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GRASS CONTROL IN SOYBEANS [*GLYCINE MAX* (L.) Merr.] WITH SELECTIVE POSTEMERGENCE HERBICIDES

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William Meggitt
Major professor

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GRASS CONTROL IN SOYBEANS [GLYCINE MAX (L.) Merr.] WITH SELECTIVE POSTEMERGENCE HERBICIDES

By

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ABSTRACT

GRASS CONTROL IN SOYBEANS [*GLYCINE MAX* (L.) Merr.]
WITH SELECTIVE POSTEMERGENCE HERBICIDES

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Several selective postemergence herbicides provided excellent midseason quackgrass [*Agropyron repens* (L.) Beauv.] control and regrowth control 10 months after treatment. Early treatments in one year provided less midseason control and regrowth control than late treatments with most of the herbicides tested. In another season, late treatments provided less control of quackgrass regrowth compared to early treatments. Sequential applications provided equivalent or greater quackgrass control than single applications of the same total rate. Several antagonistic interactions resulted from herbicide applications in combination with acifluorfen {sodium 5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoate} or bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide]. Excellent postemergence annual grass control with flexibility in time of application was observed with each experimental herbicide evaluated. Soybean [*Glycine max* (L.) Merr.] injury was significantly greater for each treatment where acifluorfen was included in the spray mixture; however, this injury did not significantly reduce yield. Herbicidal activity and persistence from soil treatments with fluazifop-butyl {(±)-butyl 2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate} was observed.

More rapid absorption of ^{14}C-fluazifop-butyl was observed in soybeans with 75% of the recovered ^{14}C absorbed 6 h after treatment compared to 36% in quackgrass. Translocation of the radiolabel 144 h after treatment was 16.5% and 14.1% in soybeans and quackgrass, respectively. Data indicate that differential absorption or translocation did not contribute to the selectivity of fluazifop-butyl. Quackgrass phytotoxicity from fluazifop-butyl was lower on plants at the five- to six-leaf stage compared to those at the two- to three-leaf stage. Significantly more ^{14}C was removed in leaf washes from the older plants 144 h after treatment. Herbicidal activity and foliar absorption of fluazifop-butyl was significantly greater at 30 C compared to 20 C. Plants exposed to full light translocated significantly more ^{14}C than plants maintained in the shade. Moisture stress significantly reduced quackgrass control with fluazifop-butyl; however, no significant differences in absorption or translocation were observed.

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INTRODUCTION

Soybeans [Glycine max (L.) Merr.] have become one of the major agronomic crops in the United States and elsewhere. Similar to other crops, adequate weed control is a prerequisite to production of maximum soybean yields. With the cost of production currently experienced by the producer, an effective and consistent program for weed control is essential to profitable production.

Several herbicides are available as soil treatments to control broadleaved weeds and annual grasses in soybeans. Acifluorfen {sodium 5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoate} and bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] are available for selective postemergence control of broadleaved weeds and diclofop-methyl {methyl 2-[4-(2',4'-dichlorophenoxy)phenoxy]propanoate} can provide selective postemergence grass control; however, this herbicide has very little activity on perennial grasses such as quackgrass [Agropyron repens (L.) Beauv.]. Several experimental herbicides have been shown to provide effective postemergence control of both annual and perennial grasses with little soybean injury. Postemergence applications of a grass control herbicide in combination with acifluorfen or bentazon is desirable since it would increase the weed spectrum controlled.

Fluazifop-butyl {(±)-butyl 2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy] propanoate} is one of a number of selective postemergence herbicides which have herbicidal activity on annual and perennial grasses in broadleaved crops. Little is known about absorption and translocation of this herbicide.

The objectives of this study were to: (a) evaluate the influence of factors including rate, time of application, sequential applications, and herbicide combinations on the efficacy and soybean tolerance of several selective post-emergence herbicides for quackgrass and annual grass control, (b) examine the soil herbicidal activity and persistence of fluazifop-butyl, (c) compare the absorption and translocation of ^{14}C-fluazifop-butyl in quackgrass and soybeans, (d) examine the influence of factors including plant growth stage, temperature, light, and moisture stress on absorption, translocation, and activity of fluazifop-butyl on quackgrass.

CHAPTER I

REVIEW OF LITERATURE

The past decade has seen the introduction and development of a new and important component to agronomic and horticultural production and research. Selective postemergence grass control in broadleaved crops represents a unique addition to the available methods for economic control of weeds. Several graminicides are presently being developed in the United States and other countries throughout the World. A broad understanding of these compounds is important for their effective use in the agricultural community.

GENERAL INFORMATION ON HERBICIDES

General information on the history, herbicidal activity, and physical properties of diclofop-methyl {methyl 2-[4-(2',4'-dichlorophenoxy)phenoxy] propanoate} (1,9), metriflufen {methyl 2-[4-(4'-trifluoromethyl phenoxy) phenoxy] propanoate} (9), mefluidide {N-[2,4-dimethyl-5-[[(trifluoromethyl)sulfonyl] amino] phenyl] acetamide} (57), sethoxydim {2-[1-(ethyloxyimino)butyl] -5-[2-(ethylthio) propyl] -3-hydroxy-2-cyclohenen-1-one} (4), difenopenten {ethyl 4-[4-[4-(trifluoromethyl)phenoxy] phenoxy] -2-pentenoate}

17,42), RO-13 8895 {acetone 0-[D-[2-[p-(α,α,α-trifluoro-p-tolyl)oxy] phenoxy]propionyl]oxime} (44), CGA-82725 {2-propynyl 2-[4-[(3,5-dichloro-2-pyrindinyl)oxy]phenoxy] propanoate} (19), NCI-96683 (Nissan Chemical Ind., LTD.) (63), NCI-96721 (Nissan Chemical Ind., LTD.) (63), Fluazifop-butyl {(±)-butyl 2-[4-[[5-(trifluoromethyl)-2-pyridinyl oxy]phenoxy]propanoate} (47,68), and Dow 453 {methyl 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy propanoate} (28) are presented in Table 1. Chemical names and structures of herbicides whose chemistry has been released are given in Figure 1.

Each of the herbicides previously discussed has been reported to have significant activity on certain grassy weeds and to exhibit some level of tolerance to broadleaved crops such as soybeans [Glycine max (L). Merr.]. It is important that certain comparisons be discussed between the compounds.

For control of rhizome johnsongrass [Sorghum halepense (L.) Pers.], melfuidide has been found to be less effective than difenopenten (80,93,95,106), sethoxydim (45,77,80,93, 95,106) CGA-82725 (45), or RO-13 8895 (94). Sethoxydim has been reported to be more effective than difenopenten (40). RO-13 8895 and fluazifop-butyl have been shown to be more effective than sethoxydim (37). Mefluidide has also been shown to create significant soybean injury (35,77,110) even to the point of reducing soybean yield (36).

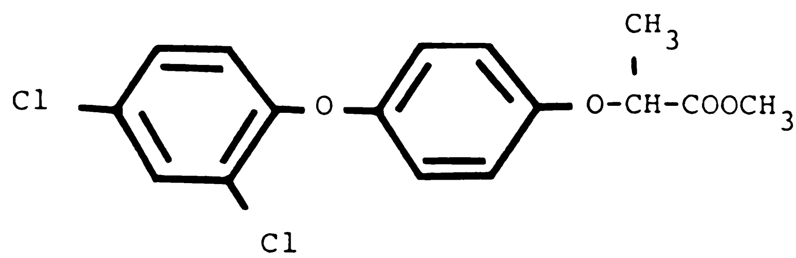
Table 1. General characteristics of selective postemergence grass for broadleaved crops.[a]

Herbicide	Originally Discovered	Development in the United States	Year Introduced	Experimental Designation	Trade Name	Physical State	Melting Point	Vapor Pressure	Solubility in H_2O	Grasses Controlled
Diclofop-methyl		Hoechst, A. G. Frankfurt, Germany	1973	HOE-23408	HOELON-USA HOE-GRASS-Canada	colorless, odorless	39-41C	(20C)-3×10^{-7} mm Hg	50 ppm	Annual
Metriflufen		Hoechst, A.G. Frankfurt, Germany (discontinued in 1978)	1976	HOE-29152				(43C)-9.7×10^{-5} torr	1.4 ppm	Annual Perennial
Difenopenten	Kumiai Chemical Industries, LTD, Japan	Chevron Chem. Co., Richmond, CA (discontinued in 1981)	1978	KK-80		viscous liquid		(20C)-3.33×10^{-9} mm Hg	(25C)-<1 ppm	Annual Perennial
Sethoxydim	Nippon Soda Co., LTD, Japan	BASF Wyandotte Corp. Passippany, NJ	1978	BAS-9052	POAST	amber, odorless		(25C)-1×10^{-7} mm Hg	(25C)-48 ppm	Annual Perennial
RO-138895		Maag Agrochemicals Research and Development HLR Sciences, Inc. Vero Beach, FL (discontinued in 1982)	1980	RO-138895		colorless, odorless			very slightly soluble	Annual Perennial
CGA-82725		Ciba-Geigy LTD. Basle, Switzerland	1980	CGA-82725					(20C)-3 ppm	Annual Seedling
NCI-96683	Nissan Chemical Industries, LTD, Tokyo, Japan	Nissan Chemical Industries, LTD, Tokyo, Japan	1980	NCI-96683		white crystalline solid	84-85C		(20C)-insoluble	Annual Perennial
NCI-96721	Nissan Chemical Industries, LTD, Tokyo, Japan	Nissan Chemical Industries, LTD, Tokyo, Japan	1980	NCI-96721		white crystalline solid	78-79C		(20C)-insoluble	Annual Perennial
Fluazifop-butyl	Ishihara Sangyo Kaisha LTD, Japan	Imperial Chemical Industries, LTD, London, England	1980	PP009-United States TF-1169-Canada	FUSILADE	light straw colored, odorless liquid	5C	(20C)-5.5×10^{-5} pa.	2 ppm	Annual Perennial
Dowco 453		Dow Chemical Co. Midland, MI	1981	Dowco 453		light amber liquid		(25C)-3.87×10^{-7} mm Hg	1.5 ppm	Annual Perennial
Melfuidide		3M Company Minneapolis, MN		MBR-12325	EMBARK VISTAR	white crystalline solid	183-185C		180 ppm	Annual Perennial

[a]Information not included in the table was not available.

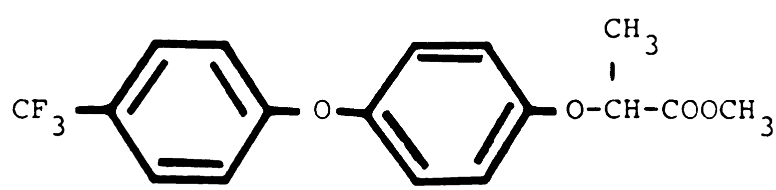
Figure 1. Molecular structure of several selective postemergence grass herbicides in soybeans.

Diclofop-methyl (HOE-23408)



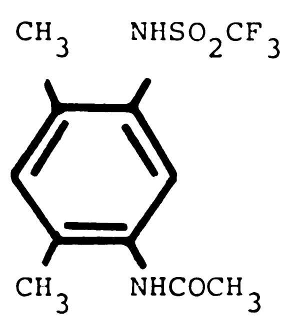
methyl 2- [4-(2',4'-dichlorophenoxy)phenoxy]propanoate

Metriflufen (HOE-29152)



methyl 2-[4-(4'-trifluoromethyl phenoxy)phenoxy] propanoate

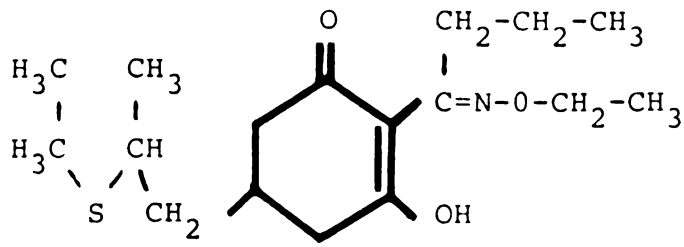
Mefluidide (MBR-12325)



N-[2,4-dimethyl-5-[[(trifluoromethyl)sulfonyl]amino] phenyl]acetamide

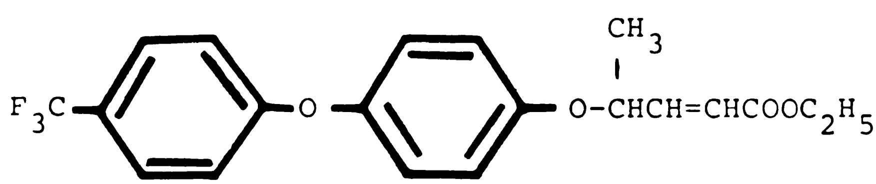
Figure 1. Continued

Sethoxydim (BAS-9052)



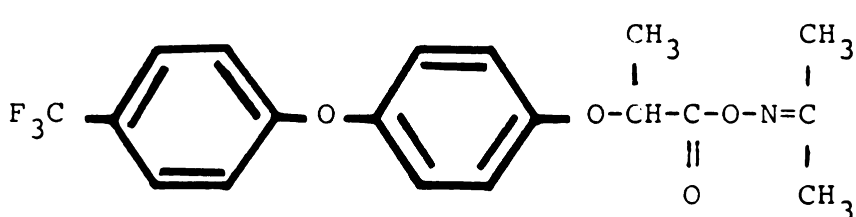
2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one

