THE INFLUENCE OF GAF 141, HERBICIDE CONCENTRATION, AND NUTRIENT STATUS ON HERBICIDE TRANSLOCATION IN FIELD BINDWEED

By

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Each of the two parts of this thesis is a separate manuscript to be submitted for publication in _Weed Science_, the journal of the Weed Science Society of America.

PART I

THE INFLUENCE OF HERBICIDE CONCENTRATION ON THE STIMULATION OF BASIPETAL HERBICIDE TRANSLOCATION BY GAF 141 IN FIELD BINDWEED

THE INFLUENCE OF HERBICIDE CONCENTRATION ON THE STIMULATION OF BASIPETAL HERBICIDE TRANSLOCATION BY GAF 141 IN FIELD BINDWEED

Abstract. Foliar applications of GAF 141 [(2-chloro-ethyl)phosphonic acid plus _N_-methylpyrrolidone], an ethylene-releasing agent, improved the control of field bindweed (_Convolvulus arvensis_ L.) obtained with dicamba (3,6-dichloro-_o_-anisic acid) at two of five locations, but had no influence on the efficacy of glyphosate [_N_-(phosphonomethyl)glycine] or 2,4-D [(2,4-dichlorophenoxy)acetic acid] under field conditions. In laboratory studies, GAF 141 was used as a foliar treatment 24 h prior to application of various concentrations of the same herbicides to the foliage of field bindweed plants. Basipetal translocation of dicamba and glyphosate was enhanced by GAF 141 when only the ^{14}C-labelled herbicides were used, but were not significantly affected by GAF 141 at herbicide concentrations more comparable to field application rates. GAF 141 had no influence on translocation of 2,4-D at any 2,4-D concentration used in this study.

INTRODUCTION

Programs for control of deep-rooted perennial weed species such as field bindweed with herbicides such as dicamba, glyphosate, and 2,4-D have been expensive and have provided inconsistent control (3,7). Good control can be observed in the year of application, but follow-up treatments are required to maintain control over time (10,13). Low efficacy appears to result from insufficient basipetal herbicide translocation to control regrowth from roots (6). Sandberg et al. (12) found that field bindweed translocated 3.5% of applied glyphosate from treated foliage in three days, whereas hedge bindweed (Convolvulus sepium L.), Canada thistle (Cirsium arvense (L.) Scop.), and wild buckwheat (Polygonum convolvulus L.) translocated 22, 8, and 5% respectively. Ogg (10) reported that two applications of 2,4-D or dicamba at 1.1 and 0.6 kg/ha gave 97% control of Canada thistle, whereas a third application was required to give similar control of field bindweed.

Many chemicals affect herbicide translocation, but few have a stimulatory effect on basipetal translocation. Goss (4) found that ethephon [(2-chloro-ethyl)phosphonic acid] foliarly applied prior to application of 2,4-D increased penetration and translocation of ^{14}C-2,4-D to roots of field bindweed plants, and enhanced herbicidal activity on regrowing shoots. Similarly, ethephon was found to enhance basipetal translocation of dicamba in field bindweed (9). Chykaliuk et al. (2) reported that GAF 141, an experimental ethylene-releasing agent, increased basipetal translocation of dicamba, glyphosate, and acifluorfen {5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitro-benzoic acid} in bean (Phaseolus vulgaris L.) plants when applied 24 h prior to herbicide application. Chykaliuk (1), however, found that basipetal translocation of ^{14}C-2,4-D was not affected by GAF 141 in beans. Harrison et al. (5) found that GAF 141 at 2000 ppm foliarly applied prior to application of dicamba and glyphosate increased basipetal translocation of these herbicides by 197 and 80%, respectively. Shaw et al. (14) also found that GAF 141 applied simultaneously or 24 h prior to herbicide application increased the accumulation of ^{14}C-dicamba in roots of field bindweed.

In the field, addition of ethephon to glyphosate applied for field bindweed control did not increase control except when glyphosate rates were less than 0.8 kg/ha (11). These results raised the question of whether herbicide concentration would affect the stimulatory action of GAF 141 seen under laboratory conditions.

The objectives of this research were to determine how GAF 141 influenced the control of field bindweed obtained with dicamba, glyphosate and 2,4-D in established field bindweed, and to determine the influence herbicide concentration has on the stimulation of basipetal herbicide translocation by GAF 141 in field bindweed.

