Field Bindweed Adaxial Leaf Surface 24 Hours After Treatment with SA-77 at 5% v/v. 1300x

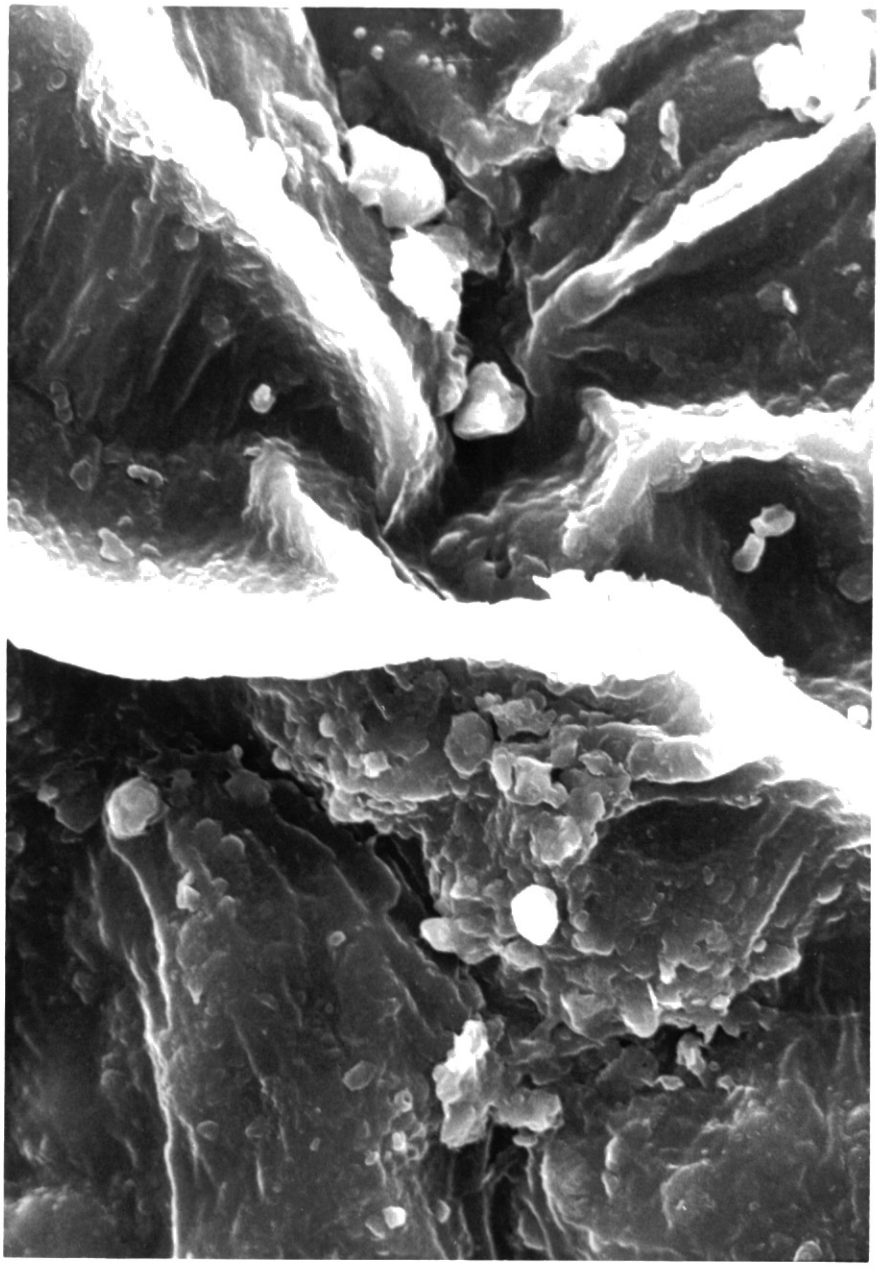
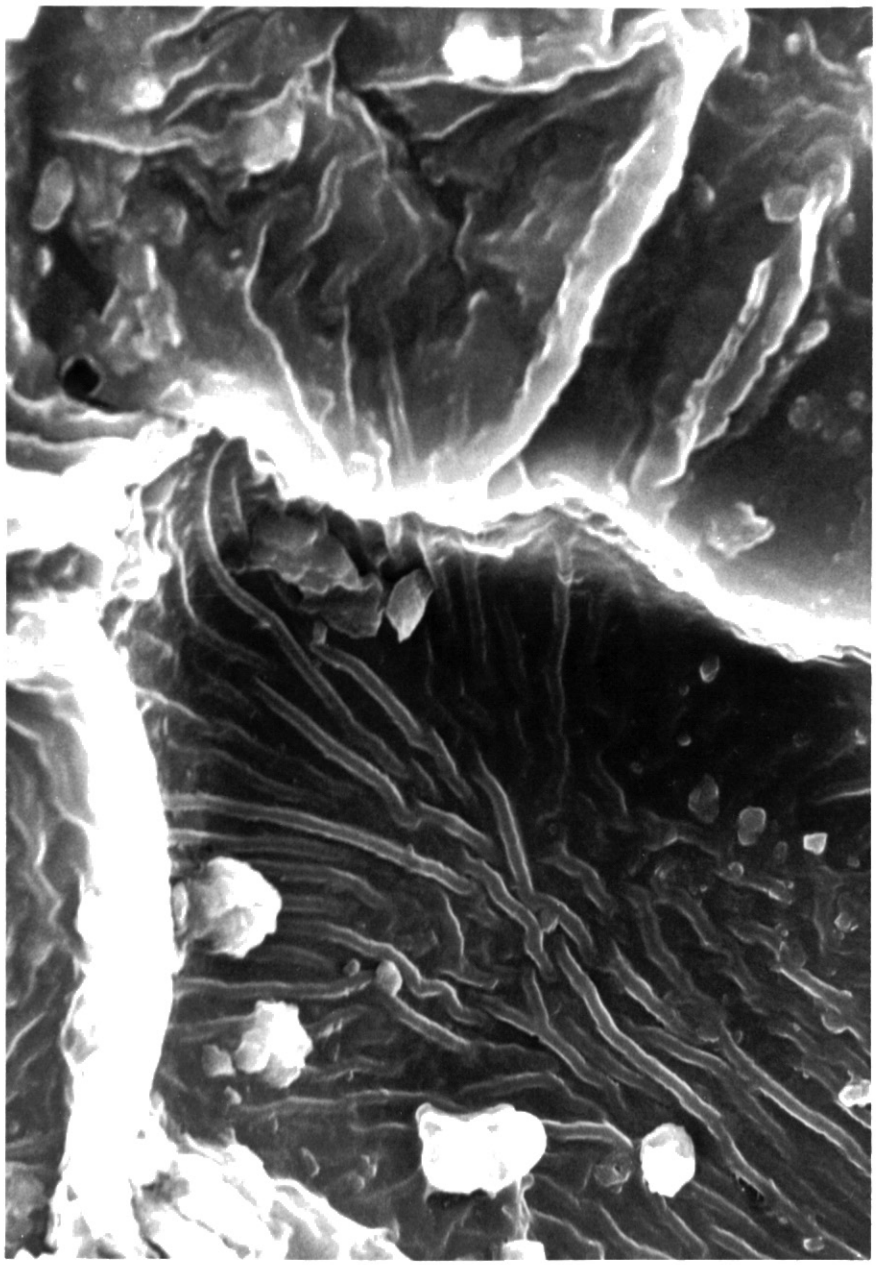


Figure 8. Scanning Electron Micrograph of a Mature Field Bindweed Adaxial Leaf Surface 24 Hours After Treatment with SA-77 at 5% v/v. 1300x



^{14}C-dicamba. This response may be similar to the one discussed earlier for leaf maturity.

Effects of Plant Growth Regulators or Additives on Herbicide Translocation in Beans and Field Bindweed

Effects of GAF 141 on ^{14}C-2,4,5-T Translocation in Beans

GAF 141 applied 4 or 24 hours prior to ^{14}C-2,4,5-T treatment was very active as an inhibitory agent of acropetal translocation to young shoots (Table II). All treatments except for 500 ppm GAF 141 applied simultaneously resulted in 0.6% or less ^{14}C recovered in young shoots compared to 1.4% for the control.

Pretreatments with GAF 141 significantly increased ^{14}C levels in primary leaves. With the 4 hour and 24 hour pretreatments with GAF 141 (500 and 2000 ppm) there was between 18 and 20% ^{14}C recovered, while the control and simultaneous GAF 141 treatments 14.7, 12.2 and 15.3% were recovered, respectively.

There were no distinguishable trends observed in the epicotyl data even though there were significant differences between treatments. The epicotyl is considered a transient zone for both acropetal and basipetal ^{14}C-herbicide movement.

Foliar treatments of GAF 141 4 hours (2000 ppm) and 24 hours (500 and 2000 ppm) prior to ^{14}C-2,4,5-T stem injection resulted in the recovery of 30.3 to 31.6% ^{14}C in treated areas (Table II). Plants exposed to simultaneous (0 hours) GAF 141 treatments at both levels (500, 2000 ppm) had 37.0 and 38.9%^{14}C recovered. Similar amounts of ^{14}C were

TABLE II

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS CONCENTRATIONS AND TREATMENT INTERVALS ON THE DISTRIBUTION OF ^{14}C ACTIVITY 4 HOURS AFTER INJECTION OF ^{14}C-2,4,5,-T INTO THE COTYLEDONARY NODE OF BEANS

GAF 141 Pretreatment Time[1]	GAF 141	Young[2] Shoot	Primary Leaves	Treated Epicotyl	Area	Hypocotyl	Root	Nutrient Solution
	(ppm)	% ^{14}C-2,4,5,-T of Total Recovered						
0 hours	500	1.7 a	12.2 c	23.6 b	37.0 a	24.4 a	0.7 d	0.6 a
	2000	0.6 b	15.3 b	21.6 bc	38.9 a	24.1 a	0.5 d	0.8 a
4 hours	500	0.5 b	19.7 a	20.5 c	35.2 a	23.5 a	1.5 c	0.4 a
	2000	0.4 b	19.9 a	20.3 c	31.6 b	23.4 a	2.8 b	0.8 a
24 hours	500	0.5 b	18.4 a	26.8 a	30.8 b	20.6 b	3.7 a	0.3 a
	2000	0.4 b	18.7 a	23.6 b	30.3 b	20.7 b	3.1 a	0.5 a
Control[3]	0	1.4 a	14.7 bc	25.3 a	36.5 a	23.0 a	1.1 c	0.6 a

[1] GAF 141 was applied foliarly either 0 (simultaneous), 4 or 24 hours prior to stem injection of ^{14}C-2,4,5-T.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's new multiple range test.

