CHAPTER THREE

LIGNIN AS A CONTROLLED RELEASE MATERIAL FOR QUINCLORAC

ABSTRACT

Quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) provides effective pre and postemergence weed control in rice. Reports indicate that quinclorac is effective on a number of Midwestern weeds of agronomic significance. Questions exist regarding the phytotoxicity of the herbicide on crops grown in this region. Quinclorac when placed in the root zone inhibits the root growth of corn (*Zea mays* L), soybean (*Glycine max* L), barnyardgrass (*Echinochloa crus-galli* (L) Beauv.), ivyleaf morningglory (*Ipomoea wrightii* Gray) and several cereal grains. Foliar and soil applications of ^{14}C labeled quinclorac were absorbed by weeds and crops. Once adsorbed the herbicide translocated acropetally and basipetally to the actively growing regions of the plants. Despite root and foliar uptake, specific placement and retention of the herbicide results in selective phytotoxicity. Under identical conditions quinclorac leached twice as far as metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide) in the Spinks loamy sand. This propensity to leach makes retention in the soil above the seeds difficult. Effective

placement and retention of the herbicide was enhanced by the use of a quinclorac-lignin formulation. A dry flowable formulation was created by incorporating technical grade quinclorac into a lignin matrix. By physically binding the quinclorac in the lignin less was available to be leached during any irrigation or rainfall event. The lignin formulation also extended herbicidal activity in leaching studies. The lignin formulation shows promise in reducing the vertical off-site movement of quinclorac.

Additional index words. Quinclorac acid, BAS 514, controlled release

INTRODUCTION

Quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) controls a number of weeds commonly found in the Midwest (15, 14). The chemical is a chlorinated organic molecule with the molecular formula of $C_{10}H_5O_2NCl_2$ and a molecular weight of 242. Pure quinclorac is a colorless crystalline material with a vapor pressure less than 1.1 x 10^{-7} mm Hg at 25°C. Quinclorac is soluble in: acetone at 0.2 g, xylene at 1.0 g, and water at 6.2 g, all at 100 g of solvent (1). Phytotoxicity varies from plant species to species. Preliminary results indicate that the pesticide has herbicidal activity when applied pre-plant incorporated, pre-emergence or postemergence (data not presented). A few weed species appear to be more susceptible to root uptake of the pesticide. Quinclorac shows promise as a herbicide in rice (*Oryza sativa*), oats (*Avena sativa*), hard red spring wheat (*Triticum aestivum*), winter wheat and broccoli (*Brassica oleracea* var. *botrytis*) production (1, 12, 13, 15).

The commercial development of a selective herbicide is not limited to those pesticides that exploit plant differences in morphology, metabolic degradation, rates of metabolism, selective uptake or sites of action (17). A number of physiologically nonselective herbicides have been commercially marketed as selective by utilizing innovative application methods. For example the selective application of glyphosate (*N*-(phosphonomethyl) glycine) utilizing wicks, paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) with shields, or 2,4-D ((2,4-dichlorophenoxy)acetic acid) by avoiding application during various formative stages of grain development (7).

Innovations designed to optimize selectivity are often discovered late in the development of an herbicide. At times they develop from the efforts of growers and extension specialist working with minor crops. Variations in the formulation of a pesticide can reduce or enhance the selectivity of a chemical (20). Modifications of pesticide formulations can also be used to reduce the acute toxicity of a pesticide formulation (6). For example, the formulation of parathion (O,O-diethyl-O-(4-nitrophenyl) phosphorothioate) in polymeric encapsulated beads reduces mixer and applicator exposure to the insecticide (2, 3). The early use of molescides in paints extended the delivering and the effectiveness of these pesticides to their intended targets (4, 7).

The unintended movement of herbicides away from their targets and into groundwater has been highlighted by recent ground water surveys. Altering formulations have addressed concerns regarding efficacy and toxicity (5, 6, 8, 16). Altering formulations may hold similar answers for a number of environmental concerns (19). Controlled release materials may provide a means of reducing or eliminating contamination of ground waters by herbicides, while retaining an economically and efficaciously desirable material.

Guidelines developed by the Environmental Protection Agency require the review of the leaching properties of a pesticide as part of the registration process. The regulatory agency also limits or eliminates the use of chemicals known to leach when used in regions with sandy soils. These policies reduce the weed control options available to growers. The development of controlled release formulations could address the concerns of the EPA while providing the growing community with options.