MATERIALS AND METHODS

Field Experiments. Five field experiments were established in north-central Oklahoma from 1980 through 1982 to determine whether applications of GAF 141 would improve the efficacy of dicamba, glyphosate, and 2,4-D in controlling established field bindweed (Table 1). A randomized complete block design was used in each experiment, and all treatments were replicated four times. Field bindweed populations of 20 to 25 plants/m^2 were present at each location. All treatments were applied in early fall when the field bindweed plants were in a vegetative stage, with stems 15 to 30 cm in length. Compressed air type plot sprayers were used to apply all treatments. GAF 141 was applied either as a tank mixture with the herbicide, or applied 48 h prior at the Enid location or 24 h prior at the Carrier location. Application rates at the Carrier location for all herbicides and GAF 141 were one-half that for all other locations reported. Payne and Carrier locations were seeded with hard red winter wheat 43 and 7 days after herbicide application, respectively. All other locations were on fallow wheat land. All locations were tilled 7 to 10 cm deep in late June or early July of the following year to control emerging seedling field bindweed. The Enid location was also tilled on April 1, 1982, for the control of early emerging seedlings. Control was determined at the Enid and Carrier locations by counting the number of stems present in 0.3 by 3 m quadrats. Control at the other locations was determined by visual ratings approximately nine months after herbicide application. The herbicide rates utilized in these studies were less than those recommended for field bindweed control programs in order to evaluate the effect of GAF 141 on the control given by these herbicides. All herbicides used were formulated as amine salts.

Laboratory Experiments. Field bindweed plants were germinated and grown in 500 ml half strength Hoaglands (8) nutrient solution for 28 days. GAF 141 was applied 24 h prior to herbicide application by momentarily immersing the foliage of field bindweed plants into a solution containing 2000 ppmw of the material in distilled water with 0.5% v/v alkylaryl polyether alcohol[1]. The plants were treated 24 h later with 1 μg dicamba (17.06 Ci/mole, ring-^{14}C-UL), 8.7 μg glyphosate (1.95 Ci/mole, methyl-^{14}C), or 1 μg 2,4-D (57 Ci/mole, carboxyl-^{14}C). The glyphosate was formulated into the isopropylamine salt by adding an equimolar amount of isopropylamine to 2.17 mg ^{14}C-glyphosate plus nonionic polyethoxylated tallow amine[2] at 15.2% v/v, plus 84.3% distilled water to equal the commercial formulation. The dicamba and 2,4-D were in 95%

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[1]Triton X-100.

[2]MON 0818.

ethanol. All ^{14}C-herbicides were applied with a 10 μl microsyringe pipette by placing a total of four 2.5 μl drops on the adaxial leaf surface of the second and third expanded leaves above the cotyledons. Various concentrations of each herbicide were applied just prior to ^{14}C-herbicide application by completely wetting the foliage of field bindweed plants with solutions containing 0, 1500, 3000, 6000, or 12000 ppmw of commercially formulated dimethylamine salts of dicamba or 2,4-D, or 0, 3000, 6000, 12000, or 24000 ppmw of the isopropylamine salt of glyphosate. Plants were harvested 24 h after herbicide treatment and sectioned into the foliage above the treated area, the treated area, the cotyledons and stem between the treated area and roots, and the roots. A sample of the nutrient solution was also retained for analysis.

The treatments were replicated seven or eight times and each experiment was repeated. The field bindweed plants were arranged in a randomized complete block design within the growth chamber, and a factorial arrangement of treatments was employed. Plants were grown in growth chambers adjusted to provide a 14 h, 30 C day and a 10 h, 25 C night. Relative humidity was 80±5%, and light intensity was 300±50 $\mu E \cdot m^{-2} \cdot sec^{-1}$. The plant parts were freeze dried after sampling and then oxidized[3]. The $^{14}CO_2$ gas was trapped in a cocktail solution[4] and was quantified using liquid scintillation spectrophotometry.

RESULTS AND DISCUSSION

<u>Field Experiments.</u> A tank mix application of GAF 141 plus dicamba

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[3]R.J. Harvey Instrument Corp.