[3] Control treatments were treated with ^{14}C-2,4,5-T with no GAF 141 and harvested 4 hours following stem injections.

recovered in treated areas with 500 ppm GAF 141 4 hour pretreatments and controls, which had 35.2 and 36.5% ^{14}C, respectively. This data indicates that by increasing GAF 141 pretreatment time greater ^{14}C will translocate from the treated area, while with shorter pretreatment intervals (4 hours) greater concentrations of GAF 141 (2000 ppm) were necessary to facilitate similar translocation (Table II). Pretreatment with 500 ppm GAF 141 was sufficient to enhance translocation from the treated area.

Decreased ^{14}C translocation to hypocotyls was observed in plants receiving 24 hour pretreatments of GAF 141 at either concentration, when compared to controls and other time intervals with GAF 141 treatments.

Significantly enhanced ^{14}C-2,4,5-T translocation to roots was observed with GAF 141 applications (all concentrations) 24 hours prior to ^{14}C-2,4,5,-T treatment. A three fold increase in ^{14}C translocation to roots was stimulated with these treatments compared to 4 hour and simultaneous (0 hour) GAF 141 pretreatments or control plants (Table II). No significant differences in ^{14}C recovery from the nutrient solution were observed between treatments.

Dry weight data indicates that GAF 141 at both concentrations applied 24 hours prior to the ^{14}C-2,4,5-T injection caused significantly lower young shoot dry weights (13.4-16.8 mg) than other GAF 141 and control treatments (21.5-29.1 mg) (Table III). This suggests that GAF 141 may affect photosynthate movement in bean plants. Dry weights for other plant parts indicated no specific trends from GAF 141 treatments.

TABLE III

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS CONCENTRATIONS AND TREATMENT INTERVALS ON THE PLANT PART DRY WEIGHT OF BEANS THAT WERE INJECTED WITH ^{14}C-2,4,5-T

GAF 141 Pretreatment Time[1]	GAF 141	Young[2] Shoot	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
	(ppm)	Dry Wt/mg/plant part					
0 hours	500	21.6 b	195.0 ab	15.7 ab	13.8 a	49.2 a	64.9 a
	2000	21.5 b	204.4 ab	14.8 b	14.6 a	52.5 a	70.7 a
4 hours	500	29.1 a	219.0 ab	18.7 a	15.9 a	54.1 a	79.7 a
	2000	23.0 b	223.1 a	16.5 a	16.6 a	50.3 a	76.7 a
24 hours	500	16.8 c	212.4 ab	18.0 a	17.6 a	56.4 a	78.9 a
	2000	13.4 c	183.8 b	16.3 a	17.2 a	58.6 a	72.4 a
Control[3]	0	21.5 b	184.8 b	16.9 a	14.1 a	47.1 a	66.0 a

[1] GAF 141 was applied foliarly either 0 (simultaneous), 4 or 24 hours prior to stem injection of ^{14}C-2,4,5-T.

[2] Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Control treatments were treated with ^{14}C-2,4,5-T with no GAF 141 and harvested 4 hours following stem injections.

Ethephon versus GAF 141 on
^{14}C-2,4,5-T Translocation in Beans

Ethephon at 2000 ppm and GAF 141 at both concentrations applied to foliage simultaneously with ^{14}C-2,4,5-T injection significantly inhibited acropetal translocation of ^{14}C to young shoots (Table IV). Ethephon and GAF 141 at both concentrations applied 24 hours before ^{14}C-2,4,5-T had a greater effect than the simultaneous applications. Overall, greater inhibition of acropetal translocation to young shoots occurred with GAF 141 24 hour pretreatments than with the control or ethephon treatments. The amount of ^{14}C recovered in young shoots due to ethephon treatments was significantly greater than those provided by GAF 141 treatments (Table IV). Therefore, under the conditions of this study, GAF 141 inhibited acropetal translocation of ^{14}C-2,4,5-T to young shoots significantly more than ethephon treatments.

Data for ^{14}C translocation to primary leaves showed significant, but not large, effects due to ethephon or GAF 141 treatments (Table IV). Recovery of ^{14}C ranged from 10.4 to 18.1%, with lower levels prevailing for 24 hour pretreatments. GAF 141 pretreatments and simultaneous treatments increased translocation to the primary leaves, while only simultaneous treatments with ethephon enhanced accumulation of ^{14}C-2,4,5-T in the primary leaves.

Pretreatment with either concentration of ethephon or GAF 141 resulted in less ^{14}C recovery in epicotyl sections than either simultaneous applications or the control. No differences at similar concentrations were observed between simultaneous ethephon and GAF 141 treatments. However, significant differences between the two compounds for the 24 hour pretreatments were evident. Epicotyls from ethephon treated plants

TABLE IV

EFFECTS OF GAF 141 AND ETHEPHON FOLIAR TREATMENTS AT VARIOUS CONCENTRATIONS AND TIME INTERVALS ON THE DISTRIBUTION OF ^{14}C ACTIVITY 4 HOURS AFTER INJECTION OF ^{14}C-2,4,5-T INTO THE COTYLEDONARY NODE

Treatment[1]	Ppm	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
		% ^{14}C-2,4,5,-T of Total Recovered						
Simultaneous								
Ethephon	1000	4.4 a	15.1 b	27.1 a	39.9 ab	17.6 b	0.6 d	0.3 d
	2000	1.9 c	16.7 ab	23.7 b	38.4 ab	20.0 a	0.5 d	0.4 d
GAF 141	1000	3.1 b	14.5 b	27.0 a	37.9 ab	21.5 a	0.6 d	0.4 d
	2000	3.5 b	15.2 b	22.4 b	42.6 a	21.7 a	0.5 d	0.4 d
24 hour Pretreatment								
Ethephon	1000	1.4 c	11.2 c	15.4 d	39.9 ab	22.2 a	3.4 b	1.5 b
	2000	0.9 d	10.4 c	16.8 d	33.3 b	21.7 a	5.9 a	3.6 a
GAF 141	1000	0.6 e	13.6 bc	19.6 c	37.5 ab	21.1 a	2.5 c	1.1 c
	2000	0.3 e	18.1 a	20.0 c	34.1 b	20.9 a	4.0 b	1.8 b
Control[3]	0	4.2 a	12.0 c	23.7 b	42.7 a	17.5 b	0.3 d	0.3 d

[1] GAF 141 or Ethephon were applied foliarly either simultaneously, 4 or 24 hours prior to stem injection of ^{14}C-2,4,5-T.

[2] Percent or dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Control designates no foliar applications of Ethephon or GAF 141 prior to 2,4,5-T treatment.

had 15.4 and 16.8% ^{14}C for the 1000 and 2000 ppm ethephon treatments, respectively. GAF 141 treatments at 1000 and 2000 ppm had 19.6 and 20.0% ^{14}C recovered, respectively.

Applications of ethephon and GAF 141 at 2000 ppm (24 hour pretreatment) resulted in significantly lower ^{14}C levels in treated areas than controls. These results indicate that both plant growth regulators enhanced movement of ^{14}C-2, 4,5-T from this region.

Compared to the control, ethephon (except simultaneous 1000 ppm treatments) and GAF 141 at both concentrations and treatment intervals enhanced ^{14}C accumulation in hypocotyls.

Although simultaneous applications had no effect, pretreatment with ethephon or GAF 141 stimulated basipetal translocation of ^{14}C-2,4,5-T to roots (Table IV). However, with 24 hour pretreatments substantial differences between the two compounds were observed. Recovery from plants treated with ethephon at 1000 ppm and plants treated with GAF 141 at similar concentrations was 3.4% and 2.5% ^{14}C, respectively. Ethephon at 2000 ppm resulted in 5.9% recovery, while the GAF 141 treatment (2000 ppm) resulted in only 4.0% ^{14}C recovered. Therefore, ethephon stimulated greater basipetal translocation of ^{14}C-2,4,5-T to roots than GAF 141 pretreatments.

Similar trends were found in translocation of ^{14}C-2,4,5-T to the nutrient solution (Table IV). Higher levels of ^{14}C were recovered with 24 hour pretreatments than for the simultaneous or control treatments. Simultaneous treatments had no effect on ^{14}C recovered in the nutrient solution. Greater levels of ^{14}C were recovered in the nutrient solution of plants pretreated with ethephon than similar concentrations of GAF 141.