Cost is the most serious limitations affecting the development of controlled release pesticides in agriculture. During the nineteen fifties and sixties pest control researchers in agriculture were at the forefront of controlled release research (2, 3, 10, 11, 18). Cost limitations have shifted the development of control release technology from agriculture to the pharmaceutical industry. The development of a commercially viable control release material in agriculture must be based on a readily available inexpensive raw material. Even a readily available low cost material may fail as a result of increases in transportation cost. A marked changed in the percentage of active ingredient can negatively impact transportation cost resulting in the product being economically nonviable. The objectives of these studies were to; determine the site of uptake of quinclorac, study methods of exploiting phytotoxic differences between crops and weeds, to evaluate whether quinclorac might be used on other crops, explore the possibility of utilizing lignins to extend the time period for weed control, reduce the movement of quinclorac by using lignins as a controlled release agent.

MATERIAL AND METHODS

Rate and placement studies (Table 1 and 2) An air dried Spinks loamy sand soil was used as the growing media for all greenhouse studies. The Spinks loamy sand's organic matter was 0.8% and the Ph 6.5. Soil was screened prior to each study. A soil sieve with 2 mm square openings was used to standardize soil structure from study to study. After sieving the soil was placed in 1 L plastic pots.

The quinclorac was applied below the seeds, above the seeds, and postemergence at the two-leaf stage. All applications were made with water as the carrier at 375 L ha^{-1} with a flatfan SS8002E nozzle. Boom pressure was maintained at 10 kg cm^{-1}. Application rates of quinclorac were 1.4, 0.6, 0.1 and 0 kg ha^{-1} of active ingredient. Soil applications were incorporated by pouring the contents of the treated pot into a non-treated pot 10 time and then pouring the inverted soil into the seeded pot.

Barnyardgrass was used as the bioassay species. Twenty seeds were evenly dispersed across the container and each treatment was replicated four times. The efficacy of quinclorac on barnyardgrass was determined by visual comparison relative to the non-treated controls. The impact of the herbicide on wheat and rye was evaluated using shoot weight, shoot length and emergence.

Barnyardgrass, wheat and rye seedlings used in the postemergence test were evaluated 8 days after application.

Watering and herbicide placement studies. Selective placement of quinclorac was accomplished by postemergence application and seed placement above or below treated soil. Subsequent movement of quinclorac to non-treated areas was restricted by using activated carbon or vermiculite. Quinclorac from the soil applications was isolated from the seeds by using activated carbon and soil. A 1 to 2-cm band of soil was placed between the 0.5-cm band of activated carbon and the treated area. A 1 to 2 cm-surface layer of vermiculite was placed on the soil to isolate the foliar applications. The vermiculite was removed 24 h after application. The movement of quinclorac into the carbon layer was minimized by supplementing surface irrigation with sub-irrigation. Post applications and above seed applications are sub-irrigated. Below seed applications were surface watered. After two weeks the soil was sub and surface irrigated.

Soil treatments were incorporated by spraying an surface area of soil 5.0 cm deep and inverting the soil 10 times. The soil was added above or below the seeds The seeds would be planted on the opposite side of a 0.25 cm-layer of activate carbon. All seeds were sown the day of soil application. Postemergence applications were applied at the two leaf stage for the grasses or at the initiation of the first trifoliate leaf for soybean and morningglory. Treatments were replicated eight times with one-half of the pots in each treatment being either sprinkler or sub-irrigated. Sub-irrigation was accomplished by filling 40 ml aluminum pie pans placed beneath pots with water. Sprinkler irrigation was conducted by passing a boom with a single teejet 8004E nozzle over the pots until the required amount of water has been added (100 ml h^{-1} pot).

Barnyardgrass, corn, morningglory, soybean, rye and wheat were used to study the effect of herbicide placement on each species. The number of seeds sown per pot for each species were 4 corn, 6 soybean, 8 morningglory and 10 wheat and rye seeds. Shoot heights were measured for all species.

Use of a lignin mixture for controlled release of quinclorac. Attempts to introduce technical grade quinclorac into the lignin matrix by co-grinding in a mortar and pestle failed. Addition of both lignin and quinclorac in aqueous solutions adding lignin first or quinclorac allowing equilibration periods in excess of 144 h or heating the aqueous solutions were also unsuccessful. Attempts to co-melt the co-ground lignin-quinclorac combinations resulted in lignin liquefying prior to the quinclorac and the subsequent separation of the materials. Solubilization of the lignin with tetrahydrofuran, toluene, n-propyl failed to create a single phase. Efforts to use carbon disulfide yielded limited success. Solubilization of most lignins in acetone was successful. Introduction of lignin, quinclorac and acetone yield a single phase solution, with viscosity properties directly responsive to the proportion of acetone present. Subsequent volatilization of the acetone resulted in a solution of increasing viscosity, the matrix initially adopted liquid, then tar, and ultimately glass-like properties. The viscosity of the final product was temperature dependent. Successful preparation of the material required for application utilizing standard agricultural application equipment (Tee Jet nozzles, screens, etc.) required grinding under freezing or near freezing conditions. To avoid clogging the screens in application equipment the matrix was maintained in a cool environment until application. Warming of the formulation resulted in a congealing of the screen lignin-quinclorac mix. Increased stability may be enhanced by the more extensive removal of the acetone. The lignin-quinclorac matrix had a density greater than one and required constant agitation to avoid settling.