[4]CO_2unt Sorb, Research Products International Corp.

at the Kay location increased control of established field bindweed compared to that obtained with dicamba alone (Table 2). At Carrier, when GAF 141 was applied 24 prior to application of dicamba, field bindweed regrowth was reduced from 196 stems/m^2 with dicamba alone to 87 stems/m^2 with GAF 141 pretreatment to dicamba. A tank mix of GAF 141 and dicamba did not improve the control obtained with dicamba at this location. Also, GAF 141 had no effect on field bindweed control provided by dicamba at Logan, Payne, or Enid locations.

Efficacy of glyphosate and 2,4-D was not affected by tank mixing or pretreatment with GAF 141 at any location nine to eleven months after herbicide application. It should be noted, however, that ten months after treatment, none of the treatments at the Logan location were controlling over 15% of the field bindweed.

Laboratory Experiments. Averaged over all dicamba concentrations, GAF 141 significantly decreased acropetal translocation of ^{14}C-dicamba from 16.1% to 8.5% of that applied, and increased the percent of ^{14}C-dicamba remaining in the treated area from 72.3% to 79.3% of applied (Table 3). However, as dicamba concentration increased, the effects of GAF 141 became less evident. GAF 141 had no effect on the percent of applied ^{14}C-dicamba recovered in the lower stem. In field bindweed roots and their nutrient solution, a significant interaction between GAF 141 concentration and dicamba concentration occurred. When only four droplets of ^{14}C-dicamba were applied 24 h after application of GAF 141, a significant increase occurred in the amount of ^{14}C recovered in both the roots and nutrient solution. However, when higher dicamba concentrations were used in addition to the ^{14}C-dicamba, this effect was no longer significant. A maximum of 5.9% of applied ^{14}C-dicamba was recovered in the roots when GAF 141 was applied prior to ^{14}C-labelled dicamba only, compared to 2.7% without the use of GAF 141. Maximum ^{14}C recovery in the nutrient solution (13.3%) also occurred when GAF 141 was applied prior to application of only ^{14}C-dicamba, compared to 6.4% when GAF 141 was not applied. With dicamba concentrations of 3000 ppm or more, 1.1% or less of recovered ^{14}C was found in the roots or nutrient solution.

When all glyphosate and GAF 141 concentrations are considered, no significant differences in ^{14}C-glyphosate translocation to the upper foliage were observed (Table 4). However, when the ^{14}C-glyphosate and the ^{14}C plus 3000 ppm glyphosate are analyzed individually, GAF 141 significantly inhibited acropetal translocation of glyphosate. GAF 141 had no influence on translocation of ^{14}C-glyphosate from the treated area or into the lower stem. When only ^{14}C-glyphosate was applied, GAF 141 increased ^{14}C accumulation in the roots. However, as higher glyphosate concentrations were used, GAF 141 no longer significantly affected ^{14}C-glyphosate accumulation in field bindweed roots. Higher concentrations of glyphosate did, however, result in lower percent of recovered ^{14}C-glyphosate found in the roots.

GAF 141 had no significant effect on the translocation of 2,4-D into or from any plant part. However, 2,4-D concentration affected translocation patterns (Table 5). Concentration of 2,4-D had no significant effect on the percent of ^{14}C recovered from the upper foliage. However, as 2,4-D concentration increased, the percent of ^{14}C-2,4-D accumulating in the lower stem, roots, and nutrient solution decreased sharply. Lower percent recovery in the roots and nutrient solution occurred when higher concentrations were applied, whereas highest recovery occurred when only the ^{14}C-2,4-D was applied. In the treated area, the opposite was true. The use of only the ^{14}C-labelled 2,4-D resulted in more movement of ^{14}C-2,4-D from the treated area than did the two highest 2,4-D concentrations.

Thus, GAF 141 treatments stimulated basipetal translocation of dicamba and glyphosate, but not 2,4-D, when only the ^{14}C-labelled herbicides were used. However, when herbicide concentrations which simulated field application rates for control of perennial weeds were used, GAF 141 did not significantly alter basipetal translocation. Previous work (1) indicated that basipetal translocation of glyphosate, dicamba, acifluorfen, and 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] is enhanced by the use of GAF 141. However, in that research, only small quantities of these herbicides were applied. Our research indicates that the mechanism by which this enhancement occurs is influenced by herbicide rate. Apparently as herbicide concentration increases, the ability of GAF 141 to stimulate basipetal translocation decreases. Therefore, rates required for the control of perennial weed species may be too high for the stimulatory effects of GAF 141 to be observed. However, GAF 141 may prove beneficial in control of annual weeds with lower rates of some translocated herbicides than those required for the control of perennial species.