Difenopenten (KK-80)



ethyl 4-[4-[4-(trifluoromethyl)phenoxy]phenoxy]-2-pentenoate

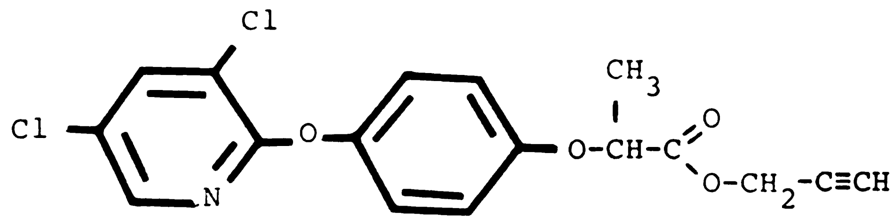
RO-13 8895



acetone O-[D-[2-[p-(α,α,α-trifluoro-p-tolyl)oxy]phenoxy]propionyl]oxime

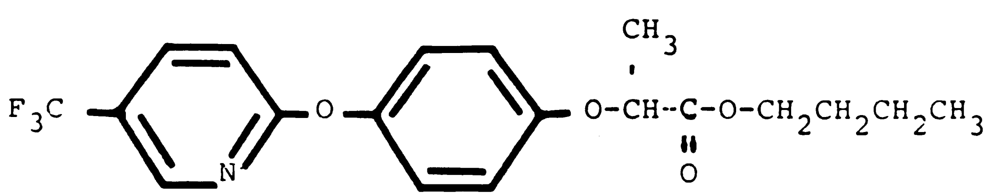
Figure 1. Continued

CGA-82725



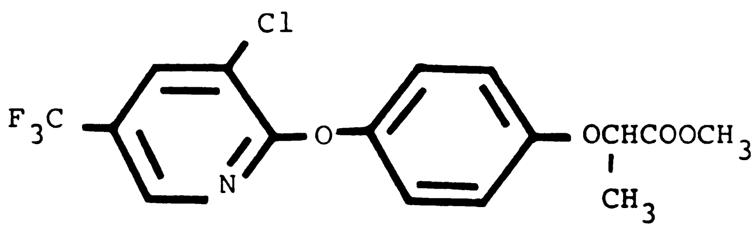
2-propynyl 2-[4-[(3,5-dichloro-2-pyridinyl)oxy]
phenoxy]propanoate

Fluazifop-butyl (PP009)



(±)-butyl 2-[4-[[5-trifluoromethyl)-2-pyridinyl]oxy]
phenoxy]propanoate

Dowco 453



methyl 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]
oxy]phenoxy]propanoate

For control of quackgrass [Agropyron repens (L.) Beauv.], Wyse (86) reported only limited control with mefluidide compared to metriflufen. Waldecker and Wyse (99) reported midseason quackgrass control to be significantly greater from RO-13 8895 than from difenopenten or sethoxydim. Westra and Wyse (102) reported greater control from sethoxydim than from difenopenten. Similar results were found for bermudagrass [Cynodon dactylon (L.) Pers.] control (104). In another study comparing sethoxydim, NCI-96683, fluazifop-butyl, RO-13 8895, and Dowco 453, Dekker (22) found fluazifop-butyl, NCI-96683, and Dowco 453 to be the most effective for control of quackgrass.

For control of annual grasses, Gealy and Slife (33), using yellow foxtail [Setaria lutescens (Weigel) Hubb] as the test species, found difenopenten to be more effective than diclofop-methyl. In a later study, Oliver et al. (65) compared several experimental herbicides for control of a number of annual grass species including barnyardgrass [Echinochloa crus-galli (L.) Beauv.]. They found that regardless of grass species or rate, the order of phytotoxicity was Dowco 453, RO-13 8895, sethoxydim, fluazifop-butyl, and difenopenten.

Although the results presented here are only a representative fraction of the data reported and differences exist in the comparisons, it does serve as an overview of these herbicides.

TIME OF APPLICATION

It is generally accepted that control of annual grasses with diclofop-methyl decreases when the herbicide is applied at later growth stages (32,91,101,109). Rogers et al. (73) found that many grass species were not susceptible to metriflufen at the three-leaf stage with susceptibility decreasing as plants developed. Many annual grass species have been found to become more tolerant to difenopenten as they advanced into tillering (42). Similar results were reported for sethoxydim (40). Hill and Peek (41) reported that plant growth stage is not an important factor in obtaining annual grass control with CGA-82725. In a study on large crabgrass [Digitaria sanguinalis (L.) Scop.] control, Himmelstein and Peters (43) found that RO-13 8895 and CGA-82725 were effective at all stages of application. Drew (30) reported that higher rates of fluazifop-butyl were required to control advanced growth stages of a number of annual grasses. In a study reported by Oliver et al. (65), several annual grass species including barnyardgrass, broad signalgrass [Brachiaria platyphylla (Griseb) Nash], giant foxtail [Setaria faberi (Herrm.)], goosegrass [Eleusine indica (L.) Gaertn.], grain sorghum [Sorghum bicolor (L.)], fall panicum [Panicum dichotomiflorum (Michx)], large crab-grass, and red rice [Oryza sativa (L.)] were treated with difenopenten, sethoxydim, RO-13 8895, fluazifop-butyl and Dowco 453. At the two- to four-leaf stage all of the herbicides tested controlled all the grass species in the study. However, at the 5- to 15-leaf stage, none of the herbicides were effective on red rice, grain sorghum, giant foxtail or barnyardgrass.

Plant growth stage has been shown to be an important factor in the control of perennial grasses such as johnsongrass with selective postemergence herbicides. Swisher and Kapusta (86) have reported greater johnsongrass control with metriflufen at the boot stage than with earlier applications. Similar results were reported by Down and Rieck (29). Rogers (76) reported a decrease in johnsongrass control with metriflufen when plants were past the boot stage at time of treatment. This suggests that a window of greatest control may exist where earlier or later treatments are less effective. Johnsongrass control with difenopenten has been reported to be reduced on 1- to 2-m tall plants compared to smaller plants (62). Early applications (15 to 20 cm) of sethoxydim, RO-13 8895, and fluazifop-butyl were shown to be more effective than late (45 to 70 cm) applications (37). Rogers et al. (76) suggested that johnsongrass control with later applications can be improved by increasing the rate of application.

Studies have been conducted on the influence of plant growth stage on quackgrass control. Majek and Duke (49) reported no difference in quackgrass control with metriflufen between plants in the three-leaf and six-leaf stage. However, metriflufen has been reported to give slightly greater quackgrass control when applied to plants 10- to 15-cm tall compared to 8- to 10-cm tall (24). Waldecker and Wyse (99) reported no difference in control between growth stages of quackgrass from 0.84 kg/ha rates of sethoxydim, difenopenten, or RO-13 8895. Dekker and Anderson (22), however, found that sethoxydim, NCI-96683, RO-13 8895, fluazifop-butyl, and Dowco 453 were more effective on quackgrass when applied at the four- to five-leaf stage compared to the three- to four-leaf stage. Plant growth stage has been reported to have little influence on grass control with Dowco 453 (84). It is apparent that other factors such as rate and environmental factors, etc. influence grass control at different plant growth stages and may account for some of the discrepancies reported in the literature.

Various studies have investigated sequential applications for more effective control of perennial grasses such as johnsongrass and quackgrass. Johnsongrass control with sequential applications was often greater than with single applications at the same rate for metriflufen (86), sethoxydim (51,77,93,94,96,97), difenopenten (87,93,94,95), RO-13 8895 (5,41,94), CGA-82725 (41), and fluazifop-butyl (21,68).

Sequential applications have been found to provide greater quackgrass control with sethoxydim (51,77,79,96,97, 102), difenopenten (102), RO-13 8895 (5), and fluazifop-butyl (21). However Bhowmik and Doll (7) reported that sequential applications gave no added quackgrass control with sethoxydim, difenopenten, or CGA-82725. This observation may be related to environmental conditions or the procedure followed in the study.

Cultivation as a substitute for the second herbicide application has been examined in several studies. Young and Wyse (112) found that a cultivation following treatment with metriflufen increased quackgrass control. Scoresby et al. (80) found that johnsongrass control was increased from a cultivation following a postemergence application of difenopenten but not sethoxydim. However, McAvoy (51) reported that a timely cultivation following sethoxydim may increase control of perennial grasses such as johnsongrass and quackgrass. Westra and Wyse (102) found that single applications of sethoxydim or difenopenten followed by a cultivation gave similar quackgrass control to sequential treatments and both were better than single treatments alone. Waldecker and Wyse (99) found that a cultivation after treatment aided in quackgrass control more with difenopenten and sethoxydim than with RO-13 8895. Significant increases in yield have also been reported from cultivations following treatments of sethoxydim, RO-13 8895, and CGA-82725 (7).

HERBICIDE INTERACTIONS

Effect on Herbicidal Activity. Considerable research has been conducted in the area of herbicide interaction between selective postemergence herbicides for broadleaved crops, much of it with diclofop-methyl. Reduced control of various annual grass species with diclofop-methyl was observed when the herbicide was combined in a tank mixture with bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] (6,15,72,107), desmedipham (ethyl m-hydroxy-carbanilate carbanilate) (26,59,202), MCPA (2-methyl-4-chlorophenoxyacetic acid) (59,69), 2,4-D [(2,4-dichlorophenoxy) acetic acid] (24,83,89,92) 2,4-DB [4-(2,4-dichlorophenoxy) butansic acid] (78), dinoseb [2-(1-methylpropyl)-4,6-dinitrophenol] (6) and nitrofen (2,4-dichlorophenyl p-nitrophenyl ether) (10). No reduction in giant foxtail control was observed by Ritter and Harris (72) with tank mixtures of diclofop-methyl and acifluorfen {sodium 5-[2-chloro-4-(trifluoromethyl)-phenoxy]-2-nitrobenzoate}. These results may be due to the reported phytotoxicity of acifluorfen itself on annual grasses such as giant foxtail (88). More difficult to explain, however, is the synergistic interaction between diclofop-methyl and bentazon on yellow foxtail reported by Shurtleff and Buchanan (83).

Herbicide interactions such as these reported on diclofop-methyl have also been studied with a number of more resent postemergence grass herbicides. Dortenzio and Norris (26) reported decreased barnyardgrass control with metriflufen when the herbicide was combined in a tank mixture with desmedipham. Antagonistic trends have also been observed with combinations of metriflufen with bentazon or acifluorfen for control of johnsongrass (29). However, no antagonism was observed between metriflufen and bentazon or acifluorfen for control of fall panicum. Shurtleff and

Buchanan (83) reported increased control of yellow foxtail, large crabgrass, wild oats [Avena fatua (L.)], and johnsongrass from combinations of metriflufen and dinoseb. This is in conflict with findings of Nalawaja et al. (61) who reported reduced grass control from combinations of metriflufen and dinoseb. Hartzler and Foy (38) reported a reduction in large crabgrass control when either bentazon or acifluorfen were combined with sethoxydim. Ritter and Harris (72) also reported on antagonism between sethoxydim and bentazon and between difenopenten and acifluorfen. In a study examining compatability of several postemergence broadleaf herbicides including bentazon and acifluorfen with several postemergence grass herbicides, Nalawaja et al. (60) found that combinations with any of the broadleaf herbicides decreased yellow foxtail control from difenopenten and CGA-82725. Yellow foxtail control from sethoxydim was reduced only when the herbicide was combined with bentazon or desmedipham. Smith (84) has reported that Dowco 453 is compatible with bentazon and acifluorfen. Although most interactions between postemergence herbicides have been antagonistic, one synergistic interaction has been well documented. Reports indicate that combinations of mefluidide and bentazon are more effective for control of red rice than either compound used alone (103).

It is apparent from examining antagonistic herbicide interactions that the rate of the grass herbicide is an important function in the intensity of any interaction.

Hartzler and Foy (38) indicated that antagonism between sethoxydim and bentazon or acifluorfen was lessened by increasing the rate of sethoxydim from 0.28 kg/ha to 0.56 kg/ha. In addition, Nalawaja et al. (60) suggested that antagonisms involving sethoxydim may have existed which were not detected due to the rate of sethoxydim used and the sensitivity of the grass being treated.

Basis for Antagonisms. Woletatios and Harvey (108) suggested that the antagonism between diclofop-methyl and bentazon may be explained by lower ^{14}C-diclofop-methyl uptake in leaves pretreated with a diclofop-methyl-bentazon mixture. Qureski and VanderBorn (69) reported that uptake of diclofop is reduced in the presence of MCPA. They also reported that MCPA inhibits deesterification of diclofop-methyl to the free acid diclofop, and accelerates the conversion of diclofop to inactive conjugates. In examining the antagonism between diclofop-methyl and 2,4-D, Todd and Stobbe (92) found translocation of ^{14}C to roots and shoot apices of wild oat to be reduced following application of 2,4-D. They suggested that deesterification of diclofop-methyl to the free acid diclofop was inhibited by 2,4-D. They suggested that diclofop-methyl moved acropetally in the apoplast and was responsible for leaf tissue damage while the free acid diclofop moved basipetally in the symplast and was responsible for inhibition of meristematic activity.

ENVIRONMENTAL EFFECTS ON HERBICIDE ACTIVITY

The major environmental factors which have been examined include temperature, relative humidity and soil moisture. Nalawaja et al. (59) reported that diclofop-methyl was more effective at 10C than at 30C for wild oat control, but was more effective at 30C than 20C for yellow foxtail control. McWhorter (52) reported no control of johnsongrass with metriflufen regardless of rate when plants were exposed to post treatment temperature of 16C. Much greater control was observed when the post treatment temperature was 24C or 32C. Young and Wyse (112) found phytotoxicity to quackgrass from 0.56 kg/ha or lower rates of melfuidide to be greater to plants with a post treatment temperature of 30C compared with 17C or 27C. Wills (104) reported a two-fold increase in difenopenten activity at 35C compared to 18C.