Soil column leaching studies. The leaching properties of quinclorac were tested by utilizing a soil column bioassay. Polyvinyl-chloride tubes were used. Columns were cut along two radial axis 30 cm apart. Radial openings have 7 cm diameters. Tubes were tangentially approximately 2 cm deep. The tangential cut allowed accurate selective removal of soil. Multiple layers of cheese cloth were used on the lower radial opening. Cheese cloth provided support to allow drainage.

An air dry Spinks loamy soil was screened to remove all material larger than 2 mm. Organic matter content of the soil was

0.8% and the Ph 6.5. Columns were dropped on the floor from 10 to 15 cm to facilitate equivalent settling.

Treatments applied to the columns were quinclorac, quinclorac:lignin (1:1 ratio), metolachlor and a non-treated control. All treatments were replicated on four columns. Metolachlor was used as a reference. All applications were made across the open air radial surface of the columns. Water applied at 375 L ha^{-1} was used as the carrier. Applications were made by passing the columns under a fixed position flatfan SS8002E nozzle. Boom pressure was maintained at 10:25 kg cm^{-1}. A 1.12 kg ha^{-1} rate of quinclorac was applied. Metolachlor was applied at 2.24 kg ha^{-1}.

All columns were sprinkler irrigated immediately after application. One hundred and fifty ml (3.9 cm) of water was applied over a 30-minute period. Rainfall was simulated by repeatedly passing a belt driven SS4004E nozzle over the columns. Sequential passes were timed to avoid puddling.

Forty-eight hours after the application the tangential cut on each column was removed. Columns were divided into 10 3-cm sections along the tangential surface. Soil was removed from each section and maintained distinct from the other nine sections.

Barnyardgrass was used as the bioassay species. The soil from each section was used to cover 20 barnyardgrass seeds. Barnyardgrass was then grown in the greenhouse under natural lighting. Once controls reach an average height of 10-cm the plants were harvested. Average shoot length defined as the length of the tallest leaf from soil to apex was used to measure efficacy. The individual pot values were then divided by the mean on the four controls. The percent of control value was used in the statistical evaluation of herbicidal efficacy.

Distribution of ^{14}C quinclorac in plant. Radiolabeled quinclorac was ^{14}C labeled at the third carbon with a specific activity of 40.4 uCi mg^{-1}. Plants were exposed to ^{14}C quinclorac in one of three locations. Plants were exposed by placing: the seeds above a treated band of soil, planting the seed below the treated band or by foliar application.

Movement of the soil applied quinclorac was restricted by using a layer of activated carbon. Seventy-five ml test tubes were used for the soil studies with 1 Uci of quinclorac being added to each test tube. Plants were grown in a growth chamber. Initial applications of ^{14}C quinclorac added formulated quinclorac 00 H (soil treated at 1.5 kg ha^{-1} into soil 3-cm deep) resulted in death of for all plants. All subsequent soil uptake studies were conducted using only ^{14}C quinclorac. The application rate of active material was 0.17 kg ha^{-1}. The acetone carrier was allowed to volatilize prior to planting. All applicable treatments were spiked with 1 Uci of quinclorac per test tube. Plants were removed from the test tubes and divided into foliage and roots. All plant material above the soil surface being foliage and all below the surface being classified roots.

The ^{14}C quinclorac was applied to the second leaf of corn plants after emergence of the fourth leaf. The third leaf of the barnyardgrass was treated after the emergence of the fourth leaf. The first leaf of the morningglory was treated after the emergence of the second leaf. All ^{14}C quinclorac applications were made immediately following the application of 0.5 kg ha^{-1} of quinclorac as a broadcast application. All ^{14}C quinclorac foliar applications were made by diluting the ^{14}C quinclorac with non-labeled quinclorac to a ratio of 1 to 33.7. So the concentration totaling 172,000 DPM were applied per plant in five 2 ul-drops. Applications were made with a 10 ul-syringe. Acetone was added to the labeled and non-labeled solution to facilitate stability. A surface layer of vermiculite 1.25 cm deep was used to restrict the movement of pesticide into the soil for all foliar applications. Movement of ^{14}C quinclorac in soil applications were restricted by placing a 3 to 5 mm band of activated carbon between the seed and the treated soil. All test tubes were wrapped with aluminum foil. Test tubes used in the soil applications were covered to reduce evaporation rates until the emergence of the seedlings.