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Table 1. Soil characteristics and treatment information for the field bindweed control experiments.

	Location	Soil characteristics Classification	pH	O.M. (%)	Treatment date	Carrier vol. (1/ha)	Plot size (m^2)	Evaluation date
1.	Kay	Kirkland silt loam	6.8	1.4	Oct. 8, 1980	187	24	July 6, 1981
2.	Logan	Kirkland silt loam	5.4	1.2	Oct. 14, 1980	187	24	Aug. 4, 1981
3.	Payne	Grainola-Lucien clay loam	5.8	0.5	Oct. 21, 1980	187	20	July 6, 1981
4.	Enid	Bethany silt loam	5.9	1.2	Sept. 2, 1981	140	36	July 12, 1981
5.	Carrier	Shellabarger-Carwile fine sandy loam	5.3	1.3	Nov. 17, 1981	93	36	July 13, 1981

Table 2. Effect of GAF 141 on field bindweed control with dicamba, glyphosate and 2,4-D 9 to 11 months after fall treatment at five locations.

		Location				
		Kay	Logan	Payne	Enid	Carrier
Chemical[a]	Rate	Control				
	(kg/ha)	(%)			(stems/m^2)	
Dicamba	1.1	25	10	73	69	--
Dicamba + GAF 141	1.1+0.3	76	4	95	48	--
GAF 141;dicamba	0.3;1.1	--	--	--	48	--
Dicamba	0.6	--	--	--	--	196
Dicamba + GAF 141	0.6+0.1	--	--	--	--	168
GAF 141;dicamba	0.1;0.6	--	--	--	--	87
Glyphosate	3.3	72	9	78	22	--
Glyphosate + GAF 141	3.3+0.3	85	15	76	15	--
GAF 141;glyphosate	0.3;3.3	--	--	--	18	--
Glyphosate	1.7	--	--	--	--	17
Glyphosate + GAF 141	1.7+0.1	--	--	--	--	10
GAF 141;glyphosate	0.1;1.7	--	--	--	--	33
2,4-D	1.1	35	8	78	78	--
2,4-D + GAF 141	1.1+0.3	30	8	84	84	--
GAF 141;2,4-D	0.3;1.1	--	--	--	79	--
2,4-D	0.6	--	--	--	--	208
2,4-D + GAF 141	0.6+0.1	--	--	--	--	226
GAF 141;2,4-D	0.1;0.6	--	--	--	--	170
GAF 141	0.3	0	0	0	76	---
GAF 141	0.1	--	--	--	---	248
Untreated check	-	0	0	0	104	202
LSD (0.05)		27	14	32	32	79

[a]A "+" indicates a tank mix, whereas a ";" designates sequential applications.

Table 3. Effects of dicamba concentration and GAF 141 on distribution of ^{14}C recovered 24 h after foliar application of ^{14}C-dicamba.

		Distribution of recovered ^{14}C				
Dicamba concentration[a]	GAF 141 concentration	Upper foliage	Treated area	Lower stem	Root	Nutrient solution
(ppm)	(ppm)	(%)				
0	0	32.2	40.7	18.0	2.7	6.4
0	2000	20.9	43.5	16.4	5.9	13.3
1500	0	14.8	69.8	12.9	1.7	0.8
1500	2000	8.5	76.4	10.9	2.6	1.6
3000	0	15.0	79.9	3.6	1.1	0.5
3000	2000	3.8	91.7	3.6	0.5	0.4
6000	0	10.9	83.0	4.3	0.9	0.9
6000	2000	4.6	92.4	2.0	0.3	0.7
12000	0	7.7	87.9	3.8	0.1	0.5
12000	2000	4.7	92.4	2.4	0.1	0.4
LSD (0.05)		8.2	10.3	6.6	1.7	2.3

[a]Not including ^{14}C-dicamba.

Table 4. Effects of glyphosate concentration and GAF 141 on distribution of ^{14}C recovered 24 h after foliar application of ^{14}C-glyphosate.