The effect of relative humidity in conjunction with temperature has been studied by McWhorter (52). He reported significantly greater johnsongrass control with metriflufen when the post treatment conditions were 24C and 100% relative humidity compared to 40% relative humidity. Wills (104) found sethoxydim to be most toxic on bermudagrass when the post treatment environment was 18C and 100% relative humidity and reported that difenopenten activity was often greater at 100% relative humidity than at 40% relative humidity.

In examining the effect of moisture stress on grass control Nalawaja et al. (59) reported that in general, grass plants under moisture stress after application were more tolerant to diclofop-methyl. West et al. (101) reported reduced control of moisture stressed barnyardgrass with diclofop-methyl, especially under cool, slow growing conditions. On several species of annual grasses including yellow foxtail and barnyardgrass, Dortenzio and Norris (27) found a significant reduction in control with diclofop-methyl or metriflufen under a low moisture environment (2 to 3% above permanent wilt point). Norris (64) also found that the reduction in diclofop-methyl activity from moisture stress on wild oat was much less under 85 to 89% relative humidity compared to 30 to 35% relative humidity. Dry conditions have been reported to lengthen the time for symptoms to appear on perennial grasses from sethoxydim; however, the end result is the same (51). Ready and Wilkerson (71) reported that both initial control and regrowth control of johnsongrass with fluazifop-butyl was greater with plants grown under adequate moisture. The reduced control of plants under moisture stress may be related to the more developed leaf cuticle that would be expected under those conditions.

The effect of rhizome fragmentation on perennial grass control with fluazifop-butyl has been examined by Plowman et al. (68). They reported excellent control of quackgrass and johnsongrass with fluazifop-butyl in a cultivated area where fragmentation of rhizomes had occurred. Also, the authors indicated that higher rates were required to control johnsongrass when rhizomes remained unfragmented. Colby et al. (21) stated that for effective control of johnsongrass, bermudagrass and quackgrass with 0.28 kg/ha to 0.56 kg/ha of fluazifop-butyl, thorough fragmentation of the rhizomes by tillage was necessary, and higher rates were required for undisturbed perennials. However, Wagner and Letendre (98) reported that additional fragmentation of quackgrass rhizomes by discing or rototilling did not increase control with fluazifop-butyl in field tests plowed the preceding fall. This observation may be confounded with one or more other important factors previously discussed.

ADJUVANTS

Increased activity from adjuvants have been reported for diclofop-methyl (59,66), metriflufen (52,61), sethoxydim (51,67,95,96,102), difenopenten (60,102), RO-13 8895 (3), CGA-82725 (7,19), fluazifop-butyl (20) and Dowco 453 (84). Most studies indicate that crop oils or crop oil concentrates give the best results. However, Michieka and Ilnicki (56) found that fall panicum control with metriflufen was greater with a non-ionic surfactant than with crop oils.

It is apparent that many factors such as rate and environmental conditions influence the need for an adjuvant. Umeda and Kapusta (95) reported that crop oil concentrate enhanced johnsongrass control with sethoxydim only at rates less than 0.56 kg/ha or when applied to more mature (76 cm) plants. McAvoy (51) suggested that the addition of crop oil concentrate to sethoxydim would compensate for approximately 0.28 kg/ha of the herbicide. Similar results were reported by Veenstra et al. (96). Addition of surfactants to metriflufen increased johnsongrass phytotoxicity only under low (40%) relative humidity (52). It appears that adjuvants increase herbicidal activity by increasing the penetration of the herbicides into the leaves. Oil concentrates may also increase activity by solubilizing a portion of the leaf cuticle to aid in penetration. This may be particularly important under dry conditions or with more mature plants where a more impermeable cuticle is expected.

ABSORPTION AND TRANSLOCATION

Absorption and translocation of diclofop-methyl in several species including barnyardgrass and soybeans have been reported by Boldt and Putnam (11). No difference in absorption or translocation was observed between the two species. Translocation was limited to less than 2% with 98% of the applied ^{14}C remaining in the treated leaf. Campbell and Penner (16) reported that sethoxydim was rapidly absorbed and translocated to all plant parts of both johnsongrass and soybeans. Unlike diclofop-methyl or sethoxydim, ^{14}C-mefluidide absorption and translocation has been reported to be greater in giant foxtail than in soybeans initially after treatment; however, this trend reversed after the first 24 h (8).

The length of the absorption period is an important factor to be considered. Absorption of ^{14}C-diclofop-methyl was reported to continue over a 192 h period in green foxtail [*Setaria viridis* (L.) Beauv.], wild oat, wheat [*Triticum aestivum* (L.)] and barley [*Hordeum vulgare* (L.)] (91); however, ^{14}C uptake ended within 48 h after treatment in soybeans (108). Campbell and Penner (16) found that the duration of absorption of ^{14}C-sethoxydim in quackgrass was 12 h or less with 90% of the applied ^{14}C absorbed. The site of greatest absorption has also been examined. Young and Wyse (111) reported that both penetration and toxicity of diclofop-methyl was greater as the chemical was applied closer to the base of wild oat. Similar results were reported by Walter et al. (100). Wills and McWhorter (105) reported three to four times more distribution of ^{14}C when ^{14}C-mefluidide was applied to the stems compared to the leaves.

Limited translocation of diclofop-methyl in both the symplast and the apoplast have been reported (82). Mefluidide translocation has been reported to be primarily in the phloem with movement to areas of high metabolic activity in giant foxtail and soybeans (8). However, McWhorter and Wills (55) reported movement of ^{14}C from ^{14}C-mefluidide to be primarily acropetal in johnsongrass, soybean, and common cocklebur [*Xanthium pensylvanicum* (Wallr.)]. Both acropetal and basipetal movement of metriflufen were reported in johnsongrass (53). Rapid translocation of ^{14}C from ^{14}C-sethoxydim in the phloem with accumulation in the metabolic sinks of quackgrass has been reported (16). Fluazifop-butyl has been reported to be both xylem and phloem mobile (68).

Environmental factors. McWhorter and Wills (55) reported that increasing post treatment temperature from 22C to 32C resulted in a two- to three-fold increase in absorption and an eight-fold increase in translocation of ^{14}C from ^{14}C-mefluidide in soybeans. An increase in relative humidity from 40% to 100% resulted in less than a two-fold increase in absorption or translocation. In johnsongrass, when no surfactant was used, an increase in temperature from 22C to 32C resulted in less than a two-fold increase in absorption and affected translocation only at 40% RH. The addition of adjuvants increased absorption and translocation of ^{14}C-mefluidide in johhsongrass, especially at lower relative humidity (55).

McWhorter (53) reported a two- to four-fold increase in translocation of ^{14}C-metriflufen when the post treatment temperature was 35C compared to 18C; however, translocation always represented less than 1% of the applied ^{14}C. Relative humidity had little effect on translocation of ^{14}C-metriflufen. Absorption was not greatly influenced by either temperature or relative humidity. Translocation of ^{14}C in soybeans also responded similarly to temperature and relative humidity. More ^{14}C was recovered from soybeans than from johnsongrass (53).

Dortenzio and Norris (27) reported that, although soil moisture stress did effect control of several grass species with diclofop-methyl, no significant differences in absorption or translocation could be detected. However, regrowth data indicate that more rapid translocation of fluazifop-butyl occurred on johnsongrass plants growing under adequate moisture compared to those growing under moisture stress (71).

PHYSIOLOGICAL EFFECTS

Little is known of the physiological effects of postemergence grass herbicides for broadleaved crops; however, some information has been reported on certain herbicides. Diclofop-methyl has been shown to interfere with both cell division and cell elongation (46). This herbicide has also been reported to disrupt membrane integrity and inhibit chlorophyll synthesis (3). In addition, it has been reported that diclofop-methyl acts as a strong auxin antagonist (81).

Studies indicate that metriflufen inhibits protein synthesis in corn [(*Zea mays* (L.)] and soybean tissue (14) and inhibits electron flow in isolated chloroplasts of corn and peas (13).

Johnsey and Harger (48) reported that following treatment with sethoxydim, johnsongrass plants initially stopped growing with the first symptoms of injury occurring in the meristem of treated plants. Sethoxydim has been shown to reduce photosynthesis and transpiration in corn (34);

however, this may be a secondary effect. In corn, inhibition of adventitious root initiation and growth, reduced elongation of root and shoot, and at low concentrations, inhibited chlorophyll synthesis have been reported (2). Hatzios (39) suggested that sethoxydim may act by modifying the lipid structure of plant membranes.

Fluazifop-butyl appears to adversely interfere with ATP production (68). The meristematic area within the susceptible plants are the first to show symptoms of injury. Plant growth typically ceases after treatment with fluazifop-butyl (68).

Mefluidide has been shown to act as a plant growth regulator in susceptible plants (54,57). Wilkinson (70) suggested that mefluidide may inhibit production of a precurser to gibberellin and thus suppress gibberellin biosynthesis.

MECHANISMS OF SELECTIVITY

In examining the mechansim of selectivity of diclofop-methyl, Todd and Stobbe (90) reported that the active form of the herbicide is the free acid diclofop. Shimabukuro et al. (82) reported that both wheat, a tolerant grass, and wild oat, a susceptible grass, converted diclofop-methyl to diclofop. In wheat, diclofop was irreversibly ring hydroxylated and finally conjugated. However, in wild oat, diclofop was conjugated to a neutral glycol ester which may hydrolyze to reform diclofop. Boldt and Putnam (12) compared metabolism of diclofop-methyl in barnyardgrass, a susceptible grass, wild proso millet [*Panicum milliaceum* (L.)], a moderately susceptible grass, longspine sandbur [*Cenchrus longispinus* (Hack.) Fern.], a tolerant grass, soybean and cucumber [*Cucumis sativus* (L.)], both tolerant broadleaved plants. Both tolerant and susceptible plants converted the herbicide to the free acid diclofop. Tolerant broadleaved plants ring hydroxylated diclofop followed by glucosidic conjugation. In susceptible grasses, diclofop was conjugated on the propionate side chain which was readily reversible. Reports indicate that retention, absorption, translocation or volatility are not selectivity mechanism of diclofop-methyl (11).

Swisher and Corbin (85) suggested that differences in tolerance to sethoxydim between soybeans and johnsongrass may be related to reduced ability of johnsongrass cells to degrade the herbicide. The selectivity of fluazifop-butyl between grass and broadleaved plants is thought to be due to a rapid degradation followed by conjugate formation in broadleaved plants (68). Bloomberg and Wax (8) suggested that selectivity of mefluidide may be partially explained by differential absorption and translocation in tolerant and susceptible plants.

SOIL ASPECTS

Significant soil activity has been reported with diclofop-methyl (18,59) metriflufen (73), CGA-82725 (41), RO-13 8895 (44), NCI-96683 (63), Dowco 453 (28) and fluazifop-butyl (47,68). In every case, soil activity is considerably less than foliar activity. However, it appears that the soil component may be an important consideration in the use of certain postemergence grass herbicides.

Several factors have been examined relating to soil considerations such as persistence and soil mobility. Norris (65) found with the use of vermiculite on the soil surface that soil activity from a postemergence application of diclofop did not contribute to wild oat control. However, Nalawaja et al. (59) reported a 6% reduction in wild oat control when vermiculite covered the soil at time of treatment. Diclofop-methyl has been shown to be absorped through both shoots and roots in barnyardgrass (101). Diclofop-methyl residual was reported three weeks after treatment (18), but not eight weeks after treatment (109). Data also indicate dissipation to be more rapid under warm soil conditions (50,109). Soil temperature appears to be more important than moisture. The mobility of diclofop-methyl has been reported to be comparable to trifluralin (109); however, Mulder and Nalawaja (58) reported more leachability of ^{14}C-diclofop than ^{14}C-trifluralin.

Rogers et al. (73) reported that 0.28 kg/ha of soil applied metriflufen provided 89% or greater control of a number of annual grasses including barnyardgrass and giant foxtail. A rate of 0.84 kg/ha provided 95% or greater control of johnsongrass. Metriflufen has been shown to provide similar control as trifluralin at the same rates on annual grasses (76). Dekker et al. (23) reported reduction in control from both root and shoot uptake in barnyardgrass and yellow foxtail. More rapid decrease in activity was observed under soil moisture of 15% compared to 5% or 25% (75). The rate of degradation increased as temperature increased from 15C to 25C. Rogers and Talbert (74) found that herbicidal activity from 1.1 kg/ha of metriflufen persisted for 40 and 63 days in 1977 and 1978 respectively and suggested that the loss of activity was due primarily to microbial degradation. Mobility of metriflufen in soil was also reported (74). Within a column of silt loam soil, metriflufen moved 7.5 cm and 18.5 cm from 7.5 cm and 10.0 cm of water respectively.

Sethoxydim has been found to provide very little herbicidal activity at postemergence use rates when applied to the soil (4,43,67). The soil persistence of sethoxydim is very short (4). NCI-96683 has been reported to have considerable soil activity but is very immobile in the soil and incorporation is necessary for good soil activity (63). Dowco 453 has good soil activity with sufficient soil persistence but requires two to four times higher rates than postemergence applications (28). Soil activity from CGA-82725 has been reported to be of little significance (19). Fluazifop-butyl has considerable soil herbicidal activity on annual grasses and will persist for several weeks from recommended rates (47). Useful soil activity can be obtained from rates of 0.56 kg/ha or higher (20). Results indicate an important soil component of activity with fluazifop-butyl (68). The soil component of herbicidal activity appears to be adequate with certain herbicides to justify further examination.