RESULTS AND DISCUSSION

The visual phytotoxicity expressed in the barnyardgrass increased with the concentration of quinclorac (Table 1). During this initial study activated carbon and vermiculite were not used. Pots were surface watered and attempts to control the movement of quinclorac were not implemented. Above-seed applications gave the best barnyardgrass control. The below-seed applications yielded the least effective weed control. On termination of the study, root growth of the surface applied treatments were restricted to the upper zone of soil. Under the relatively mild conditions of the greenhouse (i.e. optimum water, etc.) seedlings with root growth limited to the top few centimeters of soil produced foliar growth comparable to the controls. The phytotoxicity differences observed between the lower and upper soil applications appear to be the result of the morphology of the barnyardgrass.

Under similar conditions, wheat and rye seedlings were not as sensitive to quinclorac as the barnyardgrass (Table 2). Above seed applications reduced the germination rate in wheat and rye but only significantly in wheat. No differences were observed in the foliar weight or length of the seedlings.

Shoot and root growth of both dicots, soybean and morningglory were reduced by foliar applications (Tables 7 and 8). These applications of quinclorac had the most significant phytotoxic effect on the morningglory and barnyardgrass (Tables 3 and 8).

Sprinkler irrigation enhanced the phytotoxicity of the foliar applications. This enhanced response of was most prevalent in the root measurements taken on corn and morningglory seedlings (Table 6). The sprinkler irrigation was presumed to have washed the quinclorac from the leaves and into the soil. The lack of activated carbon in the foliar applications and the removal of vermiculite 24 h after application allowed the herbicide to move through the soil unimpeded.

For the soil applications the herbicidal effects in most studies were reduced when the watering placed the herbicide between the activated carbon and the source of water. The response was most notable in barnyardgrass and morningglory (Table 3 and 6). This reduced phytotoxicity was assumed to result from the movement of the herbicide into the activated carbon.

When quinclorac was applied and retained in the upper soil horizon no visual or gravimetric damage was evident (Tables 4, 5, 6 and 7). In contrast, growth by both weed species were significantly arrested when quinclorac was applied and retained in the upper soil horizon (Table 3 and 8). Selective placement and retention of the herbicide might provide added selectivity.

In an attempt to reduce the movement of quinclorac, optimize weed control and protect the crops studies exploring the use of lignin to control the release of quinclorac.

Co-grinding technical grade quinclorac with lignin resulted in a fine, well-mixed powder. Addition of the powder to water resulted in the separation of the pesticide and the lignin. The passive partitioning of technical grade quinclorac from a saturated or supersaturated aqueous solution into the lignin matrix was not visually evident.

The melting point of quinclorac was higher than the lignin fractions. Once liquified the lignin did not dissolve the technical grade quinclorac. On cooling the lignins and the quinclorac remained in distinct phases.

Since quinclorac has a relatively low solubility in organic solvents, attempts were made to partition the pesticide into the lignin. Solubilization of the lignin with tetrahydrofuran, toluene, n-propyl failed to create a single phase. Efforts to use carbon disulfide yielded limited success but were stopped due to concerns or the toxicity of CS_2.

Quinclorac and most lignin fractions are soluble in acetone. The combination of lignin, quinclorac, and acetone yield a single phase solution. The viscosity of the mixture was indirectly related to the proportion of acetone present. Subsequent volatilization of the acetone resulted in a solution of increasing viscosity. The matrix changes initially from a liquid, then tar, and ultimately to a glass-like materials. The viscosity of the final product was temperature dependent. Successful preparation of the material in quantities required for field applications utilizing standard agricultural application equipment (Tee-Jet nozzles, screens, etc.) required grinding and sieving of the material under freezing or near freezing conditions. To avoid clogging the screens in application equipment the matrix was maintained in a cool environment until application. Warming of the formulation resulted in a congealing of the screened lignin-quinclorac formulation. On a laboratory scale increased stability was achieved by the more extensive removal of acetone. The lignin-quinclorac matrix has a density greater than one and requires constant agitation to maintain a suspension in an aqueous carrier. The effectiveness of the formulation in reducing the movement of the quinclorac in soil was tested in a soil columns (Table 9)