		Distribution of recovered ^{14}C				
Glyphosate concentration[a]	GAF 141 concentration	Upper foliage	Treated area	Lower stem	Root	Nutrient solution
(ppm)	(ppm)	(%)				
0	0	2.4	89.0	3.4	4.7	0.2
0	2000	0.5	84.8	4.1	10.5	0.2
3000	0	2.1	84.4	6.4	6.8	0.2
3000	2000	0.2	84.0	7.5	8.0	0.3
6000	0	1.7	90.4	3.3	4.3	0.3
6000	2000	2.6	81.0	9.7	6.5	0.2
12000	0	2.8	87.9	6.1	3.0	0.3
12000	2000	1.9	88.9	5.6	3.3	0.3
24000	0	2.0	91.6	5.0	1.2	0.5
24000	2000	3.5	90.1	4.6	1.6	0.1
LSD (0.05)		NSD	NSD	NSD	4.1	NSD

[a]Not including ^{14}C-glyphosate.

Table 5. Effect of 2,4-D concentration on distribution of ^{14}C recovered 24 h after foliar application of ^{14}C-2,4-D.

	Distribution of recovered ^{14}C				
2,4-D concentration[a]	Upper foliage	Treated area	Lower stem	Root	Nutrient solution
(ppm)			(%)		
0	2.2	70.5	15.8	8.0	3.7
1500	8.7	80.6	7.0	2.5	1.3
3000	8.2	79.5	9.9	1.6	0.9
6000	3.5	86.6	9.1	0.4	0.5
12000	6.8	87.1	5.4	0.5	0.3
LSD (0.05)	NSD	10.2	7.3	1.5	1.0

[a]Not including ^{14}C-2,4-D.

PART II

RELATION OF NITROGEN AND PHOSPHORUS NUTRITION TO THE TRANSLOCATION OF THREE HERBICIDES IN FIELD BINDWEED

RELATION OF NITROGEN AND PHOSPHORUS NUTRITION TO THE TRANSLOCATION OF THREE HERBICIDES IN FIELD BINDWEED

Abstract. Twenty-eight day old field bindweed (*Convolvulus arvensis* L.) plants grown in culture solutions deficient in nitrogen or phosphorus for the last seven days of growth translocated significantly less foliarly applied dicamba (3,6-dichloro-*o*-anisic acid) and 2,4-D [2,4-dichlorophenoxy)acetic acid] to their roots than did plants grown in complete nutrient solutions. In contrast, nitrogen deficiency stimulated basipetal translocation of glyphosate [*N*-(phosphonomethyl)glycine] and inhibited its acropetal translocation in field bindweed. Deficiencies of both nitrogen and phosphorus decreased translocation of dicamba from the treated area, but had no influence on glyphosate or 2,4-D translocation from the treated area.

INTRODUCTION

Most research conducted on the impact of environmental factors on herbicide translocation and efficacy has emphasized the effects of temperature, light, rainfall, soil moisture, and relative humidity, with little work done on the influence of nutrient availability. Doll (5) found that the phytotoxicity of amiben (3-amino-2,5-dichlorobenzoic acid), atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine], and linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] was greatly enhanced by nitrogen fertilization of oats (*Avena sativa* L.), whereas phosphorus and potassium had no interaction with herbicidal toxicity to oats. However, Doll et al. (6) found that higher phosphorus levels did increase the suppression of corn (Zea mays L.) and cucumber (Cucurbita maxima Duchesne) by these herbicides. Soil fertilization was found to have an effect on barban [4-chloro-2-butynyl-N-(3-chlorophenyl)carbamate] effectiveness through both increases in wild oat (Avena fatua L.) control and competition from wheat (Triticum aestivum L.) (17).

Nutrient status of various annual species has proven to influence the efficacy of some foliar-applied herbicides. Rohrbaugh and Rice (19) found less stem curvature and accumulation of ^{14}C-2,4-D in roots of tomato (Lycopersicon esculentum Mill.) plants deficient in phosphorus than in plants grown with adequate phosphorus. Baird et al. (1) reported that application of nitrogen to quackgrass (Agropyron repens L.) 30 days prior to treatment with glyphosate significantly improved control by increasing vegetative growth. High nitrogen levels increased control of seven cultivars or species in the Gramineae family with paraquat (1,1'-bipyridlium ion) (15). McCarty and Scifres (16) reported that picloram (4-amino-3,5,6-trichloropicolinic acid) and dicamba at 0.14 and 2.2 kg/ha, respectively, reduced regrowth of smooth bromegrass (Bromus inermis Leyss.) only when nitrogen fertilizer was applied.