TABLE V

EFFECTS OF GAF 141 AND ETHEPHON FOLIAR TREATMENTS AT VARIOUS CONCENTRATIONS AND TIME INTERVALS ON THE PLANT PART DRY WEIGHT OF BEANS THAT WERE INJECTED WITH ^{14}C-2,4,5-T

Treatment[1]	Ppm	Young[2] Shoot	Primary Leaves	Treated Area: Epicotyl	Treated Area	Hypocotyl	Root
		Dry wt/mg/plant part					
Simultaneous							
Ethephon	1000	19.4 a	205.1 a	14.8 a	14.3 a	41.6 b	63.4 a
	2000	17.6 a	202.1 a	13.2 a	13.7 a	42.8 b	58.4 a
GAF 141	1000	16.4 a	190.8 a	15.1 a	14.4 a	42.1 b	54.6 a
	2000	17.2 a	196.6 a	14.2 a	16.2 a	39.7 b	57.0 a
24 hour Pretreatment							
Ethephon	1000	10.2 b	192.9 a	18.3 a	18.3 a	53.0 a	65.7 a
	2000	10.2 b	195.7 a	17.8 a	18.1 a	52.5 a	69.7 a
GAF 141	1000	8.6 c	199.2 a	15.1 a	15.4 a	46.7 b	59.5 a
	2000	8.4 c	173.0 a	13.5 a	14.0 a	40.8 b	57.8 a
Control[3]	0	19.6 a	208.2 a	14.8 a	15.8 a	40.5 b	66.0 a

[1]GAF 141 was applied foliarly either simultaneously, 4 or 24 hours prior to stem injection of ^{14}C-2,4,5-T.

[2]Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3]Control designates no foliar applications of Ethephon or GAF 141 prior to 2,4,5-T treatment.

Analysis of the dry weight data (Table V) indicated no significant treatment effect on primary leaf, epicotyl, treated area or root dry weight. However, decreased young shoot weights were observed with the 24 hour pretreatments with ethephon or GAF 141. GAF 141 at both concentrations resulted in significantly lower young shoot weights (8.4-8.6 mg) compared to samples from ethephon treated plants (10.2 mg) at the 24 hour pretreatment interval. No differences were observed when comparing concentration levels of ethephon or GAF 141.

At both concentrations higher weight gains were observed for hypocotyls of ethephon treated plants (24 hour pretreatments) than all other treatments. This effect on hypocotyls may be due to enhanced photosynthate accumulation stimulated by ethephon.

Effects of GAF 141 on Translocation of ^{14}C-Dicamba in Beans

Simultaneous or 24 hour pretreatment with GAF 141, at all concentrations, inhibited ^{14}C-dicamba translocation to young shoots (Table VI). Maximum inhibition resulted from 24 hours pretreatment with 2000 ppm with only 7.8% of the total applied being recovered, while in controls 34.1% of the applied ^{14}C-dicamba was recovered in young shoots. Paralleling this decrease in ^{14}C recovered, a decrease in dry weight occurred for shoots of pretreated plants (Table VII). Shoots of control plants or plants receiving simultaneous GAF 141 and ^{14}C-dicamba treatments had 13.0-19.4 mg of dry weight, while shoots of the 24 hour GAF 141 pretreated plants averaged only about 9.0 mg. There were no other significant trends observed in dry weight data of other plant parts which appeared related to treatment effect except for the treated area.

TABLE VI

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS CONCENTRATIONS AND TREATMENT INTERVALS ON THE DISTRIBUTION OF ^{14}C ACTIVITY 4 HOURS AFTER INJECTION OF ^{14}C-DICAMBA INTO THE COTYLEDONARY NODE

Treatment[1]	GAF 141	Young Shoot[2]	Primary Leaves	Treated Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
	(ppm)	% C of Total Recovered						
Simultaneous	250	28.0 b	21.1 b	14.1 b	26.1 cd	7.5 d	2.8 de	1.2 e
	500	15.7 c	20.4 bc	16.4 a	34.2 ab	9.4 c	2.2 de	1.7 de
	2000	14.5 c	29.1 a	8.6 c	28.3 cd	14.7 a	2.2 de	2.4 c
24 hours	250	13.9 c	22.4 b	15.9 ab	30.4 bc	12.1 b	3.1 c	2.0 cd
	500	11.5 cd	31.0 a	15.6 ab	26.5 cd	11.5 b	4.8 b	1.3 e
	2000	7.8 d	15.9 c	15.7 ab	37.1 a	14.8 a	6.4 a	4.1 a
Control[3]	0	34.1 a	10.2 bc	14.7 ab	25.6 d	6.4 d	1.7 e	1.3 c

[1] GAF 141 was applied foliarly either 0 (simultaneous), 4 or 24 hours prior to stem injection of ^{14}C-2,4,5-T.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Control designates no foliar applications of GAF 141 prior to ^{14}C-2,4,5-T treatments.

TABLE VII

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS CONCENTRATIONS AND TREATMENT INTERVALS ON THE PLANT PART DRY WEIGHT OF BEANS TREATED WITH ^{14}C-DICAMBA

Treatment[1]	GAF 141	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
	(ppm)	Dry wt/mg/plant part					
Simultaneous	250	17.8 ab	230.9 ab	13.7 ab	18.1 abc	27.1 c	68.3 a
	500	16.4 ab	226.4 ab	13.1 ab	17.0 bc	32.8 bc	63.4 ab
	2000	19.4 a	249.6 a	14.2 ab	19.0 ab	35.0 abc	67.0 a
24 hours	250	9.0 c	185.0 c	11.2 b	17.3 bc	44.3 a	58.8 ab
	500	8.9 c	214.5 abc	13.4 ab	19.8 ab	43.7 a	64.4 ab
	2000	9.2 c	210.5 abc	14.9 a	21.0 a	41.0 ab	63.9 ab
Control[3]	0	13.0 bc	194.0 bc	12.6 ab	15.0 c	35.0 abc	53.7 b

[1] GAF 141 was applied foliarly either simultaneously or 24 hours prior to stem injection of ^{14}C-2,4,5-T.

[2] Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Control designates no foliar applications of GAF 141 prior to ^{14}C-2,4,5-T treatments.

Increases in treated area dry weight were observed with 2000 ppm GAF 141 (24 hour pretreatment) compared to all other treatments.

Hypocotyl ^{14}C accumulation was maximum at 14.7-14.8% with 2000 ppm GAF 141 using either simultaneous or 24 hours pretreatments while only 6.4% was recovered in the control. Maximum ^{14}C-dicamba recovered in roots was 6.4% with the 2000 ppm GAF 141 24 hour pretreatments, while only 1.4% of the ^{14}C was found in roots of control plants. Consistent with this trend, within nutrient solutions of plants pretreated with 2000 ppm GAF 141, 4.1% of the ^{14}C was recovered while only 1.3% was recovered in the nutrient solutin of control plants. GAF 141 at 2000 ppm either pretreated 24 hours prior to stem injection or with simultaneous applications inhibited acropetal movement of ^{14}C-dicamba to young shoots but only pretreatments enhanced basipetal movement to roots. Thus, a time requirement was essential for allowing GAF 141 to alter some physiological process which affects basipetal movement of ^{14}C-dicamba.

Translocation of ^{14}C-dicamba due to GAF 141 treatments were so erratic for the primary leaves or epicotyl that no consistent trend can be distinguished (Table VI). Other than dry weight differences found for young shoots no significant trends were observed with GAF 141 treatments for other plant parts (Table VII).

Effects of GAF 141 on Translocation of ^{14}C-2,4-D in Beans

Acropetal translocation of ^{14}C-2,4-D to young shoots tended to increase with treatment longevity (Table VIII). At 4, 24, 48 and 78 hours after 2,4,-D injection, 2.4, 5.7, 6.0 and 7.3% of the applied ^{14}C

TABLE VIII

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS TREATMENT INTERVALS ON THE DISTRIBUTION OF ^{14}C ACTIVITY FOLLOWING INJECTION OF ^{14}C-2,4-D INTO BEANS

Treatment[1]	GAF 141	Young Shoot	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
	(ppm)	% ^{14}C-2,4-D of Total Recovered						
4 hours	0	2.4 b	5.9 a	22.7 a	45.6 a	19.2 d	1.2 d	0.3 e
	1500	2.8 b	5.8 a	25.9 a	40.4 a	22.0 cd	0.9 d	0.3 e
24 hours	0	5.7 a	3.2 bc	13.3 b	30.0 b	23.7 c	5.4 c	10.9 d
	1500	5.6 a	4.1 b	12.0 b	30.0 b	29.9 b	5.9 bc	8.1 d
48 hours	0	6.0 a	2.7 cd	8.5 c	21.9 c	35.0 a	7.1 abc	20.3 c
	1500	3.6 b	2.4 cd	7.6 c	24.5 c	36.4 a	7.0 abc	23.8 b
72 hours	0	7.3 a	2.2 cd	9.1 c	24.3 c	35.4 a	7.4 ab	25.0 b
	1500	3.6 b	1.6 d	8.8 c	20.9 c	33.7 a	8.1 a	30.2 a

[1] GAF 141 was applied foliarly simultaneously with the stem injection of ^{14}C-2,4-D and plants were then harvested 4, 24, 48 or 72 hours later.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

was recovered in young shoots. Although this data shows no statistically significant increases, a definite trend is evident. Simultaneous foliar applications of GAF 141 at 1500 ppm stimulated no significant effect until 48 hours after treatment after which GAF 141 at 1500 ppm inhibited translocation of 2,4-D to young shoots. Dry weight data (Table IX) indicates no statistically significant differences between the 0 and 1500 ppm (GAF 141) treatments.

A steady decline was observed in ^{14}C recovered from primary leaves, from 5.8-5.9% at 4 hour harvests to 1.6-2.2% at 72 hour harvests (Table VIII). No significant differences were observed between 0 and 1500 ppm GAF 141 treatments (Table VIII). Dry weight data for primary leaves also indicate no significant differences between treatment concentrations or harvest times (Table IX).

Similar declining trends in ^{14}C recovery, with respect to increasing harvest times (Table VIII), was observed for both epicotyl and treated areas. No significant differences were observed between 0 and 1500 ppm GAF 141 treatment levels. Recovery of ^{14}C in epicotyls decreased from 22.7-25.9% at 4 hours to 8.8-9.1% at 72 hours. Treated areas had 40.4-45.6% ^{14}C at 4 hours and 20.9-24.3% at 72 hours. There were no dry weight differences for epicotyls when comparing GAF 141 levels or harvest intervals (Table IX). However, significant increases in dry weight occurred for treated areas at 48 and 72 hour harvest intervals. Dry weights for treated areas increased from 17.0 (0 ppm) to 20.6 mg (1500 ppm) after 48 hours and 21.8 (0 ppm) to 27.2 mg (1500 ppm) following 72 hours, while no differences between both treatment levels were observed at 4 or 24 hours.