The quinclorac in the commercial formulation was more susceptible to leaching than metolachlor (Table 9). The upper most 3-cm section of soil treated with the lignin-quinclorac formulation contained the largest concentration of quinclorac. Barnyardgrass was similar to the controls in upper most 6 cm of soil in the columns treated with commercial formulation of quinclorac. The majority of the quinclorac applied with the commercial formulation was found in the 9 through 21 cm-area of the column. Notably less quinclorac was available to move through the columns treated with the lignin-quinclorac formulation. The foliar uptake of ^{14}C quinclorac in barnyardgrass, corn, morningglory, and soybeans varied from 0.4 to 0.9 percent of the total recovered isotope (Tables 10 - 13). Recoveries ranged from 86 to 100 percent with the lowest recoveries coming from the weed species. As expected the level of isotope found in the food source of the young seedlings (cotyledons or seeds) was negligible. With the exception of corn the average DPM g^{-1} value in new leaves was greater than the other organs. ^{14}C-material was identified in roots of all species. Movement of the ^{14}C-quinclorac from the treated areas to the leaf tips of the dicots was relatively large when compared to the levels found in leaf tips of the grasses.

The herbicidal properties of quinclorac prevented the emergence of 100 percent of the barnyardgrass and 83 percent of the soybeans when quinclorac was placed above the seeds. Emergence was 83 percent for soybeans and better than 90 percent for the barnyardgrass for the below seed applications of quinclorac. A marked increase in the level of ^{14}C was found in the shoots of morningglory and corn relative to the levels in the roots in plants grown in an above seed application of quinclorac.

The ^{14}C levels in the shoots of the barnyardgrass grown with quinclorac applied below the seeds were higher than the level in the roots. This occurred because of the extensive barnyardgrass root system that developed near the soil surface. The roots that penetrated the activated carbon layer did not continue to grow in the presence of the treated soil. A the same time the contact was significant enough to allow the take up and translocation of observable levels to the shoots. Similar root to shoot distribution of the isotope was observed in the other species.

The selective placement and retention of quinclorac in the soil above the seeds of corn, soybean, wheat and rye resulted in the selective control of both morningglory and barnyardgrass. Uptake and translocation of ^{14}C quinclorac occurred from below and above seed soil applications as well as from foliar application. The growth of barnyardgrass and morningglory shoots through the treated soil resulted in greater injury when compared to the below seed soil applications of quinclorac. Foliar applications of quinclorac on corn and wheat did not reduce growth when the spray was excluded from the root zone. Once again both weed species were either killed or the growth retarded due to post-emergence applications. The roots of all species tested were adversely affected when the herbicide was available for root uptake. The effect of placement on the phytotoxic properties of quinclorac and differential species responses opens the possibility for exploiting the selective properties of the pesticides. The lignin formulation of quinclorac retained a measurable quantity of the herbicide in the upper horizon, whereas the dry flowable formulation was completely leached to the lower zones. The further development a controlled release formulation of quinclorac may provide a product suitable for Midwestern crops.

Table 1. Visual evaluation of the phytotoxic effects of rate and site of placement of quinclorac on barnyardgrass.

Treatment site	Quinclorac rate	Control[1]
	(kg/ha)	(%)
Above seed	1.4	99 A[2]
Above seed	0.6	99 A
Below seed	1.4	82 B
Foliage	1.4	71 C
Foliage	0.6	65 CD
Above seed	0.1	56 D
Foliage	0.1	31 E
Below seed	0.6	10 F
Below seed	0.1	0 F

1 Control of barnyardgrass was evaluated 16 days after the soil applications and 8 days after the postemergence applications.

2 Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test at the 1% level of significance.

Activated carbon, peat or vermiculite was not used.

Table 2 Selective placement of quinclorac on wheat and rye seedling emergence and shoot growth.

Treatment	Shoot weight[1] wheat	rye	Shoot length wheat	rye	Emerged seedling wheat	rye
	(g)/plant		(cm)/plant		number/plot	
BASF 514						
Post	.29 A	2.3 A	23 A	20.3A	10 A	9 A
Check	.28 A	2.1 A	23 A	19 AB	10 A	9 A
Below	.28 A	1.9 A	21 A	18 B	9 A	8 A
Above	.24 A	1.8 A	18 B	17 B	6 B	7 A

1. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test at the 1% level of significance.

Table 3. Placement of quinclorac and irrigation on barnyardgrass growth.