LITERATURE CITED

1. American Hoechst Corp. 1976. HOE-23408, technical information bulletin. American Hoechst Corp., Agric. Chem. Dept. Somerville, N.J. pp. 7.

2. Asare-Boaneah, N. K. and R. A. Fletcher. 1982. Phytotoxicity of sethoxydim on corn seedlings. Abstr. Weed Sci. Soc. Am., p. 90.

3. Bagley, R. W., G. L. Genson, A. R. DeMur and H. D. Woofter 1980. RO-13-8895, a selective postemergence herbicide for grass control. Proc. North Central Weed Control Conf. 35:45.

4. BASF Wyandotte Corp. 1980. Poast, technical information bulletin. BASF Wyandotte Corp., Agricultural Chemicals Division. Parsippany, N.J. pp. 4.

5. Benson, G. L., R. W. Bagley and A. R. DeMur. 1981. RO-13-8895, a selective postemergence herbicide for grass control. Proc. Northeast Weed Sci. Soc. 35:80.

6. Betts, M. F. and I. N. Morrison. 1978. Antagonism of diclofop activity by sequential treatments of bentazon or dinoseb applied to fababeans. Proc. North Central Weed Control Conf. 33:72.

7. Bhowmik, P. C. and J. D. Doll. 1980. Postemergence quackgrass control in soybeans. Proc. North Central Weed Control Conf. 35:45-46.

8. Bloomberg, J. R. and L. M. Wax. 1978. Absorption and translocation of mefluidide by soybean (Glycine max), common cocklebur (Xanthium pensylvanicum), and giant foxtail (Setaria faberi). Weed Sci. 26:434-440.

9. Boldt, P. F. 1979. Fate and selectivity of phenoxyphenoxy herbicides in plants. Ph.D. Thesis, Michigan State University, 82 pp.

10. Boldt, P. F. and A. R. Putnam. 1976. Onion and weed response to several newer herbicides. Proc. North Central Weed Control Conf. 31:107.

11. Boldt, P. F. and A. R. Putnam. 1980. Selectivity mechanisms for foliar application of diclofop-methyl. I. Retention, absorption, translocation and volatility. Weed Sci. 28:474-477.

12. Boldt, P. F. and A. R. Putnam. 1981. Selectivity mechanism for foliar applications of diclofop-methyl. II. Metabolism. Weed Sci. 29:237-241.

13. Bugg, M. W., W. S. Cohen and C. E. Rieck. 1978. Inhibition of chloroplast electron flow by HOE-29152. Proc. North Central Weed Control Conf. 33:51.

14. Bugg, M. W., W. S. Cohen and C. E. Rieck. 1979. Inhibition of protein synthesis by HOE-29152. Proc. South. Weed Sci. Soc. 32:325.

15. Campbell, J. R. and D. Penner. 1980. Factors affecting the activity of bentazon with diclofop and BAS 9052 [2-(N-ethoxybutrimidoyl)-5-(2-ethylthiopropyl)-3-hydroxy-2-cyclohexen-1-one]. Abstr. Weed Sci. Soc. Am., p. 13.

16. Campbell, J. R. and D. Penner. 1981. Absorption and translocation of BAS 9052 OH (2-[1-ethoxyimino)-butyl]-5-[2-ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one). Abstr. Weed Sci. Soc. Am., p. 108.

17. Chevron Chemical Co. 1979. KK-80, technical information bulletin. Chevron Chemical Co. Richmond, CA. pp. 4.

18. Chow, P. N. D. 1978. Selectivity and site of action in relation to field performance to diclofop. Weed Sci. 26:352-358.

19. Ciba-Geigy Corp. 1980. CGA-82725, technical information bulletin. Ciba-Geigy, Agricultural Division. Greensboro, NC. pp. 5.

20. Colby, S. R., J. R. Bone and A. A. Akhavein. 1982. PP009, a selective herbicide for control of perennial and annual grasses. Abstr. Weed Sci. Soc. Am., p. 14-15.

21. Colby, S. R., J. T. Daniel and D. A. Thomas. 1982. Postemergence control of perennial grasses with sequential and single applications of PP009. Abstr. Weed Sci. Soc. Am., p. 16.

22. Dekker, J. H. and G. W. Anderson. 1982. Efficacy of several new postemergence grass herbicides. Abstr. Weed Sci. Soc. Am., p. 128.

23. Dekker, J. H., W. F. Meggitt and P. F. Boldt. 1981. Soil herbicidal activity from HOE-29152 and diclofop applied postemergence. Weed Sci. 29:314-316.

24. Dekker. J. H., W. F. Meggitt, P. F. Boldt and T. Malefyt. 1978. Soil herbicidal activity from postemergence applications of HOE-29152 and diclofop. Proc. North Central Weed Control Conf. 33:115.

25. Doll, J. D. and D. C. Drost. 1977. New herbicides for quackgrass control in soybeans. Proc. North Central Weed Control Conf. 32:52.

26. Dortenzio, W. A. and R. F. Norris. 1979. Antagonistic effects of desmedipham on diclofop activity. Weed Sci. 27:539-544.

27. Dortenzio, W. A. and R. F. Norris. 1980. The influence of soil moisture on the foliar activity of diclofop. Weed Sci. 28:534-539.

28. Dow Chemical Co. 1982. Dowco 453 ME, technical information bulletin. Dow Chemical Co., Midland, MI pp. 4.

29. Downs, J. P. and C. E. Rieck. 1978. The evaluation of HOE 29152 for selective johnsongrass control. Proc. South. Weed Sci. Soc. 31:53

30. Drew, B. M. 1982. Postemergence fluazifop-butyl for control of grasses in oilseeds and grain legumes. Abstr. Weed Sci. Soc. Am., p. 113.

31. Fletcher, R. A. and D. M. Drexler. 1980. Interactions of diclofop-methyl and 2,4-D in cultivated oats (Avena sativa). Weed Sci. 28:363-366.

32. Friesen, H. A., P. A. O'Sullivan and W. H. VandenBorn. 1976. HOE-23408, a new selective herbicide for wild oats and green foxtail in wheat and barley. Can. J. Plant Sci. 56:567-578.

33. Gealy, D. R. and F. W. Slife. 1978. KK80-a post-emergence grass herbicide for soybeans. Proc. North Central Weed Control Conf. 33:46-47.

34. Gealy, D. R. and F. W. Slife. 1982. Effect of selective postemergence grass herbicides on intact leaf photo-synthesis and growth of corn and soybeans. Abstr. Weed Sci. Soc. Am., p. 88-89.

35. Glenn, S. and C. E. Rieck. 1977. Selective post-emergence johnsongrass herbicides for soybean production. Proc. North Central Weed Control Conf. 32:30.

36. Glenn, S. and C. E. Rieck. 1977. The activity of mefluidide on johnsongrass and shattercane. Proc. South. Weed Sci. Soc. 30:54.

37. Harger, T. R., R. W. Prince and P. R. Nester. 1982. Comparison of BAS-9052, PP009 and RO-13-8895 for postemergence control of grasses in soybeans. Abstr. Weed Sci. Soc. Am., p. 6-7.

38. Hartzler, R. G. and C. L. Foy. 1982. Evaluation of BAS 9052 OH alone and in combination with acifluorfen or bentazon for control of large crabgrass (*Digitaria sanguinalis* L.). Abstr. Weed Sci. Soc. Am., p. 5-6.

39. Hatzios, K. K. 1982. Studies on the mode of action of the herbicide BAS 9052 OH. Abstr. Weed Sci. Soc. Am., p. 117.

40. Helms, R. L., W. J. Blackmon and B. D. Reynolds. 1980. Comparisons of BAS 9052, KK-80 and MBR-18337 for the control of johnsongrass and annual grasses in cotton. Proc. South. Weed Sci. Soc. 33:55.

41. Hill, E. R. and J. W. Peek. 1982. CGA-82725--a new grass herbicide for broadleaved crops. Abstr. Weed Sci. Soc. Am., p. 16.

42. Hill, L. V. 1980. KK-80 a topical postemergence herbicide for use in cotton & soybeans. Proc. South. Weed Sci. Soc. 33:338.

43. Himmelstein, F. J. and R. A. Petters, 1982. Non-incorporated herbicides for large crabtrass [*Digitaria sanguinalis* (L.) Scop.]. Abstr. Weed Sci. Soc. Am., p. 21-22.

44. HLR Sciences,Inc. 1980. RO-13-8895, technical information bulletin. HLR Sciences Inc., Maag Agro-chemicals Research and Development. Vero Beach, Fla. pp. 4.

45. Hook, B. J. and S. Glenn. 1981. Selected herbicides for johnsongrass control in cropping systems. Proc. Northeast Weed Sci. Soc. 35:64.

46. Hoppe, H. H. 1980. Effect of diclofop-methyl on the growth and development of *Zea mays* L. seedlings. Weed Research. 20:371-376.

47. ICI Americas Inc. 1981. Fusilade, technical information bulletin. ICI Americas Inc., Agricultural Chemicals Division. Goldsboro, NC. pp. 41.

48. Johnsey, P. S. and T. R. Harger. 1982. Visible and microscopic effects of BAS 9052 on johnsongrass [*Sorghum halepense* (L.) Pers.] and itchgrass (*Rottboellia exaltata* L.F.). Abstr. Weed Sci. Soc. Am., p. 85-86.

49. Majek, B. A. and W. B. Duke. 1979. Influence of the time of application and plowing of quackgrass [Agropyron repens (L.) Beauv.] control with glyphosate and HOE 29152. Proc. Northeast Weed Control Conf. 33:43.

50. Martens, R. 1978. Degradation of the herbicide ^{14}C diclofop-methyl in soil under different conditions. Pestic. Sci. 9:127-134.

51. McAvoy, W. J., J. T. Thompson, W. G. Steinert, J. W. Daniel, J. F. Vesecky, L. W. Hendrick, M. A. Veenstra, W. J. Sciarappa, M. Schroeder and A. Tasker. 1980. Selective postemergence perennial grass control with BAS 9052 OH [2-(N-ethoxybutyrimidoyl)-5-(2-ethylthiopropyl)-3-hydroxy-2-cyclohexen-1-one] in broadleaf crops. Proc. North Central Weed Control Conf. 28:13.

52. McWhorter, C. G. 1979. The effect of surfactant and environment on the toxicity of metriflufen to soybeans (Glycine max) and johnsongrass (Sorghum halepense). Weed Sci. 27:675-679.

53. McWhorter, C. G. 1981. Effect of temperature and relative humidity on translocation of ^{14}C-metriflufen in johnsongrass (Sorghum halepense) and soybean (Glycine max). Weed Sci. 29:87-93.

54. McWhorter, C. G. and W. L. Barrentine. 1979. Weed control in soybeans (Glycine max) with mefluidide applied postemergence. Weed Sci. 27:42-47.

55. McWhorter, C. G. and G. D. Willis. 1978. Factors affecting the translocation of ^{14}C mefluidide in soybeans (Glycine max), common cocklebur (Xanthium pensylvanicum), and johnsongrass (Sorghum halepense). Weed Sci. 26:382-388.

56. Michieka, R. W. and R. D. Illnicki. 1979. Chemical control of fall panicum (Panicum dichotomiflorum Michx.) in soybeans [Glycine max (L.) Merr.] with acifluorfen, HOE-29152 [2,4-(4-trifluoremethyl-phenoxy) phenoxy propanoate] and bentazon in combinations with spray adjuvants. Abstr. Weed Sci. Soc. Am., p. 14.

57. 3M Co. 1980. MBR-12325, technical information bulletin. 3M Co., Agricultural Products, St. Paul, MN pp. 4.

58. Mulder, C. E. G. and J. D. Nalewaja. 1977. Influence of moisture on diclofop applied to the soil. Proc. North Central Weed Control Conf. 32:114.

59. Nalewaja, J. D. K., A. Adamczewski, L. Garcia-Torres, E. Pacholak and S. D. Miller. 1976. Factors affecting HOE-23408 phytotoxicity. Proc. North Central Weed Control Conf. 31:132-134.

60. Nalewaja, J. D., S. D. Miller and A. G. Dexter. 1980. Postemergence herbicide combinations for grass and broadleaf weed control. Proc. North Central Weed Control Conf. 35:43-44.

61. Nalewaja, J. D., E. Pacholak, L. Liu and S. D. Miller. 1976. BAS-9021 and HOE-29152 for grass weed control. Proc. North Central Weed Control Conf. 31:137-140.

62. Nester, P. R. and T. R. Harger. 1980. Postemergence activity of KK-80 on johnsongrass [<u>Sorghum halepense</u> (L.)] and itchgrass [<u>Rottboellia exaltata</u> (L.)] in soybeans. Abstr. Weed Sci. Soc. Am., p. 29.

63. Nissan Chemical Industries, Ltd. 1980. NCI-96683, NCI-96721, technical information bulletin. Nissan Chemical Industries, Ltd. Tokyo, Japan. pp. 2.

64. Norris, R. F. 1977. Influence of soil moisture on activity of diclofop-methyl. Abstr. Weed Sci. Soc. Am., p. 102-103.

65. Oliver, L. R., D. G. Mosier and O. W. Howe. 1982. A comparison of new postemergence herbicides for control of annual grasses. Abstr. Weed Sci. Soc. Am., p. 17.

66. O'Sullivan, P. A., H. A. Friesan and W. H. VandenBorn. 1977. Influence of herbicides for broadleaved weeds and adjuvants with dichlofop-methyl on wild oat control. Can. J. Plant Sci. 57:117-125.