TABLE IX

EFFECTS OF GAF 141 APPLICATIONS ON PLANT PART DRY WEIGHT OF BEANS AT VARIOUS TIME INTERVALS FOLLOWING INJECTION OF ^{14}C-2,4-D TREATMENTS

Time Course[1]	GAF 141	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
	(ppm)	Dry wt/mg/plant part					
4 hours	0	8.7 b	152.4 a	14.3 b	13.0 d	47.9 bc	58.9 c
	1500	9.3 b	139.0 a	13.9 b	12.4 d	43.4 c	56.2 c
24 hours	0	10.6 b	165.4 a	17.3 ab	14.9 cd	46.6 bc	65.1 bc
	1500	9.6 b	165.5 a	20.5 a	15.9 cd	51.9 abc	69.6 bc
48 hours	0	13.0 ab	169.8 a	17.7 ab	17.0 c	57.8 abc	66.9 bc
	1500	11.6 ab	151.1 a	17.6 ab	20.6 b	45.8 bc	69.6 bc
72 hours	0	18.6 a	156.6 a	19.5 a	21.8 b	55.2 ab	78.0 b
	1500	12.6 ab	150.0 a	16.8 ab	27.2 a	60.5 a	102.4 a

[1] GAF 141 was applied foliarly simultaneously with the stem injection of ^{14}C-2,4-D and then harvested 4, 24, 48 or 72 hours later.

[2] Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

No significant differences in ^{14}C accumulation were observed in hypocotyls between treatment levels for each harvest time except for the 24 hour treatment which was slightly increased by GAF 141 (Table VIII). Maximum levels of ^{14}C were accumulated within hypocotyls (35.4-36.4%) 48 hours after treatment. No significant differences in hypocotyl dry weight were observed between GAF 141 levels at each time interval (Table IX).

Increases in ^{14}C-2,4-D basipetal translocation were observed in root sections respective to longer treatment to interval (Table VIII). Levels increased from 0.9-1.2% at 4 hours, and 5.4-5.9% at 24 hours to 7.4-8.1% for both 48 and 72 hours harvest intervals. No significant increases of ^{14}C recovery were observed due to 1500 ppm of GAF 141. No significant differences were observed for root dry weights when comparing the controls for the 4, 24 and 48 hour harvests or among the GAF 141 treatment for the same treatment periods (Table IX). After 72 hours GAF 141 treated plants had greater dry root weight than the controls. Applications of GAF 141 at 1500 ppm resulted in significantly greater root weight after 72 hours than all other treatments and time intervals (Table IX). These weight gains can possibly be attributed to a GAF 141 stimulation of basipetal translocation of storage sugars to accumulation sinks in the root.

GAF 141 (1500 ppm) increased ^{14}C levels in the nutrient solution following 48 and 72 hour exposures, but not after 4 and 24 hours. At 48 hours, nutrient solutions of the control plants had accumulated 20.3% ^{14}C while nutrient solutions from plants treated with 1500 ppm GAF 141 had 23.8% ^{14}C. From similar treatments, 25.0% versus 30.2% ^{14}C recovery was observed after 72 hours. Therefore, while there were no significant

increases in ^{14}C-2,4-D translocation to roots due to GAF 141 treatments, GAF 141 did slightly increase levels of ^{14}C in nutrient solutions.

Effects of Simultaneous Foliar Applications of GAF 141 on ^{14}C-Glyphosate Translocation in Bean Plants, 4, 24, 48 and 72 Hours Following Treatment

As much as 71.0 to 72.4% of ^{14}C glyphosate translocated was recovered within primary leaves at the 4 hour harvest interval for both the 0 and 1000 ppm GAF 141 treatments (Table X). Treatment intervals longer than 4 hours show decreasing levels of ^{14}C until only 22.5 and 30.9% of the applied ^{14}C was recovered in primary leaves at 72 hours after treatment with 0 and 1000 ppm GAF 141, respectively. The data shows that ^{14}C-glyphosate first accumulates in primary leaves and then is translocated to other plant parts. After 48 and 72 hours GAF 141 treated plants accumulated significantly more ^{14}C (32.0 and 30.9% of applied ^{14}C, respectively) compared to plants without GAF 141 (19.0 and 22.5% of the applied ^{14}C, respectively). Primary leaves increased in dry weight with time (Table XI), but no significant differences were observed between 0 and 1000 ppm GAF 141 treatments respective to the individual harvest times.

One of the first possible sinks in which ^{14}C-glyphosate may accumulate would be actively growing young shoots. The relative amount of ^{14}C recovered in young shoots increased from 4 to 72 hours (Table X). However, GAF 141 at 1000 ppm significantly inhibited ^{14}C accumulation in young shoots when plants were harvested at 24, 48, and 72 hours. No significant differences in dry weight for young shoots were observed between treatment levels for all harvest intervals (Table XI).

TABLE X

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS TIME INTERVALS ON THE DISTRIBUTION OF ^{14}C ACTIVITY FOLLOWING INJECTION OF ^{14}C-GLYPHOSATE INTO BEANS

Time Interval	GAF 141[1]	Young[2] Shoots	Primary Leaves	Treated Area: Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
(Hours)	(ppm)	% ^{14}C-Glyphosate of Total Recovered						
4	0	3.4 f	72.4 a	15.3 a	2.2 c	2.9 e	2.8 e	0.2 cd
	1000	4.3 f	71.0 a	14.1 ab	3.0 c	4.2 de	4.2 e	0.1 d
24	0	14.2 c	44.8 b	11.2 bc	4.5 ab	6.6 bc	18.2 d	0.3 bc
	1000	7.2 e	40.9 b	11.5 bc	5.0 a	9.5 a	27.0 c	0.2 cd
48	0	26.5 a	19.0 d	13.4 ab	2.9 c	7.0 b	31.8 b	0.4 b
	1000	10.3 d	32.0 c	12.3 ab	4.0 b	8.6 a	32.7 b	0.4 b
72	0	22.4 b	22.5 d	11.0 bc	2.9 c	6.3 bc	34.1 b	0.7 a
	1000	13.9 c	30.9 c	8.3 c	2.7 c	5.1 cd	38.6 a	0.5 b

[1] Foliar applications of GAF 141 were applied simultaneously with stem injections of ^{14}C-glyphosate.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

TABLE XI

EFFECTS OF GAF 141 APPLICATIONS ON PLANT PART DRY WEIGHT OF BEANS AT VARIOUS TIME INTERVALS FOLLOWING INJECTION OF ^{14}C-GLYPHOSATE

Time Interval	GAF 141[1]	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
(Hours)	(ppm)	Dry wt/mg/plant part					
4	0	6.8 d	135.9 c	11.5 b	7.0 c	29.6 c	49.9 b
	1000	10.0 cd	151.0 bc	13.5 b	9.0 c	38.8 ab	64.7 a
24	0	14.2 bc	166.5 ab	14.0 b	11.2 b	34.2 bc	62.3 a
	1000	10.2 cd	146.7 bc	13.8 b	10.6 bc	33.2 bc	54.8 ab
48	0	17.6 ab	172.1 ab	15.6 ab	12.4 ab	36.4 ab	64.1 a
	1000	13.4 bc	152.8 abc	16.4 ab	12.0 ab	35.1 ab	58.9 ab
72	0	21.1 a	182.0 a	18.6 a	14.3 a	42.8 a	67.0 a
	1000	18.2 ab	156.0 ab	19.4 a	14.3 a	39.4 ab	63.1 a

[1] Foliar applications of GAF 141 were applied simultaneously with stem injections of ^{14}C-glyphosate.

[2] Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

Treated areas showed an initial increase of ^{14}C glyphosate recovery from 2.2-3.0% at 4 hours, to 4.5-5.0% at 24 hours, then a decrease to 2.7-2.9% ^{14}C at 72 hours (Table X). No significant difference at individual harvest times were observed between GAF 141 treatment levels. GAF 141 had no effect on total dry weight of the treated area within each time interval (Table XI).

No statistical differences between 0 and 1000 ppm GAF 141 treated plants at all harvest times, were observed for epicotyls. No significant differences in total dry weight for epicotyls between treatment levels were observed (Table XI).

There were similar trends in ^{14}C accumulation in hypocotyls and epicotyls (Table X). An increase from 2.9-4.2% ^{14}C, (4 hour harvest), to 7.0-8.6% ^{14}C for 24 hour harvests, and then a decrease to 5.1-6.3% at 72 hours, was observed. Significant increases in hypocotyl % ^{14}C accumulation were observed in GAF 141 treated plants after 24 and 48 hours, but not after 4 or 72 hours. No significant differences in hypocotyl dry weight totals were observed between treatments at all harvest times (Table XI).

Basipetally translocated herbicides will ultimately reach the roots and accumulate there or leak out into the surrounding medium. No significant increases in ^{14}C levels in roots due to GAF 141 treatments were observed 4 hours after treatment (Table X). Significant increases were observed at 24 hours with GAF 141 (1000 ppm). Roots of 1000 ppm GAF 141 treated plants contained 27.0% of applied ^{14}C while roots from the 0 ppm treated plants contained only 18.2%. Significant increases were again observed after 72 hours between 1000 ppm GAF 141 treatments (38.6%) compared to 0 ppm treatments (34.1%). No root dry weight differences due

to GAF 141 treatments for individual harvest intervals were observed (Table XI). No special trends in ^{14}C accumulation were observed from assayed nutrient solutions that were consistent with treatments or harvest times (Table X).