Quinclorac Treated zone	Watering	Shoot weight	Shoot length
		--------% of control[1]--------	
Postemergence	sprinkler	1.00 D	3.00 D
Above seed	"	25.75 BC	27.25 C
Below seed	"	44.50 B	68.25 B
Postemergence	sub	14.00 CD	28.25 C
Above seed	"	0.00 D	0.00 D
Below seed	"	112.50 A	114.50 A

Evaluated as a percent of the nontreated control.

1. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test as the 5% level of significance.

Table 4. Placement of quinclorac and the effect of surface vs. sprinkler irrigation on wheat growth.

Quinclorac Treated Zone	Watering	Shoot Length
		% of control
Postemergence	sprinkler	87[1]B[2]
Above seed	"	100 A
Below seed	"	87 B
Postemergence	sub	100 A
Above seed	"	100 A
Below seed	"	100 A

1. Evaluated as a percent of the nontreated control.

2. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test at the 5% level of significance.

Table 5. Placement of quinclorac and the effect of surface vs. sprinkler irrigation on rye growth.

Quinclorac Treated Zone	Watering	Shoot Length
		% of control
Postemergence	sprinkler	63[1]E[2]
Above seed	"	112 A
Below seed	"	80 D
Postemergence	sub	90 C
Above seed	"	100 B
Below seed	"	105 B

1. Evaluated as a percent of the nontreated control.

2. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test at the 5% level of significance.

Table 6. Placement of quinclorac and the effect of surface vs. sprinkler irrigation on corn growth.

Quinclorac Treated zone	Watering	Root weight	Root length	Shoot weight	Shoot length
		% of control[1]			
Postemergence	sprinkler	84 C[2]	59 D	62 C	68 C
Above seed	"	98 AB	98 B	94 AB	103 A
Below seed	"	26 D	78 C	67 CA	80 B
Postemergence	sub	92 BC	98 B	74 BC	100 A
Above seed	"	101 A	122 A	104 A	99 A
Below seed	"	99 AB	87 BC	109 A	102 A

1. Evaluated as a percent of the nontreated control.

2. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test as the 5% level of significance.

Table 7. Placement of quinclorac and the effect of surface vs. sprinkler irrigation on soybean growth.

Quinclorac Treated zone	Watering	Root weight	Root length	Shoot weight	Shoot length
		------------% of control[1]------------			
Postemergence	sprinkler	89 A[2]	83 B	49 C	63 C
Above seed	"	110 A	100 A	101 A	100 A
Below seed	"	49 B	34 C	41 C	78 B
Postemergence	sub	110 A	83 B	64 B	72 BC
Above seed	"	107 A	99 A	103 A	100 A
Below seed	"	103 A	97 A	99 A	105 A

1. Evaluated as a percent of the nontreated control.

2. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test as the 5% level of significance.

Table 8. Placement of BAS 514 and the effect of surface vs. sprinkler irrigation on morningglory growth.

Quinclorac Treated zone	Watering	Root weight	Root length	Shoot weight	Shoot length
		-----------% of control[1]-----------			
Postemergence	sprinkler	37 D[2]	55 CD	23 C	26 D
Above seed	"	110 A	91 AB	95 A	88 A
Below seed	"	87 BC	41 D	54 B	52 BC
Postemergence	sub	72 C	72 BC	32 C	33 CD
Above seed	"	92 ABC	87 AB	66 B	66 B
Below seed	"	95 AB	98 A	98 A	103 A

1. Evaluated as a percent of the nontreated control.

2. Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test as the 5% level of significance.

Table 9. Leaching properties of quinclorac, metolachlor, and lignin-quiclorac in a Spinks loamy sand soil.

Depth	Shoot Length		
	Quiclorac	Lignin-Quinclorac	Metolachlor
(cm)	(% of control)		
0-3	91 A-D[1]	38 H	5
3-6	92 A-D	93 A-D	3
6-9	82 C-F	81 C-F	11
9-12	67 EFG	82 C-F	30
12-15	60 G	82 C-F	127
15-18	65 FG	85 B-D	112
18-21	77 D-G	87 A-D	124
21-24	103 AB	98 ABC	116
24-27	101 AB	105 A	107
27-30	86 A-D	103 AB	82

LSD = 16

1 Means followed by the same letter are not significantly different from each other by the Duncan's Multiple Range Test at the 5% level of significance.

Table 10. Distribution of foliar applied ^{14}C-labeled quinclorac in morningglory.