Field bindweed is a significant perennial weed species in many wheat producing regions. Nutrient levels in many of these areas are depleted during the time of active field bindweed growth by crop uptake and subsequent harvesting of the grain, and by immobilization due to organic decomposition of wheat residues (21). Therefore, the control of field bindweed by herbicides is typically undertaken when the nutrient status of the field is low. The objective of this research was to determine the influence of nitrogen and phosphorus deficiencies on the translocation of dicamba, glyphosate, and 2,4-D in field bindweed.

MATERIALS AND METHODS

Field bindweed plants were germinated and grown in aerated bottles filled with 500 ml half strength Hoaglands (10) nutrient solution for 21 days. Plants were grown in growth chambers which were adjusted to provide a 14 h, 30 C day and a 10 h, 25 C night. Relative humidity was 80±5%, and light intensity was 300±50 $\mu E \cdot m^{-2} \cdot sec^{-1}$. The plants were then transferred to one half strength Hoaglands nutrient solutions which contained (a) K_2CO_3 and $CaCO_3$ to replace KNO_3 and $Ca(NO_3)_2$, (b) K_2CO_3 to replace KH_2PO_4, or (c) normal quantities of nitrogen as KNO_3 and $Ca(NO_3)_2$ and phosphorus as KH_2PO_4. Plants were then returned to the growth chamber and maintained for 6 days. The plants were then treated with 1 μg dicamba (17.06 Ci/mole, ring-^{14}C-UL), 8.7 μg glyphosate (1.95 Ci/mole, methyl-^{14}C), or 1 μg 2,4-D (57 Ci/mole, carboxyl-^{14}C). The glyphosate was formulated as an isopropylamine salt by adding equimolar isopropylamine to 2.17 mg ^{14}C-glyphosate plus nonionic polyethoxylated tallow amine[1] at 15.2% v/v, plus 84.3% distilled water to equal the commercial formulation. The dicamba and 2,4-D were in 95% ethanol. All ^{14}C-herbicides were applied with a 10 μl microsyringe pipette by placing a total of four 2.5 μl drops on the adaxial leaf surface of the second and third expanded leaves from the cotyledons of the field bindweed plants. Plants were then replaced in the growth chamber for a 24 h period. Plant size at this time was 8 to 12 expanded leaves,

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[1]MON 0818.

with stems 15 to 25 cm in length. After this time, plants were individually harvested and sectioned into the foliage above the treated area, the treated area, the cotyledons and stem between the treated area and the roots, and the roots. A sample of the nutrient solution was also retained for analysis.

The treatments were replicated eight times and each experiment was repeated four times. The field bindweed plants were arranged in a randomized complete block design within the growth chamber. The plant parts were freeze dried after sampling, weighed, and oxidized[2]. The $^{14}CO_2$ gas was trapped in a cocktail solution[3] and quantified by liquid scintillation spectrophotometry.

RESULTS AND DISCUSSION

Nitrogen deficiency inhibited both acropetal and basipetal translocation of ^{14}C-dicamba (Table 1). Compared to normal nutrient levels, both nitrogen and phosphorus deficiencies reduced ^{14}C accumulation in the roots and nutrient solution by more than 50%. Nitrogen stress also decreased ^{14}C-dicamba movement into the upper foliage, where only 21.5% of applied ^{14}C was recovered in nitrogen stressed plants compared to 27.9% in plants with adequate nitrogen. Phosphorus deficiency had no significant effect on acropetal translocation of dicamba, with no significance compared to either nitrogen deficient or normal solutions. When either nutrient was deficient, 56% or more of the applied ^{14}C-dicamba remained in the treated area after 24 h, whereas only 47.5%

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[2]R.J. Harvey Instrument Corp.

[3]CO_2unt Sorb, Research Products International Corp.

remained when the nutrients were present in adequate amounts.

In contrast to the effect of nitrogen levels on dicamba translocation to roots, inadequate nitrogen stimulated basipetal movement of ^{14}C-glyphosate into field bindweed roots (Table 2). Phosphorus status had no significant effect on basipetal movement of ^{14}C-glyphosate. As with dicamba, translocation of glyphosate acropetally was inhibited by inadequate nitrogen, but not by inadequate phosphorus. Nutrient status had no effect on the amount of ^{14}C-glyphosate recovered in the treated area.