Significant inhibition of ^{14}C accumulation in young shoots occured with 1000 ppm GAF 141 across all harvest times except for the 4 hour harvest. Basipetally translocation of ^{14}C-glyphosate was enhanced only at 24 and 72 hour harvests in roots.

^{14}C-Glyphosate Translocation in Bean Plants 4 Hours After Injection; Comparing Simultaneous and Foliar Pretreatments of GAF 141 at Various Concentrations

All simultaneous or pretreatment concentrations of GAF 141 significantly inhibited ^{14}C-glyphosate accumulation in young shoots 4 hours after treatment compared to controls (Table XII). Controls had 13.8% ^{14}C recovered compared to 10.1-10.3% ^{14}C accumulation in young shoots when GAF 141 was applied simultaneously (all concentration levels). Plants with 24 hour GAF 141 pretreatments accumulated 7.0, 3.9 and 1.4% ^{14}C at the 250, 500, and 1000 ppm GAF 141 treatment levels, respectively. Significant, rate dependent, decreases in dry weight for young shoots were observed from GAF 141 pretreatments when compared to control values (Table XIII).

There were no significant differences in dry weight of primary leaves and epicotyls (Table XIII) or % ^{14}C recovery (Table XII) due to concentration levels of GAF 141 applied simultaneously with ^{14}C-glyphosate. However, a slight decreased occurred in ^{14}C accumulation in epicotyls when GAF 141 was applied as a pretreatment.

TABLE XII

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS CONCENTRATIONS AND TWO TREATMENT INTERVALS ON THE DISTRIBUTION OF ^{14}C ACTIVITY 4 HOURS AFTER INJECTION OF ^{14}C-GLYPHOSATE INTO THE COTYLEDONARY NODE OF BEANS

Treatment[1]	GAF 141	Young[2] Shoot	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
	(ppm)	% ^{14}C-Glyphosate of Total Recovered						
Simultaneous	250	10.3 b	65.3 a	4.4 a	14.1 bc	2.0 c	2.5 d	0.1 a
	500	10.3 b	67.9 a	4.5 a	12.7 c	2.1 c	2.7 d	0.1 a
	2000	10.1 b	66.3 a	4.5 a	13.3 c	2.4 bc	3.1 d	0.1 a
24 hours	250	7.0 c	64.1 a	3.4 b	16.1 b	2.6 bc	7.0 b	0.1 a
	500	3.9 d	65.7 a	3.8 ab	20.4 a	2.7 bc	7.3 b	0.1 a
	2000	1.4 e	58.7 a	3.3 b	20.9 a	3.3 a	12.3 a	0.1 a
Control[3]	0	13.8 a	60.5 a	4.4 a	13.4 c	2.6 bc	5.3 c	0.1 a

[1] GAF 141 was applied foliarly either simultaneously or 24 hours prior to stem injection of ^{14}C-glyphosate.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Control designates no foliar applications of GAF 141 prior to ^{14}C-glyphosate treatments.

TABLE XIII

EFFECTS OF FOLIAR GAF 141 APPLICATIONS AT VARIOUS CONCENTRATIONS AND TWO TREATMENT INTERVALS ON THE PLANT PART DRY WEIGHT OF BEANS FOLLOWING THE ^{14}C-GLYPHOSATE TREATMENTS

Treatment[1]	GAF 141	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
	(ppm)	Dry wt/mg/plant part					
Simultaneous	250	23.9 a	252.1 a	17.4 a	20.1 abc	32.4 ab	75.0 a
	500	25.5 a	208.2 ab	17.1 a	18.7 abc	28.5 b	72.9 a
	2000	25.3 a	226.0 ab	17.2 a	17.8 bc	29.5 b	71.8 a
24 hours	250	20.2 b	242.7 ab	19.5 a	21.2 ab	30.6 b	83.0 a
	500	16.2 bc	223.5 ab	18.3 a	19.7 abc	33.8 ab	72.1 a
	2000	10.6 c	203.6 b	19.0 a	21.8 a	38.3 a	69.9 a
Control[3]	0	24.9 a	212.8 ab	16.5 a	17.1 c	27.4 b	73.1 a

[1] GAF 141 was applied foliarly either simultaneously or 24 hours prior to stem injection of ^{14}C-glyphosate.

[2] Percent or dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Control designates no foliar applications of GAF 141 prior to ^{14}C-glyphosate treatments.

No significant differences in % ^{14}C recovered for treated areas were observed when comparing plants treated with GAF 141 simultaneous applications to controls (Table XII). However, significant increases in % ^{14}C accumulation in treated areas were observed from pretreatments of GAF 141. Control plants had only 13.4% ^{14}C in the treated areas compared to 16.1, 20.4 and 20.9% ^{14}C recovered from plants treated with 250, 500 and 2000 ppm GAF 141, respectively (Table XII). Similar increases were observed for treated area dry weights (Table XIII). The only significant differences in hypocotyl dry weight and % ^{14}C recovery was between the controls and the 2000 ppm GAF 141 pretreated plants. Control hypocotyls had 2.6% ^{14}C recovered and weighed 27.4 mg, while 3.3% ^{14}C recovered and 38.3 mg dry weight was recorded for plants pretreated with 2000 ppm GAF 141.

Significant decreases in %^{14}C accumulation in roots (Table XII) were observed in plants treated with simultaneous GAF 141 applications (2.5-3.1%) compared to controls (5.3%). Basipetal translocation to roots was enhanced by all GAF 141 pretreatments.

No significant effects were observed on root dry weights or % ^{14}C recovery in nutrient solutions from GAF 141 treatments or time intervals (Tables XII and XIII).

Both simultaneous and 24 hour pretreatments of GAF 141 significantly inhibited acropetal translocation of ^{14}C-glyphosate to young shoots. Maximum inhibition and enhancement of basipetal translocation was obtained with 2000 ppm GAF 141 24 hour pretreatments.

Effects of Ethephon Versus GAF 141
on ^{14}C-Glyphosate Translocation in Beans

Ethephon and GAF 141 at 2000 ppm (24 hour harvest) inhibited ^{14}C

TABLE XIV

EFFECTS OF FOLIAR APPLICATIONS OF ETHEPHON OR GAF 141 ON THE DISTRIBUTION OF ^{14}C 24 AND 48 HOURS FOLLOWING STEM INJECTION OF ^{14}C-GLYPHOSATE INTO BEANS

Treatment[1]	GAF 141	Young Shoot[2]	Primary Leaves	Treated Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
	(ppm)	% ^{14}C-Glyphosate of Total Recovered						
24 hours								
Ethephon	1000	9.4 bcd	36.2 abc	5.3 a	6.7 bc	9.9 a	31.4 d	1.1 cde
	2000	6.9 cd	36.7 ab	5.1 a	6.6 bc	9.9 a	28.0 d	5.2 a
GAF 141	1000	9.2 bcd	41.0 a	5.4 a	6.2 c	9.5 a	28.2 d	0.6 e
	2000	5.6 d	38.7 a	5.1 a	6.5 bc	8.9 ab	33.4 d	1.7 bcd
Control	0	12.5 b	32.8 bc	4.2 b	11.3 a	8.4 abc	32.4 d	0.7 e
48 hours								
Ethephon	1000	10.3 bc	21.4 ef	3.4 b	7.1 bc	5.3 d	41.0 bc	2.3 b
	2000	7.2 cd	30.6 cd	3.6 b	8.0 bc	6.8 cd	51.3 a	1.8 bc
GAF 141	1000	9.6 bc	25.9 de	3.8 b	8.0 bc	5.9 d	45.9 b	0.9 de
	2000	8.3 cd	30.7 cd	3.6 b	6.1 c	7.2 bcd	44.2 b	1.9 bc
Control	0	23.7 a	18.0 f	2.5 c	9.9 b	5.6 d	37.4 c	0.9 de

[1] Ethephon or GAF 141 treatments were applied simultaneously with the stem injection of ^{14}C-glyphosate. Plants were harvested 24 and 48 hours later.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

accumulation in young shoots, compared to controls (Table XIV). No significant differences in % ^{14}C recovered were observed between ethephon and GAF 141 at the 24 hour interval. Dry weight data for young shoots indicated that no changes were related to ethephon or GAF 141 treatments compared to controls (Table XV).

At 48 hours after treatment, all levels of GAF 141 and ethephon inhibited ^{14}C accumulation in young shoots. Recovery of ^{14}C in this region was 7.2-10.3% of applied for these treatments compared to 23.7% for controls. No significant differences in % ^{14}C accumulation were observed between ethephon and GAF 141 at either concentrations at 48 hours after treatment. An inhibition in dry weight resulted from all GAF 141 and ethephon treatments at the 48 hour harvest (Table XV). Young shoots from control plants had a dry weight of 43.4 mg, while plants treated with ethephon and GAF 141 produced young shoots which weighed only 13.8 to 23.2 mg.

After 24 hours, there were no significant differences between ethephon and GAF 141 treatments in ^{14}C accumulation in primary leaves, nor between controls and ethephon treatments (Table XIV). However, GAF 141 at both concentrations (1000, 2000 ppm) significantly increased ^{14}C accumulation, when compared to controls. Primary leaves from control plants contained 32.8% ^{14}C compared to 38.7-41.0% from GAF 141 treated plants. All ethephon and GAF 141 treatments at the 24 hour harvest (Table XV) significantly decreased total dry weight (157.8-163.9 mg) of primary leaves compared to controls (211.1 mg).