Tip	Rinse	Treated area	Cotyledons	New leaf	Stem	Root
(DPM g^{-1})						
785	110347	5789	13	57	183	48
1095	119275	5268	17	274	23	150
2108	145465	6829	65	158	76	37
2911	136412	5828	13	219	7	58
(average DPM g^{-1})						
1725	127875	5929	27	177	72	73
(standard deviation)						
972	15953	652	25	93	80	52

Recovery 86.2%

Table 11. Distribution of foliar applied ^{14}C-quinclorac in soybeans.

Tip	Rinse	Treated Area	Cotyledons	New Leaf	Stem	Root	Unilofiate Leaf
(DPM g^{-1})							
1474	144619	19514	39	117	41	222	127
578	155387	8987	25	159	28	42	9
241	148166	14574	11	120	32	94	52
1619	164979	8247	113	177	62	108	58
(average DPM g^{-1})							
978	153288	12831	47	143	41	117	62
(standard deviation)							
673	8990	5275	45	30	15	76	49

Recovery 100.3%

Table 12. Distribution foliar applied ^{14}C-quinclorac in corn seedlings.

Tip	Rinse	Treated Area	Below Treated Area	Older Leaves	New Leaves	Roots
(DPM g^{-1})						
30	156689	3736	138	605	255	614
10	143369	2322	1187	584	200	479
16	149574	695	224	139	120	296
3	152046	2128	65	86	20	657
(average DPM g^{-1})						
15	150420	2220	403	354	149	512
(standard deviation)						
11	5549	1244	526	279	102	162

Recovery 99.3%

Table 13. Distribution of foliar applied ^{14}C-quinclorac in barnyardgrass seedlings.

Tip of Treated Leaves	Treated Area	Rinse	Below Treated Area	Older Leaves	Newer Leaves	Roots
(DPM g^{-1})						
17	3084	162724	68	22	219	25
16	38307	31569	118	12	641	178
8	5728	142610	90	9	195	46
21	2400	143491	151	13	342	22
(average DPM g^{-1})						
16	3,762	120099	107	14	349	68
(standard deviation)						
5	1436	59745	36	6	204	74

Recovery 100.7%

Table 14. Distribution of soil applied ^{14}C-quinclorac in morningglory.

Below seed applications root	Below seed applications shoot	Above seed applications root	Above seed applications shoot
(DPM g^{-1})			
18005	264	1187	7821
5372	23	1623	16829
8070	89	1039	24730
(average DPM g^{-1})			
10482	125	1283	16460
(standard deviation)			
6653	125	304	8461

Recovery: Below seed 1.2% Above seed 2.0%

Table 15. Distribution ^{14}C-quinclorac in soybeans when applied below seed.

	Root	Shoot	Seed Cotyledons
		(DPM g^{-1})	
1	59629	178	--[1]
2	1972	2903	80
3	49773	3580	72
4	4804	3267	--
5[2]			
6	54074	7596	165
		(average DPM g^{-1})	
	28795	3505	106
		(standard deviation)	
	29692	2657	52

Recovery 4.9%

1. The cotyledons of a number of seedlings were damaged or broken free of the seedling during emergence.

2. The fifth seedling failed to emerge.

Table 16. Distribution below seed applications of ^{14}C-quinclorac in corn seedlings.

Root	Shoot	Seed Cotyledons
	(DPM g^{-1})	
28170	6136	1453
13979	247	190
7286	318	79
31894	3182	981
59059	5320	867
19159	337	265
	(average DPM g^{-1})	
26591	2590	639
	(standard deviation)	
18285	2687	545

Recovery 3.4%

Table 17. Distribution of ^{14}C-quinclorac in corn seedlings when soil applied above the seed.

Root	Shoot	Seed Cotyledons
	(DPM/g)	
423	10392	32
382	11165	65
420	19737	75
222	9749	101
646	6897	59
749	32244	97
	(average DPM g^{-1})	
474	15031	72
	(standard deviation)	
191	9476	26

Recovery 1.8%

Table 18. Barnyardgrass ^{14}C-quinclorac placed below the seed.

Sample	Root tissue	Shoot tissue
	(DPM g^{-1})	
1	166	425
2	120	788
3	260	212
4	81	162
5	141	695
6	287	475
	(average DPM g^{-1})	
	176	460
	(standard deviation)	
	81	250

Recovery 0.5%

LITERATURE CITED

1. BAS 514..H Technical Data Sheet. 1985. BASF Wyandotte Corporation, Agricultural Chemicals Division, Parsippany, NJ.

2. Cardarelli, N.F. 1980. Controlled Release Products. Pages 58 - 71 in **Controlled Release Technologies**. CRC Press, Inc., Boca Raton, FL.