As was the case with dicamba, basipetal movement of ^{14}C-2,4-D into both field bindweed roots and their nutrient solution was inhibited by nitrogen deficiency (Table 3). In contrast, phosphorus deficiency did not significantly affect accumulation of ^{14}C-2,4-D in roots, but did decrease ^{14}C levels in the nutrient solution, compared to plants grown with normal nitrogen and phosphorus levels. Thus, it would appear that lack of phosphorus also inhibited basipetal 2,4-D translocation.

In comparing the influence of nutrient status on ^{14}C-dicamba (Table 1), ^{14}C-glyphosate (Table 2), and ^{14}C-2,4-D (Table 3), different results were observed. Nitrogen deficiency resulted in a decrease in basipetal translocation of dicamba and 2,4-D, but an increase with glyphosate. Nutrient deficiencies reduced the quantities of dicamba translocated from the treated area, but did not affect the level of glyphosate or 2,4-D remaining there. Acropetal translocation of dicamba and glyphosate, but not 2,4-D, was inhibited by nitrogen deficiency.

To isolate the effect of nitrogen and phosphorus status on plant growth from nutrient status effects on herbicide translocation, it is necessary to examine the ratio of ^{14}C accumulating in the upper foliage to that recovered in the roots and nutrient solution and the upper foliage to roots dry weight ratios (Table 4). Total ^{14}C recovered in the roots plus nutrient solution is considered the total of basipetal translocation. The data are presented in terms of the percent of the normal solution ratio for each nutrient deficiency. With dicamba, no significant change was noted in the ratio of acropetal to basipetal herbicide translocation when either nitrogen or phosphorus was absent, compared to the normal solution. Therefore, even though a significant increase in the amount of dicamba remaining in the treated area occurred when either nutrient was not available to the plant, no effect was observed upon the relative proportion of dicamba moving acropetally and basipetally.

The ratio of ^{14}C accumulating in the upper foliage versus the roots plus nutrient solution changed with both glyphosate and 2,4-D when nitrogen was deficient. Phosphorus, however, had no significant influence on this proportion with either herbicide. A significant reduction occurred in the amount of ^{14}C-glyphosate accumulating in the upper foliage compared to the amount found in the roots plus nutrient solution when nitrogen was absent. Lack of nitrogen caused the opposite response with 2,4-D. A five-fold increase in the relative amount of ^{14}C-2,4-D recovered in the upper foliage versus that found in the roots plus nutrient solution was found when nitrogen-stressed plants were compared with those grown in one half strength Hoaglands nutrient solution.

Nutrient status also affected the ratio of the dry weight of the upper foliage to that of the roots (Table 4). In all cases, withholding nitrogen from the culture solution caused a significant decrease in the relative growth of the upper foliage in relation to the root growth. Phosphorus also reduced the proportion of upper foliage growth compared to growth of the roots of plants used for all herbicides except dicamba. Relative decreases in this ratio were similar with all three herbicides for both deficient nutrients. This indicates that the herbicide itself had little effect on the differences observed due to nutrient status.

With dicamba, movement from the treated area was slowed substantially by lack of nutrients. Thus, less ^{14}C-dicamba moved both acropetally and basipetally in field bindweed. Hay (9) noted that dicamba is one of the more mobile herbicides, with movement both apoplastically and symplastically toward the growing tips. Chykaliuk et al. (3) found that much more dicamba moved from the treated area than did glyphosate or acifluorfen {5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid}. Hay (9) also concluded that a supply of carbohydrates is necessary for the movement of herbicides from the leaves, both to develop an assimilate flow and to supply energy for phloem loading. Therefore, if nutrient deficiencies result in reduced metabolic activity within the plant, either suggested mechanism could be slowed, resulting in less dicamba movement.

Increases in basipetal translocation of ^{14}C-glyphosate may be due to a relative increase in root growth compared to growth of the foliage. Various studies have shown that nitrogen deficient conditions decrease the relative amount of top growth compared to root growth (8, 23, 24). This research has also found this trend to occur. Hoagland and Duke (11) note that the primary means of glyphosate translocation is symplastic, with accumulation in areas of most active growth. Since movement from the treated area was not affected, glyphosate may simply be moving to the area in which the most active growth is occurring under nutrient deficient conditions.