67. Pearson, J. O. 1980. Postemergence graminicide for broadleaf crops. Abstr. Weed Sci. Soc. Am. p. 114.

68. Plowman, R. E., W. C. Stonebridge and J. N. Hawtree. 1980. Fluazifop-butyl--a new selective herbicide for the control of annual and perennial grass weeds. Proc. British Weed Control Conf. 17:29-37.

69. Qureshi, F. A. and W. H. VandenBorn. 1979. Interaction of diclofop-methyl and MCPA on wild oats (<u>Avena fatua</u>). Weed Sci. 27:202-205.

70. Rao, S. R. and T. R. Harger. 1981. Mefluidide-bentazon interactions on soybeans (<u>Glycine max</u>) and red rice (<u>Oryza sativa</u>). Weed Sci. 29:208-212.

71. Ready III, E. L. and J. Wilkerson. 1982. Postemergence control of rhizome johnsongrass [<u>Sorghum halepense</u> (L.) Pers.] with PP009 as effected by drought stress. Abstr. Weed Sci. Soc. Am., p. 15.

72. Ritter, R. L. and T. C. Harris. 1981. Interactions of postemergence soybean herbicides. Proc. Northeast. Weed Sci. Soc. 35:63.

73. Rogers, N. K., L. R. Oliver and R. E. Talbert. 1980. Response of selected grass weeds to metriflufen. Weed Sci. 28:540-542.

74. Rogers, N. K. and R. E. Talbert. 1981. Dissipation and leeching of metriflufen under field and controlled conditions. Weed Sci. 29:561-565.

75. Rogers, N. K., R. E. Talbert and L. R. Oliver. 1980. Conditions influencing the degradation of HOE-29152 [methyl 2-[4-(4-trifluoromethyl phenoxy)phenoxy] propanoate]. Abstr. Weed Sci. Soc. Am., p. 111.

76. Rogers, N. K., R. E. Talbert and L. R. Oliver. 1981. Johnsongrass (<u>Sorghum halepense</u>) control in soybeans (<u>Glycine max</u>) with metriflufen. Weed Sci. 29:291-296.

77. Rogers, S. A. and J. P. Worthington. 1979. Evaluation of BAS 9052 and 9021 for johnsongrass control in soybeans. Proc. North Central Weed Control Conf. 34:10.

78. Schreiber, M. M. and P. L. Orwick. 1977. Antagonistic action of 2,4-DB of diclofop-methyl. Abstr. Weed Sci. Soc. Am., p. 3.

79. Sciarappa, W. J., Jr. 1979. Postemergence grass control in soybeans with BAS 9052 OH. Proc. Northeast Weed Sci. Soc. 33:10.

80. Scoresby, J. R., L. E. Bendixen and G. L. Jordan. 1979. Control of johnsongrass using post applied experimental herbicides. Proc. North Central Weed Control Conf. 34:10.

81. Shimabukuro, M. A., R. H. Shimabukuro, W. S. Nord and R. A. Hoerauf. 1978. Physiological effects of methyl 2-4(2,4-dichlorophenoxy)phenoxy)propanoate on oat, wild oat and wheat. Pestic. Biochem. Physiol. 8:199-207.

82. Shimabukuro, R. H., W. C. Walsh and R. A. Hoerauf. 1979. Metabolism and selectivity of diclofop-methyl in wild oat and wheat. J. Agric. Food Chem. 27:615-623.

83. Shurtleff, J. L. and G. A. Buchanan. 1979. Diclofop and HOE-29152 interactions with five herbicides. Proc. South. Weed Sci. Soc. 23:65.

84. Smith, L. L. Jr., H. Johnston, B. C. Gerwick and E. A. Egli. 1982. Dowco 453--a new postemergence herbicide for selective annual and perennial grass control in broadleaved crops. Abstr. Weed Sci. Soc. Am., p. 107.

85. Swisher, B. and F. T. Corbin. 1982. The behavior of sethoxydim in soybeans and johnsongrass [Sorghum halepense (L.) Pers.]. Part II. Uptake and metabolism in cell cultures. Abstr. Weed Sci. Soc. Am., p. 93-94.

86. Swisher, B. A. and G. Kapusta. 1980. Selective postemergence johnsongrass (Sorghum halepense) control in soybeans (Glycine max). Weed Sci. 28:529-534.

87. Terhune, M. E. and R. E. Frans. 1980. Preliminary comparisons of KK-80 and BAS-9052 for overtop control of johnsongrass in cotton and soybeans. Proc. South. Weed Sci. Soc. 33:45.

88. Tillett, T. C. 1978. Postemergence control of Setaria faberi in soybeans with acifluorfen. Proc. North Central Weed Control Conf. 33:67.

89. Todd, B. G. and E. H. Stobbe. 1976. Basis of the antagonistic effect of 2,4-D on diclofop-methyl toxicity in wild oats. Proc. North Central Weed Control Conf. 31:40.

90. Todd, B. G. and E. H. Stobbe. 1976. Selectivity of diclofop-methyl among wheat, barley, wild oats and green foxtail. Proc. North Central Weed Control Conf. 31:140.

91. Todd, B. G. and E. H. Stobbe. 1977. Selectivity of diclofop-methyl among wheat, barley, wild oat (Avena fatua) and green foxtail (Setaria viridis). Weed Sci. 25:382-385.

92. Todd, B. G. and E. H. Stobbe. 1980. The basis of the antagonistic effect of 2,4-D on diclofop-methyl toxicity to wild oat (Avena fatua). Weed Sci. 28:371-377.

93. Umeda, K. and G. Kapusta. 1979. Mefluidide, BAS 9052 and KK-80 for selective postemergence johnsongrass control in soybeans. Proc. North Central Weed Control Conf. 34:10-11.

94. Umeda, K. and G. Kapusta. 1980. Selective rhizome johnsongrass control in soybeans with soil applied and postemergence herbicides. Proc. North Central Weed Control Conf. 35:21.

95. Umeda, K. and G. Kapusta. 1981. Postemergence rhizome johnsongrass [Sorghum halepense (L.) Pers.] control in soybeans with BAS-9052 [2-(N-ethoxybutrimidoyl)-5-(20 ethylthiopropyl)-3-hydroxy-2-cyclohexen-1-one], difenopenten and mefluidide. Abstr. Weed Sci. Soc. Am., p. 11.

96. Veenstra, M. A., J. F. Vesecky and L. W. Hendrick. 1978. BAS 9052 OH a new postemergence grass herbicide for soybeans. Proc. North Central Weed Control Conf. 33:69.

97. Vesecky, J. F., L. W. Hendrick, M. A. Veenstra and R. E. Ascheman. 1979. BAS 9052 OH for postemergence control of annual and perennial grasses in field crops. Proc. North Central Weed Control Conf. 34:34.

98. Wagner, V. and G. J. Letendre. 1982. Postemergence quackgrass [Agropyron repens (L.) Beauv.]control in broadleaf crops with TF1169 (butyl 2-[4-(5-trifluoromethyl-2-pyridyloxy)phenoxy]propionate) in eastern Canada. Abstr. Weed Sci. Soc. Am., p. 18.

99. Waldecker, M. A. and D. L. Wyse. 1980. Quackgrass control in soybeans. Proc. North Central Weed Control Conf. 35:10.

100. Walter, H., W. Koch and F. Muller. 1980. Effect of type of application on the penetration and translocation of diclofop-methy in wild oats (Avena fatua L.). Weed Research 20:325-331.

101. West, L. D., J. H. Dawson and A. P. Appleby. 1980. Factors influencing barnyardgrass (Echinocloa crus-galli) control with diclofop. Weed Sci. 28:366-371.

102. Westra, P. and D. L. Wyse. 1979. Quackgrass control in soybeans with BAS 9052 and KK-80. Proc. North Central Weed Control Conf. 34:34.

103. Wilkinson, R. E. 1982. Mefluidide inhibition of sorghum growth and gibberellin precursor biosynthesis. J. Plant Growth Regulation 1:85-94.

104. Wills, G. D. 1981. Effect of environment on the toxicity of BAS-9052 [2-(N-ethoxybutrimidoyl)-5-(2-ethylthiopropyl)-3-hydroxy-2-cyclohexen-1-one] and KK-80 [ethyl-4-[4-[4-(triflouromethyl)phenoxy]phenoxy]-2-pentenoate] to common bermudagrass (Cynodon dactylon L.). Abstr. Weed Sci. Soc. Am., p. 9.

105. Wills, G. D. and C. G. McWhorter. 1976. Translocation of MBR-12325 in soybeans and cocklebur. Abstr. Weed Sci. Soc. Am., p. 14.

106. Wilson, H. P. and T. E. Hines. 1980. Postemergence control of annual grasses in soybeans. Proc. Northeast Weed Sci. Soc. 34:6-10.

107. Woldetatios, T. and R. G. Harvey. 1977. Diclofop and bentazon interactions on soybeans and annual weeds. Proc. North Central Weed Control Conf. 32:42-43.

108. Woldetatios, T. and R. G. Harvey. 1980. Effects of bentazon, diclofop and bentazon plus diclofop on the uptake of ^{14}C-bentazon and ^{14}C-diclofop in corn, giant foxtail (Setaria faberi Herrm.) and soybeans. Abstr. Weed Sci. Soc. Am., p. 102.

109. Wu, C. H. and P. W. Santelman. 1976. Phytotoxicity and soil activity of HOE-23408. Weed Sci. 24:601-604.

110. Wyse, D. L. 1976. Quackgrass control in soybeans with postemergence herbicides. Proc. North Central Weed Control Conf. 31:92-93.

111. Young, F. L. and D. L. Wyse. 1977. Evaluation of HOE-21952 for quackgrass control in soybeans. Proc. North Central Weed Control Conf. 32:32-33.

112. Young, F. L. and D. L. Wyse. 1980. Control of quackgrass (Agropyron repens) in soybeans (Glycine max) with HOE-29152. Weed Sci. 28:493-498.

CHAPTER 2

SELECTIVE POSTEMERGENCE GRASS CONTROL

IN SOYBEANS [*Glycine max* (L.) Merr.]

ABSTRACT

Several selective postemergence herbicides provided excellent midseason quackgrass [*Agropyron repens* (L.) Beauv.] control in 1980 and 1981. Control of quackgrass regrowth 10 months after application was observed in 1980 and 1981. Greatest regrowth control in 1980 was observed with sethoxydim {2-[1-(ethyloxyimino)butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohenen-1-one}, RO-13 8895 {acetone O-[D-[2-[p-(α,α,α-trifluoro-p-tolyl)oxy] phenoxy]propionyl] oxime}, and NCI-96683 (Nissan Chemical Ind., LTD.). Greatest quackgrass regrowth control in 1981 occurred with NCI-96683 and Dowco 453 {methyl 2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate}. Early treatments applied to 7- to 9-cm tall quackgrass in 1980 were less effective than late treatments applied to 16- to 22-cm tall plants with each herbicide except NCI-96683 and NCI-96721 (Nissan Chemical Ind., LTD.). In 1981, early treatments applied to 9- to 13-cm tall plants provided similar midseason control as late treatments applied to 18- to 22-cm tall plants with each compound tested except RO-13 8895; however,

late treatments provided less control of quackgrass regrowth. In both years, sequential applications provided equivalent and in many cases greater midseason quackgrass control and regrowth control than single applications of the same rate for each of the herbicides evaluated. Several antagonistic herbicide interactions resulted from grass herbicide applications in combination with acifluorfen {sodium 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate} or bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2, dioxide]. These antagonisms were partially overcome in 1981 by increasing the rate of the grass herbicide. Excellent postemergence control of annual grasses was observed with each of the herbicides examined in 1980 and 1981. Each of the herbicides evaluated in 1981 except diclofop-methyl {methyl 2-[4-(2',4'-dichlorophenoxy)phenoxy] propanoate} provided 90% or greater control of barnyardgrass [*Echinochloa crusgalli* (L.) Beauv.] and giant foxtail (*Setaria faberi* Herrm.) at rates of application of 0.14 kg/ha. Loss of control from herbicide combinations with acifluorfen or bentazon were less apparent on annual grasses. Field results indicate flexibility in time of application for annual grass control with each of the herbicides evaluated except diclofop-methyl. In each field study soybean [*Glycine max* (L.) Merr.] injury was significantly greater for each treatment where acifluorfen was included in the spray mixture. Soybean injury did not decrease soybean yield compared to the hand weeded control. Soil applications of fluazifop-butyl {(±)-butyl 2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate} at 0.28 kg/ha or higher provided 90% or greater control of barnyardgrass seed and quackgrass rhizomes. Herbicidal activity in the soil following application of fluazifop-butyl ranged from 10 days to 40 days with rates of application of 0.28 to 2.24 kg/ha, respectively. Results indicate that activity in the soil contributed to control of 4- to 6-cm tall barnyardgrass plants following postemergence applications of fluazifop-butyl.

INTRODUCTION

Soybeans have become an important component of agricultural production in the United States and elsewhere. Maximum soybean production is often limited by interference from weeds including annual and perennial grasses. Quackgrass, an aggressive perennial grass, is a particularly serious problem in the northern United States and Southern Canada (10). Several annual grass species may also create barriers to maximum soybean yields.

Several herbicides are available for soil treatments to control annual grasses in soybeans; however, diclofop-methyl is currently the only herbicide fully registered for selective postemergence grass control in soybeans. Diclofop-methyl has little activity on quackgrass (1). Foliar applications of glyphosate [N-(phosphonomethyl)glycine] can provide excellent quackgrass control (2); however, this herbicide is non-selective and cannot be applied as a broadcast treatment after the crop has emerged. Several experimental herbicides have been evaluated for selective postemergence grass control in soybeans. Many have been shown to be effective for control of both annual and perennial grasses with little crop injury (5,12).