3. Cardarelli, Nate. 1976. **Controlled Release Pesticides Formulations.**. CRC Press, Inc., Cleveland, OH.

4. Cardarelli, Nate F., and William Evans. 1980. Chemodynamics and Environmental Toxicology of Controlled Release Organotin Molluscicides. Pages 357 - 386 in **Controlled Release of Bioactive Materials**. Academic Press, New York, NY.

5. Coffman, C.B., and W.A. Gentner. 1980. Persistence of Several Controlled Release Formulations of Trifluralin in Greenhouse and Field. Weed Sci. 28:21 - 23.

6. Cross, B., and Scher, H. B. 1988. Pesticide Toxicity Reduction Through Formulation. Pages 112 - 141. in **PESTICIDE, FORMULATIONS INNOVATIONS AND DEVELOPMENTS**. by American Chemical Society. Washington, D. C.

7. Daterman, Gary E., Charles Sartwell and Lonne L. Sower. 1980. Prospects for Controlling Forest Lepidoptera with Controlled Release Pheromone Formulations. Pages 213 - 226 in **Controlled Release of Bioactive Materials**. Academic Press, New York, NY.

8. Dellicolli, H.T. 1977. Controlled Release of Pesticides from Kraft Lignin Carriers. Pages 84 - 93 in **Controlled Release Pesticides**. ACS, Washington, DC.

9. **ELEMENTS OF CHEMICAL EXPOSURE ASSESSMENT**. 1991. Environ International Corporation. Arlington, Virginia ***EPA'S PESICIDE PROGRAMS***. 1991. EPA Pesticides and Toxic Substances (H-7506-C) 21T-1005. Washington, D.C.

10. Gebelein, Charles G. 1985. Bioactive Polymeric Systems, An Overview. Pages 1 - 29 in **Bioactive Polymeric Systems, An Overview**. Plenum Press, New York, NY.

11. Good, Mary L., Dee S. Dundee and Gary Swindler. 1980. Bioassays and Environmental Effects of Organotin Marine Antifoulants. Pages 387 - 398 in **Controlled Release of Bioactive Materials**. Academic Press, New York, NY.

12. Hatcher, Patrick G., Morris Schnitzer, Larry W. Dennis and Gary E. Maciel. 1981. Aromaticity of Humic Substances in Soils. Soil Sci. Soc. Am. J. 45:1089 - 1094.

13. Herbst, Kathleen A., and Jeffery F. Derr. 1990. Effect of Oxyfluorfen, Pyridate, and BAS 514 Applied Postemergence on Direct - Seeded Broccoli (*Brassica oleracea var. botrytis*). Weed Technology. 4:71 - 75.

14. Herbst, Kathleen A., and Jeffery F. Derr. 1990. Direct - Seeded Broccoli (*Brassica oleracea var. botrytis*) Response to Oxyfluorfen and BAS 514 Applied Preemergence. Weed Technology. 4:356 - 359.

15. Manthey, Frank A., John D. Nalewaja and Edward F. Szeleziak. 1990. Small Grain and Grass Weed Response to BAS-514 with Adjuvants. Weed Technology. 4:366 - 370.

16. McCormick, C.L. and M.M. Fooladi. 1980. Controlled Activity Polymers with Labile Bonds to Pendent Metribuzin. Pages 317 - 330 in **Controlled Release of Bioactive Materials**. Academic Press, New York, NY.

17. Ross, M. A., and Lemki, C. A. 1985. **APPLIED WEED SCIENCE**. pp. 107-141. Burgess Publishing Company.________________.

18. Vander Meer, Robert K., Clifford S. Lofgren, Danny H. Lewis and William E. Meyers. 1980. Controlled Release Formulations and Control of the Imported Fire Ant: What are the Possibilities. Pages 251 - 266 in **Controlled Release of Bioactive Materials**. Academic Press, New York, NY.

19. Voris, P. Van, D. A. Cataldo, C. E. Cowan, N. R. Gordon, J. F. Cline, F. G. Burton, and W. E. Skeins. 1988. Long-Term Controlled Release of Herbicides: Root Growth Inhibition. Pages 222 - 240. in **PESTICIDE FORMULATIONS INNOVATIONS AND DEVELOPMENTS**. American Chemical Society, Washington, D.C.

20. Wilson, Henry P., Thomas E. Hines, Kriton K. Hatzios and J. Peyton Doub. 1988. Efficacy Comparisons of Alachlor and Metolachlor Formulations in the Field. Weed Technology. 2:24 - 27. Zimdahl, R.L., and S.M. Gwynn. 1977. Soil Degradation of Three Dinitroanilines. Weed Sci. 25:247 - 251.