No significant differences in ^{14}C accumulation in primary leaves were observed between ethephon and GAF 141 treatments after 48 hours (Table XIV). Both ethephon and GAF 141 at 2000 ppm significantly

TABLE XV

EFFECTS OF FOLIAR APPLICATIONS OF ETHEPHON OR GAF 141 ON THE PLANT PART DRY WEIGHT OF BEANS 24 and 48 HOURS AFTER STEM INJECTION OF ^{14}C-GLYPHOSATE

Treatment[1]	GAF 141	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
	(ppm)	Dry weight/mg/plant part					
24 hours							
Ethephon	1000	16.1 bc	162.4 c	17.2 bc	14.8 b	41.5 bc	77.4 b
	2000	11.4 bc	157.8 c	15.4 c	14.3 b	38.6 bc	73.1 b
GAF 141	1000	9.5 c	162.0 c	15.5 c	13.5 b	35.2 c	73.0 b
	2000	11.7 bc	163.9 c	17.8 bc	14.8 b	39.5 bc	84.2 b
Control	0	17.1 bc	211.1 b	17.0 bc	14.9 b	43.4 bc	91.8 ab
48 hours							
Ethephon	1000	23.2 b	194.5 bc	21.6 ab	20.0 a	40.6 bc	89.3 ab
	2000	13.8 bc	205.1 b	25.0 a	20.1 a	46.2 b	92.4 ab
GAF 141	1000	18.2 bc	195.8 bc	22.6 a	19.1 a	43.2 bc	91.2 ab
	2000	23.0 bc	197.1 bc	24.7 a	19.7 a	44.7 bc	93.1 ab
Control	0	43.4 a	259.9 a	24.7 a	20.0 a	53.9 a	107.7 a

[1] Ethephon or GAF 141 treatments were applied simultaneously with the stem injection of ^{14}C-glyphosate. Plants were harvested 24 and 48 hours later.

[2] Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

enhanced ^{14}C accumulation to primary leaves compared to controls. GAF 141 and ethephon had 30.6-30.7% ^{14}C recovered, while controls had 18.0% ^{14}C. Dry weights for primary leaves at the 48 hour harvest were reduced from 259.9 mg for controls to only 194.5-205.1 mg for ethephon and GAF 141 treatments (Table XV). No significant differences were seen between ethephon and GAF 141 treatments at both concentrations (1000, 2000 ppm).

Increases in ^{14}C recovery were observed in epicotyls (24 and 48 hour harvests) with ethephon and GAF 141 treatments at both concentrations (Table XIV). Again, no significant differences were observed between ethephon and GAF 141 treatments for each harvest time. Controls had 4.2% ^{14}C (24 hour harvest) while both growth regulators had about 5.1-5.4% ^{14}C recovered. Overall, less ^{14}C was recovered at the 48 hour harvest. Ethephon and GAF 141 treatments (all concentrations) had 3.4-4.0% ^{14}C recovered in epicotyls while controls had 2.5% (Table XIV).

When combining all treatments within harvest intervals, significant increases in epicotyl dry weights were observed (Table XV). After 48 hours epicotyls weighed 21.6-25.0 mg compared to 15.4-17.8 mg for the 24 hour harvest. No significant differences for epicotyl dry weight were observed between treatments within similar harvest intervals.

About 50% less % ^{14}C-glyphosate remained in the treated area with ethephon (1000 and 2000 ppm) and GAF 141 (1000, 2000 ppm) treatments 24 hours after stem injection (Table XIV). No significant differences between ethephon and GAF 141 treatments were observed for similar harvest intervals. These two plant growth regulators had 6.2-6.7% ^{14}C remaining in treated areas compared to 11.3% ^{14}C for controls. At the 48 hour harvest controls decreased to 9.9% ^{14}C, which was not statistically different from the ethephon (1000, 2000 ppm) and GAF 141 (1000

ppm) treatments (Table XIV). On the other hand, 2000 ppm GAF 141 treatments had significantly less ^{14}C (6.1%) in treated areas than the controls (9.9%). Therefore, initial response to ethephon and GAF 141 treatments was an enhancement of translocation from treated areas. For later harvest intervals greater ^{14}C levels moved out from treated areas in control plants but the % ^{14}C recovered was still significantly higher (3% more) than levels observed in plants treated with 2000 ppm GAF 141.

Increases in dry weight means were observed in treated areas 48 hours after treatment (5-6 mg more) when compared to weights obtained 24 hours after treatment (Table XV). No significant differences were observed between treatments from similar harvest intervals.

No significant differences between treatments in % ^{14}C accumulation in hypocotyls within a single treatment time were observed (Tables XIV). Although there was more ^{14}C in hypocotyls from the 24 hour treatments dry weights were greater in the 48 hour controls (Table XV).

Additions of ethephon or GAF 141 did not stimulate an increase or decrease in basipetal translocation of ^{14}C-glyphosate to roots (Table XIV) within 24 hours after treatment. However, significant differences were observed for nutrient solution assays 24 hours after treatment. Ethephon and GAF 141 at 2000 ppm enhanced ^{14}C accumulation in nutrient solutions 5.2 and 1.7%, respectively, compared to 0.7% for the control (Table XIV). At this level (2000 ppm) ethephon stimulated a three-fold increase compared to GAF 141 treatments in ^{14}C movement from roots into nutrient solutions. Presently no explanation may be given for this high ethephon stimulated response in nutrient solution ^{14}C-glyphosate accumulation. This data is contrary to results obtained from other experiments (Tables XII, XXI) investigating ^{14}C-glyphosate. No differences in root ^{14}C accumulation were observed at 1000 ppm for both plant growth

regulators. No significant differences in dry weight were observed at the 24 hour harvest for all treatments (Table XV).

Ethephon at 2000 ppm and GAF 141 at both concentrations (1000 and 2000 ppm) enhanced basipetal translocation of ^{14}C-glyphosate to roots when plants were harvested 48 hours after treatment (Table XIV). Control plants contained 37.4% of applied ^{14}C while GAF 141 at 1000 and 2000 ppm had 44.2-45.9%. Ethephon treatments at 2000 ppm caused an even greater accumulation (51.3% ^{14}C). Plants treated with ethephon at both concentrations (1000, 2000 ppm) and GAF 141 at 2000 ppm had higher levels of ^{14}C accumulated in nutrient solutions than the control within the 48 hour harvest time. No significant root dry weight differences occured between treatments after 48 hours.

Similar concentrations of both plant growth regulators were inhibitory to acropetal translocation of ^{14}C-glyphosate to young shoots after 24 and 48 hours. Ethephon at 2000 ppm stimulated greater basipetal translocation to roots than any GAF 141 treatments at either harvest interval.

Effects of Simultaneous GAF 141 Applications on ^{14}C-Glyphosate or Dicamba Translocation in Field Bindweed

As was seen in studies discussed previously utilizing bean plants, GAF 141 at 2000 ppm also inhibited acropetal accumulation of ^{14}C-dicamba and ^{14}C-glyphosate in the upper foliage of field bindweed plants (Table XVI). Only 61.6 and 17.6% of applied ^{14}C-dicamba and ^{14}C-glyphosate was recovered in the upper foliage with GAF 141 treatments compared to 84.5 and 41.5% without GAF 141.

TABLE XVI

EFFECTS OF 2000 PPM GAF 141 ON TRANSLOCATION WHEN APPLIED SIMULTANEOUSLY WITH GLYPHOSATE OR DICAMBA ON FIELD BINDWEED

Treatment[1]	Upper[2] Foliage	Original Root	Upper Root	Lower Root	Total Root	Nutrient
	% ^{14}C Recovered[3]					
Dicamba	84.5 a	5.5 b	1.1 b	2.3 b	8.9 b	6.6 b
Dicamba and GAF 141	61.6 b	14.0 a	3.5 a	7.1 a	24.6 a	13.8 a
Glyphosate	41.5 a	14.1 a	6.5 b	35.9 b	56.8 b	2.0 a
Glyphosate and GAF 141	17.6 b	13.4 a	16.6 a	50.9 a	80.4 a	1.5 a

[1] GAF 141, ^{14}C-glyphosate and ^{14}C-dicamba were applied foliarly.

[2] Percent weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

[3] Data is represented as % of total recovered minus the treated leaf.

Original root sections, upper roots and lower roots accumulated significantly higher ^{14}C levels when GAF 141 was applied with ^{14}C-dicamba (Table XVI). Nutrient solution ^{14}C levels increased from 6.6% in plants without GAF 141 treatments, to 13.8% for those with 2000 ppm GAF 141 applications.

Combining values from all root parts show increases in basipetal translocation, from 8.9% when ^{14}C-dicamba was applied alone to 24.6% for ^{14}C-dicamba plus GAF 141 at 2000 ppm. Increases were consistent with each root part. Generally a 3 fold increase of ^{14}C was observed with GAF 141 treatments (Table XVI).

Basipetal translocation of ^{14}C-glyphosate was also enhanced with simultaneous applications of GAF 141 at 2000 ppm. After 24 hours there were no significant differences in ^{14}C accumulation in original root sections. Plants treated with ^{14}C-glyphosate had 14.1% of applied ^{14}C recovered in original root sections, while those treated with ^{14}C-glyphosate plus GAF 141 (2000 ppm) had 13.4% recovered. Significant increases in ^{14}C-glyphosate were observed in upper root and lower root sections with GAF 141 treatments. An increase from 6.5 to 16.6% (upper root), and 35.9 to 50.9% (lower root) was stimulated when GAF 141 was added to ^{14}C-glyphosate treatments. Total root ^{14}C recovery showed a significant increase from 56.8% without GAF 141 to 80.4% ^{14}C (with 2000 ppm GAF 141).

No significant differences between treatments were observed for nutrient solution data for ^{14}C-glyphosate treated field bindweed plants. A maximum increase in basipetal translocation was observed in upper root sections, where a 2½ fold enhancement in ^{14}C accumulation occured.

Overall, GAF 141 at 2000 ppm had a greater effect on ^{14}C-dicamba translocation to roots than on ^{14}C-glyphosate in field bindweed plants.