Grass control with diclofop-methyl was reduced when application was made to larger plants (16,18,21). Sequential applications of sethoxydim (17,19) or difenopenten {ethyl 4-[4-[4-(trifluoromethyl)phenoxy]phenoxy]-2-pentenoate} (19) have been shown to be the most effective for quackgrass control.

Postemergence applications of a grass control herbicide in combination with a broadleaved weed control herbicide such as acifluorfen or bentazon is desirable since it would increase the weed spectrum controlled. However, reduced grass control has been reported when bentazon was added to spray mixtures with diclofop-methyl (3,4,14,20), metriflufen {methyl 2-[4-(4'-trifluoromethyl phenoxy) phenoxy]propanoate} (6), or sethoxydim (7,14). Similar antagonisms were observed between acifluorfen and sethoxydim (7) or difenopenten (14).

Previous studies have shown herbicidal activity in the soil with several herbicides including diclofop-methyl (11) and metriflufen (15). The objectives of this study were to: (a) evaluate the efficacy and soybean tolerance of several selective postemergence herbicides for quackgrass and annual grass control; (b) examine the influence of plant growth stage and sequential applications on control; (c) examine the effect of herbicide combinations with acifluorfen and bentazon on grass control and soybean tolerance; (d) examine the soil activity and persistence of fluazifop-butyl.

MATERIALS AND METHODS

Field studies on grass control in soybean with several selective postemergence herbicides were conducted during the summer of 1980 and 1981. Greenhouse studies on the herbicidal activity of fluazifop-butyl were conducted in 1981 and 1982.

General procedures for field studies. Field trials were conducted in East Lansing, Michigan to evaluate the efficacy of several herbicides for selective postemergence control of annual grasses and quackgrass. All treatments were applied with a compressed air tractor sprayer using 730308[1] flat fan nozzles. The spray volume was 253 L/ha and the spray pressure was 324 kPa. All herbicide treatments except those involving acifluorfen or fluazifop-butyl were applied with an oil concentrate added to the spray mixture at 2.34 L/ha. Fluazifop-butyl treatments were applied with X-77[2] surfactant added to the spray mixture at 0.5% (v/v). With treatments involving herbicide combinations, the rate of application was 0.56 kg/ha for acifluorfen and 0.84 kg/ha for bentazon. Applications with bentazon always included oil concentrate at 2.34 L/ha. Plot size was four 75 cm wide rows by 9 m long.

Quackgrass control and soybean injury were determined by visual observations. Certain studies were harvested and soybean yields were adjusted to 13.0% moisture. All trials were designed as a randomized complete block containing three or four replications. Visual evaluations and soybean yields were subjected to analsis of variance and treatment mean comparisons were made using Duncan's multiple range test.

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[1]Spraying Systems Co., Wheaton, IL.

[2]X-77 is a non ionic surfactant composed of a mixture of alkylaryl-polyoxyethylene glycols, free fatty acids, and isopropanol produced by Chevron Chem. Co., San Francisco, CA.

Quackgrass control field studies. In 1980, a quackgrass control study was conducted on a Colwood-Brookston loam in an area of high quackgrass density that had been undisturbed for 2 years. The study was moldboard plowed in April and was disked once and field cultivated twice on May 30, 1980. 'Harcor' and 'Weber' soybeans were planted immediately after final tillage. Early postemergence (EP) treatments of sethoxydim, difenopenten, RO-13 8895, CGA 82725 {2-propynyl 2-[4-[(3,5-dichloro-2-pyridinyl)oxy]phenoxy]propanoate}, NCI-96683, NCI-96721 and herbicide combinations with acifluorfen or bentazon were applied on June 16, 1980 when quackgrass was 7 to 13 cm in height and soybeans were in unifoliolate growth stage. Late postemergence (LP) treatments of the same individual herbicides were applied on June 30, 1980. Quackgrass was 16 to 22 cm in height and soybeans were in one- to two-trifoliolate growth stage. Additional areas were treated on both June 16 and June 30, 1980. Soybean injury from early and late applications were evaluated 10 days after treatment on June 27 and July 11, 1980, respectively. Midseason quackgrass control was evaluated 4 weeks after the late (LP) treatments on July 26, 1980. Soybeans were harvested and yields determined. Quackgrass regrowth control the following season was evaluated 10 months after treatment on April 30, 1981.

The site of the 1981 quackgrass control study was on a Colwood-Brookston loam in an area with dense quackgrass. The area had been undisturbed for 7 years. The study area was moldboard plowed in the fall of 1980 and was disked twice and field cultivated twice on May 21, 1981. 'Harcor' and 'Corsoy' soybeans were planted immediately after final tillage. Early and late postemergence application of sethoxydim, RO-13 8895, fluazifop-butyl, NCI-96683, Dowco 453 and herbicide combinations with acifluorfen and bentazon were made on June 11 and June 25, 1981. Additional areas were treated on both June 11 and June 25. Corresponding quackgrass height at time of treatment was 9 to 13 cm and 18 to 22 cm for early (EP) and late (LP) treatments, respectively. Soybean growth stage for early postemergence (EP) treatments was one- to two-trifoliolate.

On June 19, 1981 the study area was treated with a broadcast application of 2,4-D at 0.56 kg/ha to control broadleaved weeds. Soybean injury following the early treatments was evaluated 7 days after treatment on June 18, 1981. Midseason quackgrass control was evaluated 4 weeks after the late (LP) treatments on July 23, 1981. Quackgrass regrowth control the following season was evaluated 10 months after treatment on April 28, 1982.

<u>Annual grass control field studies</u>. In 1980, an annual grass control study was conducted on a Marlette loam in an area of predominantly barnyardgrass and yellow foxtail [*Setaria lutescens* (Weigel) Hubb.]. 'Corsoy' and 'Weber' soybeans were planted on June 13, 1980. Postemergence treatments of sethoxydim, difenopenten, RO-13 8895, CGA 82725, NCI-96683, NCI-96721, diclofop-methyl and herbicide combinations with acifluorfen or bentazon were applied on July 8, 1980 when the

grasses were 7 to 9 cm in height and soybeans were in two-trifoliate growth stage. Soybean injury and grass control were evaluated on July 18 and August 1, 1980, respectively.

The 1981 annual grass control study was conducted on a Capac loam in an area of predominantly barnyardgrass and giant foxtail. 'Harcor' and 'Corsoy' soybeans were planted on May 29, 1981. Early postemergence (EP) treatments with sethoxydim, RO-13 8895, fluazifop-butyl, NCI-96683, CGA 82725, Dowco 453, diclofop-methyl and herbicide combinations with acifluorfen or bentazon were applied on June 19, 1981 when grasses were 7 to 9 cm in height and soybeans were in two- to three-trifoliolate growth stage. Late postemergence (LP) treatments were applied on July 1, 1981 when grasses were 17 to 22 cm in height and soybeans were in five to six-trifoliolate growth stage. Soybean injury from early and late applications were evaluated 7 days after treatment on June 26 and July 7, 1981, respectively. Grass control was evaluated 3 weeks after the late (LP) treatments on July 21, 1981. Soybeans were harvested and yields were determined.

General procedures for greenhouse studies. Experiments were conducted to examine grass control with fluazifop-butyl. Grass species evaluated were barnyardgrass and quackgrass. Studies were conducted in the greenhouse under temperatures of approximately 25 C-day/20 C-night. Natural light was supplemented with metal halide lighting, with a 16-h photoperiod at an average photosynthetic photon flux density of $280 \mu E\text{-}m^{-2}\text{-}s^{-1}$. Relative humidity ranged from 30 to 60%. All plants were surface irrigated with water to maintain the moisture level at or near field capacity. On a weekly basis, 50 ml of a soluble fertilizer solution (22.5%N - 22.5%P_2O_5 - 22.5%K_2O, 2g/l) was added to each pot. Herbicide application was made using a moving belt sprayer delivering 355 L/ha at a pressure of 206 kPa. Grass control was determined by visual observation 2 weeks after barnyardgrass treatments and 4 weeks after quackgrass treatments. All experiments were designed as a randomized complete block with four replications and were repeated. All values are the means of two experiments. Visual evaluations were subjected to analysis of variance and treatment means comparisons were made using Duncan's multiple range test.

Quackgrass rhizome sections were planted and grown in 10-cm diamater plastic pots filled with greenhouse potting soil (1:1:1 soil, sand, peat). Applications were made to 9- to 13-cm tall quackgrass plants. Herbicide treatments consisted of fluazifop-butyl at rates of application ranging from 0.14 to 0.56 kg/ha in combinations with oil concentrate at 2.34 L/ha or X-77 surfactant at 0.5% (v/v). Treatments also included fluazifop-butyl in combinations with acifluorfen at 0.56 kg/ha or bentazon plus oil concentrate at 0.84 kg/ha and 2.34 L/ha, respectively. Quackgrass control was evaluated 4 weeks after treatment.

Barnyardgrass was grown from seed in 10-cm diameter plastic pots containing a sandy loam soil with 75% sand, 12% silt, 13% clay, 0.8% organic matter, and a pH of 7.8. After emergence, 10 uniform and equally spaced plants were selected in each pot. Herbicide treatments were applied when plants were 4 to 6 cm, 8 to 10 cm, 13 to 15 cm or 17 to 19 cm tall. Herbicide treatments consisted of fluazifop-butyl at application rates of 0.07 to 0.56 kg/ha in combination with oil concentrate at 2.34 L/ha. Herbicide treatments to 4- to 6-cm tall plants also included fluazifop-butyl in combination with X-77 surfactant at 0.5% (v/v), acifluorfen at 0.56 kg/ha, or bentazon plus oil concentrate at 0.84 kg/ha and 2.34 L/ha, respectively. Plants were evaluated for phytotoxicity 2 weeks after treatment.

Soil activity and persistence studies. Barnyardgrass seeds were planted in 10-cm diamater plastic pots filled with a sandy loam soil with 75% sand, 12% silt, 13% clay, 0.8% organic matter, and a pH of 7.8. Seeds were planted at a rate of 20 seeds/pot. Immediately after planting, the pots were treated with soil applications of fluazifop-butyl at rates of 0.07 to 1.12 kg/ha in combination with X-77 surfactant at 0.5% (v/v) and were placed in the greenhouse under similar conditions as previously described. Barnyardgrass plants were harvested 10 days after planting and percent emergence and total shoot dry matter accumulation were determined. Reduction in emergence and dry matter accumulation compared to the untreated control were calculated. Immediately following harvest, the pots were replanted with barnyardgrass by inserting the seeds into the soil with a

2-mm diameter glass probe with as little disturbance of the soil surface as possible. This procedure was repeated every 10 days until six plantings and six harvests had been completed.

In another study, barnyardgrass seeds were planted and grown in 10-cm diamater plastic pots filled with a sandy loam soil previously described. Plant densities were established at 3 plants/pot and 50 plants/pot. To intercept the herbicide, vermiculite was added to the soil surface of one-half of the pots in the study prior to treatment and was removed immediately after treatment. Foliar spray treatments of fluazifop-butyl at rates of 0.07 and 0.14 kg/ha in combination with oil concentrate at 2.34 L/ha were applied to 4- to 6-cm tall barnyardgrass plants in pots with and without vermiculite on the soil surface. Barnyardgrass control was evaluated 2 weeks after treatment.

To evaluate herbicidal activity on quackgrass from soil applications of fluazifop-butyl, quackgrass rhizome sections were planted in 10-cm diamater plastic pots filled with a sandy loam soil previously described. Immediately after planting, soil applications of fluazifop-butyl were made at rates of 0.14 to 2.24 kg/ha in combination with X-77 surfactant at 0.5% (v/v). Quackgrass control was determined by visual evaluation and shoot emergence was counted 15 and 45 days after treatment.

RESULTS AND DISCUSSION

Quackgrass control. In 1980, late postemergence (LP) applications of sethoxydim, difenopenten, and RO-13 8895 at 1.12 kg/ha provided 76% or greater midseason control of 16- to 22-cm tall quackgrass (Table 1). Late postemergence (LP) and sequential (EP + LP) application of sethoxydim, difenopenten, RO-13 8895 or CGA-82725 gave significantly greater midseason quackgrass control than the same rates applied early (EP) to plants 7 to 13 cm tall. Sethoxydim and RO-13 8895 at rates of 1.12 kg/ha and NCI-96683 at 2.24 kg/ha provided 85% or greater control of quackgrass regrowth the following spring, regardless of time of application. Quackgrass regrowth control from difenopenten at 1.68 kg/ha was significantly lower from early (EP) treatments than from late (LP) or sequential (EP + LP) treatments at the same rate. CGA-82725 did not provide adequate midseason quackgrass control or quackgrass regrowth control in 1980 regardless of rate or time of application. All treatments significantly increased soybean injury compared to the uncultivated control. Greatest soybean injury was observed with late postemergence (LP) treatments of NCI-96683 and NCI-96721 with injury visually evaluated as high as 38%. However, this injury did not result in a significant yield reduction compared to the hand weeded control (Table 1).