Basipetal movement of ^{14}C-2,4-D was inhibited by nitrogen deficiency in the roots, and by both nitrogen and phosphorus deficiencies in the nutrient solution. Previous work found that nitrogen deficiency (4, 12, 20, 22) or phosphorus deficiency (2, 7) reduced protein levels in various species. Researchers have suggested the involvement of a carrier protein with auxin transport (13, 18). Long and Basler (14) reported that cyclohexamide, a protein synthesis inhibitor, significantly decreased basipetal accumulation of 2,4,5-T [(2,4-5-trichlorophenoxy)acetic acid] in bean (Phaseolus vulgaris L.) roots. Therefore, data in the present study suggest that deficiencies of nitrogen or phosphorus which would limit protein synthesis in field bindweed plants would also be limiting the carrier protein-mediated uptake and basipetal movement of 2,4-D. A decrease in vein loading could allow an increase in apoplastic translocation of 2,4-D to the upper foliage. An explanation of the decreased basipetal translocation of 2,4-D with nitrogen deficiency based on a decrease in vein loading rather than a decrease in mass flow was substantiated by the fact that nitrogen deficiency actually increased basipetal translocation of glyphosate, indicating that mass flow was not decreased by nitrogen deficiency. However, an increase in vein loading of glyphosate could account for the increase in basipetal glyphosate translocation with nitrogen deficiency.

Much of the data of this study indicate that deficiencies of nitrogen and phosphorus have a significant impact on the translocation patterns of dicamba, glyphosate, and 2,4-D in field bindweed.

Reports in the past have shown that nutrient deficiencies influence the efficacy of these herbicides in annual species (1, 16, 19). Data from this study indicate that this is also true in perennial species.

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Table 1. Effect of nitrogen and phosphorus nutrition on distribution of ^{14}C recovered 24 h after foliar application of ^{14}C-dicamba.

Nutrient level during last 7 days of growth	Distribution of recovered ^{14}C				
	Upper foliage	Treated area	Lower stem	Root	Nutrient solution
	(%)				
No nitrogen	21.5	57.4	17.1	2.1	1.9
No phosphorus	24.0	56.0	15.3	2.2	2.5
Normal N and P	27.9	47.5	15.6	4.6	4.4
LSD (0.05)	5.3	6.7	NSD	1.2	1.4

Table 2. Effect of nitrogen and phosphorus nutrition on distribution of ^{14}C recovered 24 h after foliar application of ^{14}C-glyphosate.

Nutrient level during last 7 days of growth	Distribution of recovered ^{14}C				
	Upper foliage	Treated area	Lower stem	Root	Nutrient solution
	(%)				
No nitrogen	1.2	86.4	1.8	10.1	0.5
No phosphorus	3.4	86.0	1.9	8.4	0.3
Normal N and P	3.4	87.1	1.9	7.3	0.3
LSD (0.05)	1.8	NSD	NSD	2.3	0.1

Table 3. Effect of nitrogen and phosphorus nutrition on distribution of ^{14}C recovered 24 h after foliar application of ^{14}C-2,4-D.

Nutrient level during last 7 days of growth	Distribution of recovered ^{14}C				
	Upper foliage	Treated area	Lower stem	Root	Nutrient solution
	(%)				
No nitrogen	9.0	63.2	17.7	7.4	2.7
No phosphorus	7.9	65.0	12.7	9.3	5.1
Normal N and P	3.9	66.5	12.4	10.1	7.1
LSD (0.05)	NSD	NSD	NSD	1.8	1.5

Table 4. Effect of nitrogen and phosphorus status on the ratio of foliar applied ^{14}C recovered in the upper foliage vs. that recovered in roots plus nutrient solution, and on the ratio of upper foliage to roots dry weight.

Deficient nutrient[a]	Upper foliage:roots + nutrient solution ^{14}C ratio[b]			Upper foliage:roots dry weight ratio[b]		
	dicamba	glyphosate	2,4-D	dicamba	glyphosate	2,4-D
	(%)			(%)		
Nitrogen	102	39	439	57	61	55
Phosphorus	71	83	199	79	82	81
LSD (0.05)	NSD	42	344	22	17	17

[a]Deficient nutrient=nutrient absent from culture solution for last seven days of plant growth.

[b]Ratios presented as percent of ratios for plants grown in 1/2 strength Hoaglands solution.

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