Effects of Herbex Foliar Treatments on Translocation of Various Herbicides in Bean Plants

Reports (2) have suggested that Herbex enhanced phytotoxicity of herbicides by increasing absorption and translocation. This study (Table XVII) was designed to investigate effects of Herbex on the translocation of ^{14}C-2,4-D, ^{14}C-dicamba, ^{14}C-glyphosate, and ^{14}C-acifluorfen, which have all been shown to respond to GAF 141 treatments. Herbex at 2000 ppm applied simultaneously did not influence translocation of ^{14}C-glyphosate, ^{14}C-2,4-D, ^{14}C-dicamba or ^{14}C-acifluorfen, either basipetally or acropetally from treated areas.

Similar to the percent ^{14}C data, dry weights (Table XVIII) for bean plants were not influenced by Herbex treatments. Therefore, no significant response was observed in ^{14}C distribution or dry weight in bean plants when 1500 ppm Herbex was applied under the conditions of this experiment.

Effects of NH_4VO_3 on the Translocation of ^{14}C-2,4,5-T in Beans

Vanadate has been shown to inhibit auxin-enhanced proton secretion and polar auxin transport in pea epicotyl sections (25). A study, to further investigate the potential of NH_4VO_3 as a synergistic additive for weed control, was designed to evaluate effects of NH_4VO_3 on the translocation of ^{14}C-2,4,5-T in beans (Tables XIX, XX).

TABLE XVII

EFFECTS OF HERBEX FOLIAR TREATMENTS ON THE TRANSLOCATION OF VARIOUS HERBICIDES IN BEAN PLANTS

Treatment[1]	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
	% ^{14}C of Total Recovered						
Glyphosate	20.0 a	25.6 a	5.1 a	15.4 a	9.3 a	28.2 a	0.3 a
Glyphosate and Herbex	20.0 a	30.7 a	4.4 a	11.7 a	7.2 a	25.3 a	0.7 a
2,4-D	6.4 a	3.6 a	19.8 a	25.1 a	20.4 a	7.7 a	16.7 a
2,4-D and Herbex	5.4 a	2.6 a	22.2 a	24.1 a	19.8 a	7.5 a	19.7 a
Dicamba	51.5 a	2.1 a	2.8 a	8.8 a	2.2 a	2.9 a	29.7 a
Dicamba and Herbex	52.0 a	2.1 a	2.9 a	5.8 a	1.7 a	3.0 a	32.6 a
Acifluorfen	9.4 a	54.0 a	7.2 a	19.2 a	5.9 a	2.2 a	2.1 a
Acifluorfen and Herbex 10.3 a	39.5 a	9.1 a	27.4 a	6.4 a	1.9 a	2.3 a	

[1]Herbex was applied foliarly at 2000 ppm simultaneously with the stem injection of the ^{14}C-labeled herbicides. Plants were harvested 24 hours after treatment.

[2]Percent means within a column for each herbicide followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

TABLE XVIII

EFFECTS OF HERBEX FOLIAR TREATMENTS WITH VARIOUS HERBICIDES ON THE PLANT PART DRY WEIGHT OF BEANS

Treatment[1]	Young Shoot[2]	Primary Leaves	Treated Epicotyl	Treated Area	Hypocotyl	Root
	Dry wt/mg/plant part					
Glyphosate	22.1 a	169.0 a	17.8 a	17.5 a	41.4 a	78.9 a
Glyphosate and Herbex	21.9 a	160.8 a	17.2 a	14.5 a	37.4 a	72.4 a
2,4-D	22.1 a	170.8 a	17.7 a	15.8 a	41.5 a	87.2 a
2,4-D and Herbex	19.6 a	148.9 a	16.5 a	14.5 a	37.1 a	79.4 a
Dicamba	25.4 a	205.7 a	26.1 a	18.2 a	46.1 a	98.4 a
Dicamba and Herbex	23.7 a	169.6 a	17.5 a	15.6 a	37.6 a	83.9 a
Acifluorfen	18.3 a	176.5 a	14.7 a	13.9 a	33.7 a	69.3 a
Acifluorfen and Herbex	15.7 a	173.5 a	14.2 a	14.3 a	34.5 a	65.7 a

[1] Herbex was applied foliarly at 2000 ppm simultaneously with the stem injection of the ^{14}C-labeled herbicides. Plants were harvested 24 hours after treatment.

[2] Dry weight means within a column for each herbicide followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

TABLE XIX

EFFECTS OF NH_4VO_3 ON THE TRANSLOCATION OF ^{14}C-2,4,5-T 4 AND 24 HOURS FOLLOWING STEM INJECTION INTO THE COTYLEDONARY NODE OF BEAN PLANTS

NH_4VO_3[1] (ug)	Young[2] Shoot	Primary Leaves	Treated Epicotyl	Treated Area	Hypocotyl	Root	Nutrient Solution
	% ^{14}C-2,4,5-T of Total Recovered						
4 hour treatment							
0	2.7 bc	15.0 a	19.4 a	34.2 a	29.1 cd	1.1 c	0.4 c
1	3.7 a	14.1 ab	19.0 a	34.8 a	26.7 d	1.1 c	0.4 c
2	2.8 b	14.6 ab	18.7 a	37.0 a	25.7 d	1.0 c	0.3 c
4	2.7 b	12.3 b	17.6 a	35.5 a	30.2 bcd	1.2 c	0.5 c
24 hour treatment							
0	1.4 c	3.3 c	3.8 b	19.3 b	34.7 ab	7.9 b	25.1 b
1	1.5 c	3.6 c	3.1 b	16.9 b	35.0 ab	9.1 b	30.8 a
2	0.5 d	3.6 c	3.7 b	16.4 b	34.2 abc	9.2 b	30.7 a
4	0.1 d	3.5 c	3.7 b	19.6 b	38.1 a	10.9 a	30.4 a

[1] NH_4VO_3 was injected simultaneously with the ^{14}C-2,4,5-T. Plants were harvested 4 and 24 hours later.

[2] Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

TABLE XX

EFFECTS OF NH_4VO_3 ON THE PLANT PART DRY WEIGHT OF BEANS 4 AND 24 HOURS FOLLOWING STEM INJECTION OF ^{14}C-2,4,5-T

NH_4VO_3[1] (ug)	Young Shoot[2]	Primary Leaves	Epicotyl	Treated Area	Hypocotyl	Root
	Dry wt/mg/plant part					
4 hour treatment						
0	12.5 a	140.3 a	10.4 a	13.4 b	32.5 a	53.5 a
1	12.4 a	144.1 a	10.9 a	13.7 b	33.9 a	53.5 a
2	23.2 a	136.8 a	10.6 a	13.1 b	33.8 a	62.2 a
4	14.9 a	136.3 a	11.6 a	12.1 b	32.1 a	48.5 a
24 hour treatment						
0	9.4 a	131.4 a	12.4 a	16.0 a	32.5 a	53.5 a
1	11.5 a	137.0 a	18.5 a	16.2 a	36.0 a	53.3 a
2	14.0 a	162.6 a	13.4 a	17.4 a	38.1 a	63.9 a
4	15.6 a	142.3 a	13.1 a	17.0 a	36.9 a	57.9 a

[1] NH_4VO_3 was injected simultaneously with the ^{14}C-2,4,5-T. Plants were harvested 4 and 24 hours later.

[2] Dry weight means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

No significant differences in ^{14}C levels were observed at the 4 hour harvest between 0, 1, 2 or 4 ug NH_4VO_3 per plant treatments for all plant parts and nutrient solution (Table XIX). Significantly higher levels of ^{14}C were recovered from young shoots, primary leaves, epicotyls and the treated area at 4 hour harvests than after 24 hours. Greater ^{14}C levels were recovered in hypocotyls, roots and nutrient solution after 24 hour harvests than after 4 hours. Therefore, as treatment time intervals increased, greater basipetal translocation of ^{14}C-2,4,5-T occured.

After 24 hours only 0.1-1.5% of applied ^{14}C was recovered in young shoots compared to 2.7-3.7% recovered after 4 hours. This is consistent with the data discussed previously on 2,4,5-T translocation (Table II). NH_4VO_3 additions at 2 and 4 ug per plant (24 hour harvest) significantly inhibited ^{14}C movement to young shoots with only 0.5 and 0.1% ^{14}C recovered respectively, compared to 1.4 and 1.5% for 0 and 1 ug treatments, respectively.

After 24 hours no differences in ^{14}C recovery from primarly leaves, epicotyl, treated area, or hypocotyl occurred as a results of NH_4VO_3 treatments. However, the highest rate of NH_4VO_3 enhanced basipetal translocation of ^{14}C-2,4,5-T to roots after 24 hours. The 0, 1, and 2 ug treatments had 7.9, 9.1 and 9.2% ^{14}C recovered in roots, respectively, compared to 10.9% ^{14}C recovered with 4 ug NH_4VO_3 treatments. In addition, analysis of the nutrient solution revealed significant increases in ^{14}C accumulation from all NH_4VO_3 treatments after 24 hours, but there was no rate response. No significant differences in plant part dry weight were observed from any treatments.

Comparisons Between ^{14}C-Dicamba, ^{14}C-Glyphosate, ^{14}C-2,4-D and ^{14}C-Acifluorfen Translocation in Bean Plants 24 Hours After Treatment

Herbicides injected into the cotyledonary node have three alternatives in regards to movement. They could remain stationary and not translocate from treated areas, they could translocate either acropetally or basipetally, or herbicides could move in both directions.

The greatest translocation, basipetally or acropetally, out of the treated region was achieved with ^{14}C-dicamba (Table XVI). Only 8.8% of the applied ^{14}C was recovered in this area compared to 15.1% for ^{14}C-glyphosate, 19.8% for ^{14}C-acifluorfen and 25.1% for ^{14}C-2,4-D.