In 1981, late postemergence (LP) treatments of sethoxydim, RO-13 8895, fluazifop-butyl, NCI-96683 and Dwoco 453 at 1.12

Table 1. Selective postemergence herbicides applied at several rates and quackgrass heights including sequential applications and the resultant activity on quackgrass and soybean, 1980.[a]

Herbicide	Rate	Midseason quackgrass control[e]			Quackgrass regrowth control[f]			Soybean injury[g]			Soybean yields		
		EP[c]	LP[d]	EP+LP	EP	LP	EP+LP	EP	LP	EP+LP	EP	LP	EP+LP
	(kg/ha)	(%)									(kg/ha x 100)		
Sethoxydim	0.56	64d-i	55g-j	61e-i	78abc	42efg	82ab	17d-i	17d-i	12f-j	32abc	28c	35a
Sethoxydim	1.12	46ijk	76b-g	79a-f	85a	85a	84a	10g-j	15d-i	13e-j	34ab	33ab	31abc
Difenopenten	1.12	22l		58f-i	12hi		30gh	13e-j		17d-i	30abc		32abc
Difenopenten	1.68	37jkl	81a-e	73c-h	3i	33fgh	33fgh	13e-j	23b-g	16d-i	32abc	29bc	31abc
RO-13 8895	0.56	30kl		76b-g	88a		96a	3i-j		15d-i	31abc		33ab
RO-13 8895	1.12	36jkl	88abc	83a-d	90a	88a	96a	7hij	26a-f	19d-h	31abc	30abc	34ab
CGA-82725	0.56	22l			20ghi			10g-j			31abc		
CGA-82725	1.12	27kl	53hij	61e-i	20ghi	20ghi	28gh	22c-g	27a-e	25a-f	31abc	29bc	30abc
NCI-96683	1.12	55g-j			96a			33abc			33ab		
NCI-96683	2.24	79a-f	93abc	91abc	97a	98a	98a	38a	37ab	29a-d	33ab	32abc	32abc
NCI-96721	1.68	59f-i			32fgh			23b-g			33ab		
NCI-96721	3.36	85a-d	91abc	97ab	55def	61b-e	75a-d	18d-h	38a	26a-f	32abc	31abc	32abc
Uncultivated control		0m	0m	0m	0i	0i	0i	0j	0j	0j	18d	18d	18d
Hand weeded control		100a	100a	100a	58cde	58cde	58cde	0j	0j	0j	33ab	33ab	33ab

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments included oil concentrate at 2.34 L/ha.

[c]Early postemergence (EP) treatments were applied to 7- to 13-cm tall quackgrass and unifoliolate soybeans (June 16, 1980).

[d]Late postemergence (LP) treatments were applied to 16- to 22-cm tall quackgrass and one- to two-trifoliolate soybeans (June 30, 1980).

[e]Visual evaluation 4 weeks after the late (LP) treatments were applied (July 26, 1980).

[f]Visual evaluation 10 months after the late (LP) treatments were applied (April 30, 1981).

[g]Visual evaluation 10 days after final treatment.

kg/ha provided 75% or greater midseason control of 18- to 22-cm tall quackgrass (Table 2). Greatest soybean injury occurred with NCI-96683 at 1.12 kg/ha with injury visually evaluated at 40%. Unlike the 1980 study, time of treatment or sequential applications did not influence midseason quackgrass control with any of the herbicides examined in 1981, except RO-13 8895. Late postemergence applications of RO-13 8895 at rates of 0.56 and 1.12 kg/ha provided significantly greater midseason quackgrass control than the same rates applied early (EP) to plants 9 to 13 cm in height. Quackgrass regrowth control with sethoxydim and fluazifop-butyl at 0.56 kg/ha and with NCI-96683 and Dowco 453 at 0.28 kg/ha was significantly lower when the herbicides were applied late (LP) compared to early (EP) or sequential (EP + LP) applications at the same rate. This suggests that basipetal translocation to the quackgrass rhizome was lower for the late (LP) treatments.

Differences in the effect of time of application and sequential treatments on midseason quackgrass control and quackgrass regrowth control between 1980 and 1981 may be partially related to environmental differences. These results also indicate that a window of greatest quackgrass control exists in terms of plant growth stage such that treatments earlier or later are less effective. For example, early postemergence (EP) treatments in 1980 applied to 7- to 13-cm tall quackgrass may have been applied before the plants reached optimum maturity for basipetal translocation

Table 2. Selective postemergence herbicides applied at several rates and quackgrass heights including sequential applications and the resultant activity on quackgrass and soybean, 1981.[a]

Herbicide	Rate	Midseason quackgrass control[e]			Quackgrass regrowth control[f]			Soybean injury[g]
		EP[c]	LP[d]	EP+LP	EP	LP	EP+LP	EP
	(kg/ha)	(%)						
Sethoxydim	0.28	55e-f	37f		7ijk	6ijk		0f
Sethoxydim	0.56	72a-e	60d-f	75a-e	37c-j	3fgh	30d-k	0f
Sethoxydim	1.12	83a-d	75a-e	92ab	30d-k	12h-k	48a-g	0f
RO-13 8895	0.28	72a-e	88abc		28e-k	5jk		13def
RO-13-8895	0.56	55e-f	90abc	85a-d	21f-k	13h-k	60a-e	22b-e
RO-1e-8895	1.12	67b-e	93a	81a-d	43a-h	10jik	60a-e	33ab
Fluazifop-butyl	0.28	78a-e	72a-e	88abc	23f-k	2k	37c-j	7ef
Fluazifop-butyl	0.56	89abc	77a-e	93a	59a-e	2k	58a-e	8def
Fluazifop-butyl	1.12	90abc	82a-d	97a	51a-f	38b-i	73a	22b-e
NCI-96683	0.28	77a-e	85a-d		58a-e	17g-k		23bcd
NCI-96683	0.56	78a-e	88abc	92ab	57a-e	30d-k	64abc	32abc
NCI-96683	1.12	85a-d	90abc	93a	70ab	63a-d	63a-d	40a
Dowco 453	0.28	82a-d	73a-e		73a	30d-k		18b-e
Dowco 453	0.56	83a-d	83a-d	94a	68abc	38b-i	74a	17cde
Dowco 453	1.12	88abc	92ab		60a-e	63a-d		15def
Uncultivated control		0g	0g	0g	0k	0k	0k	0f

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments except those involving fluazifop-butyl included oil concentrate at 2.34 L/ha. Fluazifop-butyl was applied with X-77 surfactant at 0.5% (v/v).

[c]Early postemergence (EP) treatments were applied to 9- to 13-cm tall quackgrass and one- to two-trifoliolate soybeans (June 11, 1981).

[d]Late postemergence (LP) treatments were applied to 18- to 22-cm tall quackgrass (June 25, 1981).

[e]Visual evaluation 4 weeks after the late (LP) treatments were applied (July 23, 1981).

[f]Visual evaluation 10 months after the late (LP) treatments were applied (April 28, 1982).

[g]Visual evaluation 7 days after treatment (June 18, 1981).

of the herbicide. In addition, some quackgrass shoots may have emerged after treatment. This window of greatest control appears to be wider for certain herbicides with the greatest flexibility in time of application observed with NCI-96683 and NCI-96721 in 1980 and with NCI-96683 and Dowco 453 in 1981 (Tables 1, 2).

In both 1980 and 1981, sequential applications were as effective or more effective than a single application of the same rate for each of the herbicides evaluated (Tables 1, 2). This agrees with results reported by Westra and Wyse (19).

The addition of acifluorfen to a tank mixture with RO-13 8895 at 0.56 kg/ha resulted in a significant reduction in midseason quackgrass control in 1980 (Table 3). In addition, quackgrass regrowth control was significantly reduced when either acifluorfen or bentazon was added to a spray mixture with sethoxydim at 0.84 kg/ha or RO-13 8895 at 0.56 kg/ha. Herbicide combinations with acifluorfen significantly increased soybean injury with all treatments with injury ranging from 50 to 58%. In addition, acifluorfen added to a spray mixture with difenopenten at 1.12 kg/ha significantly reduced soybean yield; however, this did not occur with sethoxydim or RO-13 8895 at the rates tested.

In 1981, herbicide combinations with acifluorfen resulted in reduced midseason quackgrass control and quackgrass regrowth control with sethoxydim, RO-13 8895 and fluazifop-butyl at 0.56 kg/ha (Table 4). Acifluorfen in combination with NCI-96683 at 0.56 or 1.12 kg/ha did not reduce midseason

Table 3. Combinations of selective postemergence broadleaf and grass herbicides and the resultant activity on quackgrass and soybean, 1980.[a]

Herbicide	Rate	Midseason[b] quackgrass control			Quackgrass regrowth control			Soybean injury[b]			Soybean yields		
		OC[e]	Aci	Ben	OC	Aci	Ben	OC	Aci	Ben	OC	Aci	Ben
	(kg/ha)	(%)									(kg/ha X 100)		
Sethoyxdim	0.84	45b	38bc	28b-f	77ab	17cd	27c	7bc	50a	18bc	31a	30a	31a
Difenopenten	1.12	23c-f	12efg	16d-g	12cd	13cd	22cd	13bc	58a	21b	30a	20b	29a
RO-13 8895	0.56	30b-e	8fg	35bcd	88a	3cd	20cd	3c	54a	5c	31a	28a	27a
Uncultivated control		0g	0g	0g	0d	0d	0d	0c	0c	0c	18b	18b	18b
Hand weeded control		100a	100a	100a	58b	58b	58b	0c	0c	0c	33a	33a	33a

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments were applied to 7- to 13-cm tall quackgrass plants and unifoliate soybeans (June 16, 1980).

[c]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[d]Acifluorfen was added to the spray mixture at 0.56 kg/ha.

[e]Bentazon and oil concentrate were added to the spray mixture at 0.84 kg/ha and 2.34 L/ha, respectively.

[f]Visual evaluation was made 6 weeks after treatment (July 26, 1980).

[g]Visual evaluation was made 10 months after treatment (April 30, 1981).

[h]Visual evaluation was made 10 days after treatment (June 27, 1980).

Table 4. Combinations of selective postemergence broadleaf and grass herbicides and the resultant activity on quackgrass and soybean, 1981.[a]

		Midseason quackgrass control[f]			Quackgrass regrowth control[g]			Soybean injury[h]		
Herbicide	Rate	OC[c]	Aci[d]	Ben[e]	OC	Aci	Ben	OC	Aci	Ben
	(kg/ha)	(%)						(%)		
Sethoxydim	0.56	72a-d	13i-j	3j	37b-e	0h	0h	0k	53de	29ghi
Sethoxydim	1.12	83ab	35ghi	45efg	30c-h	3f-h	5e-h	0k	80ab	37fgh
RO-13 8895	0.56	55c-g	17hij	57b-g	21d-h	0h	22d-h	22hij	68abc	52de
RO-13 8895	1.12	67a-f	35ghi	47d-g	43a-d	10e-h	7e-h	33gh	65bcd	68abc
Fluazifop-butyl	0.28	78abc	3j	42f-h	23d-h	0h	2g-h	7jk	67bcd	43efg
Fluazifop-butyl	0.56	83ab	32ghi	68a-e	34c-g	0h	23d-h	8jk	75ab	50ef
NCI-96683	0.56	78abc	68a-e	52c-g	57abc	17d-h	47a-d	32ghi	77ab	50ef
NCI-96683	1.12	85a	77abc	65a-f	70a	23d-h	36b-f	40efg	83a	55cde
Dowco 453	0.56	83ab	77abc	65a-f	68ab	48a-d	44a-d	17ij	73ab	32ghi
Uncultivated control		0j	0j	0j	0h	0h	0h	0k	0k	0k

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments were applied to 9- to 13-cm tall quackgrass plants and one- to two-trifoliolate soybeans (June 11, 1981).

[c]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[d]Acifluorfen was added to the spray mixture at 0.56 kg/ha.

[e]Bentazon and oil concentrate were added to the spray mixture at 0.84 kg/ha and 2.34 L/ha, respectively.

[f]Visual evaluation was made 6 weeks after treatment (July 23, 1982).

[g]Visual evaluation was made 10 months after treatment (April 28, 1982).

[h]Visual evaluation was made 7 days after treatment (June 18, 1981).

control but did reduce regrowth control. Herbicide combinations with bentazon resulted in reduced quackgrass control with sethoxydim at 0.56 and 1.12 kg/ha and with fluazifop-butyl at 0.28 kg/ha. In addition, reduced quackgrass regrowth control occurred with herbicide combinations of bentazon with sethoxydim at 0.56 kg/ha and with RO-13 8895 and NCI-96683 at 1.12 kg/ha. No loss of activity was observed from herbicide combinations with Dowco 453 at 0.56 kg/ha, the only rate tested. Similar to the 1980 results, soybean injury was significantly increased with each treatment where acifluorfen was added to the spray mixture.

Midseason quackgrass control ratings in 1981 indicate that antagonistic herbicide interactions with acifluorfen or bentazon were partially overcome when the rate of the grass herbicide was increased (Table 4). For example, quackgrass control with sethoxydim in combination with bentazon was increased from 3% to 45% when the rate of sethoxydim was increased from 0.56 to 1.12 kg/ha. Similar increases in control were observed with fluazifop-butyl at rates of 0.28 and 0.56 kg/ha in combination with acifluorfen or bentazon. Similar results have been reported with sethoxydim (7). This response may explain why fewer antagonistic interactions were observed in 1980 where, in general, higher rates of the herbicides were used (Table 3). For this reason it is possible that antagonistic interactions between Dowco 453 and acifluorfen or bentazon may occur at rates of Dowco 453 lower than 0.56 kg/ha. Quackgrass control with fluazifop-butyl at rates of 0.14 to 0.56 kg/ha in the greenhouse was not reduced by addition of acifluorfen or bentazon to the spray mixture (Table 5). The lack of antagonisms with fluazifop-butyl may be related to different environmental conditions in the greenhouse.

No significant differences in phytotoxicity on quackgrass with fluazifop-butyl were observed between X-77 surfactant and oil concentrate as herbicide additives in the greenhouse (Table 5).