Maximum ^{14}C-dicamba accumulation acropetally was in young shoots with 51.5%, while only 2.1 and 3.6% ^{14}C was recovered in primary leaves and epicotyls, respectively. Maximum ^{14}C-acifluorfen accumulation was observed in primary leaves at 54.0%, while only 9.4 and 7.2% was recovered in young shoots and epicotyl, respectively. Greatest accumulation of ^{14}C-2,4-D, acropetally, was to epicotyls with 19.8% compared to 5.4 and 3.6% recovered in young shoots and primary leaves respectively. More ^{14}C-glyphosate was accumulated in primary leaves (25.6%) than in epicotyls (5.1%) with slightly less in young shoots (20.1%).

Comparing all herbicides, significantly more ^{14}C-dicamba was recovered in young shoots than the other 3 herbicides. Greatest ^{14}C accumulation in primary leaves occured with ^{14}C-acifluorfen treatments, while ^{14}C-2, 4-D had the highest levels of ^{14}C recovered in epicotyls (Table XVI).

TABLE XXI

DISTRIBUTION OF ^{14}C 24 HOURS AFTER INJECTION OF ^{14}C-DICAMBA, ^{14}C-GLYPHOSATE, ^{14}C-2,4,-D AND ^{14}C-ACIFLUORFEN INTO THE COTELYDONARY NODE OF BEAN PLANTS

Treatment[1]	Young[2] Shoot	Primary Leaves	Treated Epicotyl	Area	Hypocotyl	Root	Nutrient Solution
	% ^{14}C of Total Recovered						
^{14}C-Glyphosate	20.0 b	25.6 b	5.1 b	15.1 c	7.3 b	28.2 a	0.3 d
^{14}C-2,4-D	5.4 d	3.6 c	19.8 a	25.1 a	20.4 a	7.7 b	16.7 b
^{14}C-Dicamba	51.5 a	2.1 c	2.8 c	8.8 d	2.2 c	2.9 c	29.7 a
^{14}C-Acifluorfen	9.4 c	54.0 a	7.2 b	19.8 b	5.9 b	2.2 c	2.1 c

[1]Labeled herbicides were injected into the cotyledonary node of beans.

[2]Percent means within a column followed by the same letter are not significantly different at the .05 level of probability as determined by Duncan's New Multiple Range Test.

Higher amounts of ^{14}C-2,4-D (20.4%) accumulated in hypocotyls compared to ^{14}C-glyphosate (7.3%), ^{14}C-dicamba (2.2%) or ^{14}C-acifluorfen (5.9%). Highest ^{14}C accumulation in roots was recorded for ^{14}C-glyphosate, with 28.2% ^{14}C recovered, while significantly lower % ^{14}C levels were observed in roots with ^{14}C-dicamba (2.9%) ^{14}C-2,4-D (7.7%) or acifluorfen (2.2%) treatments. Nutrient solutions showed 29.7% ^{14}C-dicamba, 16.7% ^{14}C-2,4-D, 2.1% ^{14}C-acifluorfen, and 0.3% ^{14}C-glyphosate levels accumulated. The data indicates that basipetal movement to roots and nutrient solution is about the same, when combining the two assay values for ^{14}C-glyphosate (28.5%), ^{14}C-2,4-D (24.4%) and ^{14}C-dicamba (32.6%), while significantly less was recovered for ^{14}C-acifluorfen (4.3%).

While ^{14}C-dicamba and ^{14}C-2,4-D had greater ^{14}C levels in nutrient solutions, ^{14}C-glyphosate had significantly higher levels recovered in root parts. This data indicates that either ^{14}C-glyphosate leaks into the nutrient solution at a slower rate than the other herbicides or that because of its capacity to bind to organic matter (50) ^{14}C-glyphosate is more tightly bound in the roots and this tends to dissipate less into the surrounding medium.

CHAPTER V

SUMMARY AND CONCLUSIONS

The absorption and translocation of selected herbicides in field bindweed and bean plants were examined comparing various additive or plant growth regulator combinations. Dry weight data for bean plant parts was also collected and discussed to relate possible physiological responses to additive effects.

Effect of SA-77 on Herbicide Absorption by Field Bindweed

Significantly higher absorption rates of ^{14}C-2,4-D, ^{14}C-dicamba and ^{14}C-glyphosate were observed in field bindweed leaves following 24 hour treatment exposures than from 2 hour intervals for both prefrost and postfrost treatment dates. Significantly higher % ^{14}C was absorbed into mature leaves than into immature leaves for all herbicides. An average 3 fold increase in absorption occured with prefrost treatments on mature leaves as compared to immature leaves, while a 50% increase was observed into mature leaves at the postfrost date.

Scanning electron micrographs (SEMs) of immature adaxial leaf surfaces compared to mature adaxial leaf surfaces visually showed a pronounced irregularity of cells with greater ridging on mature leaf surfaces than on immature leaf surfaces. These surface disruptions may be indicative of regions characterized with thinner wax areas which

would be more susceptible to herbicide penetration.

Enhanced ^{14}C-dicamba and ^{14}C-glyphosate absorption was observed into field bindweed leaves treated with 5% v/v SA-77. Similar increases were observed for both prefrost and postfrost collected leaves. SEMs indicate that 5% v/v SA-77 solutions increased ridging and surface disruptions in both young and old field bindweed adaxial leaf surfaces.

No significant differences in % absorption was observed between ^{14}C-dicamba and ^{14}C-glyphosate treatments at the prefrost date. Higher levels of absorption in field bindweed leaves were observed at the postfrost date with ^{14}C-2,4-D.

Effects of Plant Growth Regulators or Additives on Herbicide Translocation in Beans and Field Bindweed

GAF 141 applied 4 or 24 hours prior to ^{14}C-2,4,5-T injection into beans was very active as an inhibitory agent of acropetal translocation to young shoots. A 3 fold increase, compared to controls, of ^{14}C-2,4,5-T translocation to roots was observed with 24 hour GAF 141 pretreatments. Lowered young shoot dry weights was observed with GAF 141 24 hour pretreatments compared to other treatments. These results suggest that GAF 141 may effect sugar movement within bean plants.

GAF 141 inhibited acropetal translocation of ^{14}C-2,4,5-T significantly more than ethephon treatments. However, ethephon stimulated greater basipetal translocation of ^{14}C-2,4,5-T to roots than GAF 141 treatments. Similar results were observed with ^{14}C-glyphosate.

Similar translocation patterns, acropetally or basipetally, and dry weight effects to young shoots were observed with GAF 141 treatment

combinations with ^{14}C-dicamba, ^{14}C-glyphosate, ^{14}C-2,4-D or ^{14}C-acifluorfen in bean plants. Minimum GAF 141 effects on basipetal translocation to bean roots was observed with ^{14}C-2,4-D, while maximum synergistic effects were observed with ^{14}C-2,4,5-T or ^{14}C-dicamba. Consistent inhibitory trends in acropetal translocation to young shoots was observed for all herbicides combined with GAF 141. Most significant GAF 141 effects were observed with 24 hour pretreatments prior to stem injection of herbicides. Increased synergism was directly related to treatment longevity and higher concentration levels.

Consistent with studies utilizing bean plants, GAF 141 at 2000 ppm inhibited acropetal accumulation of ^{14}C-dicamba and ^{14}C-glyphosate within upper foliage of field bindweed plants. Increases in basipetal translocation to roots with similar treatments was also observed. Overall, GAF 141 at 2000 ppm had a greater synergistic response on basipetal translocation in field bindweed plants with ^{14}C-dicamba than with ^{14}C-glyphosate.

Herbex at 2000 ppm, applied simultaneously to bean leaves, did not influence translocation of ^{14}C-glyphosate, ^{14}C-2,4-D, ^{14}C-dicamba or ^{14}C-acifluorfen, either basipetally or acropetally from treated areas.

Additions of 4 ug NH_4VO_3 enhanced basipetal translocation of ^{14}C-2,4,5-T to bean roots 24 hours following treatment. NH_4VO_3 additions at 4 ug (24 hour harvest) significantly inhibited ^{14}C movement to young shoots compared to controls.

Overall observations of acropetal translocation comparing various herbicides in bean plants showed significantly higher ^{14}C-dicamba levels recovered in young shoots than ^{14}C-2,4-D, ^{14}C-glyphosate or ^{14}C-acifluorfen. Maximum ^{14}C accumulation in primary leaves was observed with

^{14}C-acifluorfen treatments, while ^{14}C-2,4-D had the highest ^{14}C levels recovered in epicotyls and hypocotyls. ^{14}C-dicamba and ^{14}C-2,4-D had greater ^{14}C levels in nutrient solutions, while ^{14}C-glyphosate had significantly higher levels than all other treatments recovered in bean roots. Treatments with ^{14}C-acifluorfen indicated very low ^{14}C levels translocated basipetally.

Additives or plant growth regulators offer a potential in enhancing penetration and translocation of herbicides when tank mixed. This increased physiological efficiency in plants may provide more consistent control programs of deep rooted perennial weeds such as field bindweed.

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VITA

Peter Bohdan Chykaliuk

Candidate for the Degree of

Doctor of Philosophy

Thesis: INTERACTIONS OF PLANT GROWTH REGULATORS OR ADDITIVES ON ABSORPTION AND TRANSLOCATION OF HERBICIDES

Major Field: Crop Science

Biographical:

Personal Data: Born in Newark, New Jersey, in September, 1955, the son of John and Oxana Chykaliuk.

Education: Vineland Senior High School, Vineland, New Jersey, 1971-1973; General Certificate of Education Degree; received Bachelor of Science degree in Plant Science Rutgers University, New Brunswick, New Jersey, 1977; received Master of Science Degree in Crop Science Texas Tech University, Lubbock, Texas, 1979; completed the requirements for the Doctor of Philosophy degree at Oklahoma State University in July, 1981.

Professional Experience: Product Development Representative for Monsanto Agricultural Products Company working with new and commercial crop chemicals for registration and efficacy.