Quackgrass control with fluazifop-butyl in the greenhouse was lower than observed in the field in 1981 from equivalent rates (Table 2, 5). For example, fluazifop-butyl at 0.28 kg/ha with 0.5% X-77 surfactant provided 78% and 35% control of 9- to 13-cm tall quackgrass in the field and greenhouse, respectively. This may be due to reduced soil herbicidal activity in the greenhouse potting soil (7.8% organic matter).

Annual grass control. Postemergence applications of sethoxydim, difenopenten, RO-13 8895, CGA-82725, and NCI-96683 at rates of 0.56 kg/ha provided 96% or greater control of 7- to 9-cm tall barnyardgrass and yellow foxtail in 1980 (Table 6). In addition, sethoxydim and RO-13 8895 were evaluated at rates of 0.14 kg/ha and were found to provide 91% or better control. NCI-96721 required a rate of 1.12 kg/ha to obtain 99% control. Diclofop-methyl provided 83% control at 1.12 kg/ha, the only rate tested (Table 6).

Table 5. Phytotoxicity on quackgrass in the greenhouse from fluazifop-butyl in combination with X-77, oil concentrate, acifluorfen, or bentazon.[a]

Fluazifop-butyl Rate[b]	Quackgrass control[g]			
	X-77[c]	OC[d]	Aci[e]	Ben[f]
(kg/ha)	(%)			
0	0e	0e	0e	0e
0.14	28d	25d		
0.28	35cd	50bc	43cd	40cd
0.56	75a	85a	68ab	68ab

[a]Means followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments were applied to 9- to 13-cm tall quackgrass.

[c]X-77 surfactant was added to the spray mixture at 5% (v/v).

[d]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[e]Acifluorfen was added to the spray mixture at 0.56 kg/ha.

[f]Bentazon and oil concentrate were added to the spray mixture at 0.84 kg/ha and 2.34 L/ha, respectively.

[g]Visual evaluations were made 4 weeks after treatment.

Table 6. Barnyardgrass and yellow foxtail control from selective postemergence herbicides as affected by rate and herbicide combinations with acifluorfen and bentazon, 1980.[a]

Herbicide	Rate	Annual grass control[f]			Soybean injury[g]		
		OC[c]	Aci[d]	Ben[e]	OC	Aci	Ben
	(kg/ha)	(%)					
Sethoxydim	0.14	100a			9e-h		
Sethoxydim	0.28	100a	91ab	94ab	3gh	44a	24bcd
Sethoxydim	0.56	100a			8e-h		
Difenopenten	0.56	96a			8e-h		
Difenopenten	1.12	96a			14c-h		
RO-13 8895	0.14	91ab			4fgh		
RO-13 8895	0.28	97a	56c	93ab	3fgh	46a	17c-g
RO-13-8895	0.56	100a			12d-h		
CGA-82725	0.28	95ab			11d-h		
CGA-82725	0.56	99a			18c-f		
NCI-96683	0.28	100a			20cde		
NCI-96683	0.56	100a		100a	29b		28bc
NCI-96721	0.56	75bc			11d-h		
NCI-96721	1.12	99a			14c-h		
Diclofop-methyl	1.12	83ab			21cde		
Uncultivated control		0d	0d	0d	0h	0h	0h

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All treatments were applied to 7- to 9-cm tall grasses and two-trifoliolate soybeans (July 8, 1980).

[c]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[d]Acifluorfen was added to the spray mixture at 0.56 kg/ha.

[e]Bentazon and oil concentrate were added to the spray mixture at 0.84 kg/ha and 2.34 L/ha, respectively.

[f]Visual evaluations were made 3 weeks after treatment (August 1, 1980).

[g]Visual evaluations were made 10 days after treatment (July 18, 1980).

In 1981, early postemergence (EP) applications of sethoxydim, RO-13 8895, fluazifop-butyl, NCI-96683, CGA-82725, and Dowco 453 at 0.14 kg/ha provided 90% or greater control of 4- to 6-cm tall barnyardgrass and giant foxtail (Table 7). Diclofop-methyl at the same rate provided only limited control. The relative herbicidal activity of diclofop-methyl was significantly lower than each of the other herbicides examined. Late postemergence (LP) applications to 17- to 22-cm tall plants of 0.28 kg/ha of each of the herbicides tested except diclofop-methyl provided equivalent grass control as the same rate applied early (EP) (Table 7). This indicates considerable flexibility in the time of application for annual grass control with each of the herbicides tested except diclofop-methyl.

Phytotoxicity on barnyardgrass in the greenhouse with fluazifop-butyl at rates of 0.14 and 0.28 kg/ha was reduced when the grass height at application was 13 to 15 cm compared to 3 to 6 cm (Table 8). However, greater phytotoxicity with fluazifop-butyl at rates of 0.07 to 0.28 was observed when application was made to 17- to 19-cm tall plants compared to 13- to 15-cm tall plants. This was especially apparent at the 0.07 kg/ha rate. This observation may be a result of greater spray retention by the larger plants.

Herbicide combinations with acifluorfen and bentazon were examined with sethoxydim and RO-13 8895 at 0.28 kg/ha in 1980. NCI-96683 at 0.56 kg/ha was also examined in combination with bentazon. The addition of acifluorfen to a spray mixture

Table 7. Selective postemergence herbicides applied at several rates and plant heights and the resultant activity on barnyardgrass and giant foxtail, 1981.[a]

		Annual grass control[e]		Soybean injury[f]		Soybean yields	
Herbicide	Rate	EP[c]	LP[d]	EP	LP	EP[b]	LP[c]
	(kg/ha)	(%)				(kg/ha x 100)	
Sethoxydim	0.14	93ab		10def		25ab	
Sethoxydim	0.28	90ab	97a	7def	7def	23ab	24ab
RO-13 8895	0.14	90ab		19bcd		23ab	
RO-13 8895	0.28	96a	93ab	12def	10def	27ab	25ab
Fluazifop-butyl	0.14	95ab		10def		25ab	
Fluazifop-butyl	0.28	92ab	84b	18bcd	10def	24ab	27ab
NCI-96683	0.14	98a		25bc		27ab	
NCI-96683	0.28	99a	100a	38a	30ab	27ab	27ab
CGA-82725	0.14	96a		7def		31a	
CGA-82725	0.28	93ab	90ab	3h	10def	23ab	25ab
Dowco 453	0.07	94ab				25ab	
Dowco 453	0.14	98a		10def		22ab	
Dowco 453	0.28	95ab	95ab	17cde	7def	23ab	30a
Diclofop-methyl	0.14	35d		0f		21ab	
Diclofop-methyl	0.28	57c	43d	5 ef	7def	21ab	20b
Diclofop-methyl	0.56	100a		27abc		23ab	
Uncultivated control		0e	0e	0f	0f	21ab	21ab
Hand weeded control		100a	100a	0f	0f	7c	7c

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments except those involving fluazifop-butyl included oil concentrate at 2.34 L/ha. Fluazifop-butyl was applied with X-77 at 0.5% (v/v).

[c]Early postemergence (EP) treatments were applied to 7- to 9-cm grasses and two- to three-trifoliolate soybeans (June 19, 1981).

[d]Late postemergence (LP) treatments were applied to 17- to 22-cm grasses and five- to six-trifoliolate soybeans (July 1, 1981).

[e]Visual evaluations were made 3 weeks after the late (LP) treatments were applied (July 21, 1981).

[f]Visual evaluations were made 7 days after treatment.

Table 8. Phototoxicity on barnyardgrass in the greenhouse from fluazifop-butyl applied at several rates and plant heights.[a]

Fluazifop-butyl rate[b]	Barnyardgrass control[d] 4-6 cm[c]	8-10 cm	13-15 cm	17-19 cm
(kg/ha)	(%)			
0	0f	0f	0f	0f
0.07	18e	14e	18e	40d
0.14	78b	63c	40d	63c
0.28	94a	87ab	65c	78b
0.56			93c	

[a]Means followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments included oil concentrate at 2.34 L/ha.

[c]Barnyardgrass height at the time of application.

[d]Visual evaluations were made 2 weeks after treatment.

with RO-13 8895 reduced 4- to 6-cm tall barnyardgrass and yellow foxtail control from 99 to 56% (Table 6). No other antagonisms were observed in 1980.

In 1981, no reduction in control of 4- to 6-cm tall barnyardgrass and giant foxtail was observed when either acifluorfen or bentazon was added to 0.28 kg/ha rates of each of the herbicides tested except diclofop-methyl (Table 9). The addition of acifluorfen or bentazon to spray mixtures with diclofop-methyl at 0.28 kg/ha resulted in a 21 and 51% reduction in grass control, respectively (Table 9). This antagonistic interaction with bentazon has been reported by several researchers (3,4,14,20).

Addition of bentazon to spray mixtures with 0.14 kg/ha of fluazifop-butyl significantly reduced phytotoxicity on 4- to 6-cm tall barnyardgrass in the greenhouse. However, when the rate of fluazifop-butyl was increased to 0.28 kg/ha no reduction in control was observed. This observation is consistent with the results on quackgrass control in 1981 (Table 4) and further demonstrates that antagonistic herbicide interactions may be overcome, at least in part, by increasing the rate of the grass herbicide. This may also explain why no antagonistic interactions were observed on barnyardgrass and giant foxtail in 1981 (Table 9).

Phytotoxicity on 4- to 6-cm tall barnyardgrass in the greenhouse with 0.07 kg/ha of fluazifop-butyl was increased by the addition of acifluorfen to the spray mixture (Table 10).

Table 9. Combinations of selective postemergence broadleaf and grass herbicides and the resultant activity on barnyardgrass, giant foxtail, and soybean, 1981.[a]

Herbicide[b]	Rate	Annual grass control[f]			Soybean injury[g]			Soybean yields		
		OC[c]	Aci[d]	Ben[e]	OC	Aci	Ben	OC	Aci	Ben
	(kg/ha)	(%)						(kg/ha x 100)		
Sethoxydim	0.28	90ab	92ab	92ab	7ghi	70bc	28ef	23ab	26a	26a
RO-13 8895	0.28	96ab	85b	96ab	12ghi	70bc	38de	27a	25ab	26a
Fluazifop-butyl	0.28	92ab	99a	96ab	18fg	77b	60c	24ab	26a	25ab
NCI-96683	0.28	99a	96ab	98a	38de	67bc	43d	27a	26a	26a
CGA-82725	0.28	93ab	98a	97ab	3i	73b	33de	23ab	23ab	23ab
Dowco 453	0.28	95ab	96ab	94ab	17fgh	90a	27ef	23ab	20ab	27a
Diclofop-methyl	0.28	57c	45	28e	5hi	63c	38de	21ab	24ab	16b
Uncultivated control		100a	100a	100a	0i	0i	0i	21ab	21ab	21ab
Hand weeded control		0f	0f	0f	0i	0i	0i	7c	7c	7c

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments were applied to 7- to 9-cm tall grasses and two- to three-trifoliolate soybeans (June 19, 1981).

[c]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[d]Acifluorfen was added to the spray mixture at 0.56 kg/ha.

[e]Bentazon and oil concentrate were added to the spray mixture at 0.84 kg/ha and 2.34 L/ha, respectively.

[f]Visual evaluations were made 4 weeks after treatment (July 21, 1981).

[g]Visual evaluations were made 7 days after treatment.

Table 10. Phytotoxicity on barnyardgrass in the greenhouse from fluazifop-butyl in combination with X-77, oil concentrate, acifluorfen, or bentazon[a].

Herbicide[d]	Rate	Barnyardgrass control[g] X-77[c]	OC[d]	Aci[e]	Ben[f]
	(kg/ha)	(%)			
Fluazifop-butyl	0.07	28e	18ef	77cd	18ef
Fluazifop-butyl	0.14	87abc	78c	86bc	66d
Fluazifop-butyl	0.28	99a	94ab	94ab	92ab
None				73cd	8fg
Untreated control		0g	0g	0g	0g

[a]Means followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments were applied to barnyardgrass plants 7 to 9 cm in height.

[c]X-77 surfactant was added to the spray mixture at 5% (v/v).

[d]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[e]Acifluorfen was added to the spray mixture at 0.56 kg/ha.

[f]Bentazon and oil concentrate were added to the spray mixture at 0.84 kg/ha and 2.34 L/ha, respectively.

[g]Visual evaluations were made 2 weeks after treatment.

This is explained by the observation that acifluorfen provided 73% barnyardgrass control when applied alone (Table 10).

Similar to results on quackgrass control in the greenhouse, no significant difference in phytotoxicity on barnyardgrass with fluazifop-butyl was observed between X-77 surfactant and oil concentrate as additives (Table 5, 10).

In both 1980 and 1981, addition of acifluorfen to herbicide mixtures with each grass herbicide tested resulted in significantly greater soybean injury (Tables 6, 9). In addition, herbicide combinations with bentazon in 1981 resulted in significantly greater soybean injury with all herbicides examined except fluazifop-butyl and Dow 453 (Table 9). Soybean injury was observed from herbicide combinations with acifluorfen in 1981; however, this injury did not result in any reduction in yield as compared to the hand weeded control and all treatments provided significantly greater soybean yields than the uncultivated control (Table 9). This observation and similar results in the 1980 quackgrass control study (Table 1) indicate that soybeans have a high capacity to compensate for damaged tissue from foliar applications of these herbicides. These results also suggest that complete eradication of annual grasses or quackgrass may not be necessary to eliminate interference with the soybean crop. However, complete eradication may be important to eliminate seed production with annual grasses and to eliminate quackgrass regrowth in subsequent cropping systems.

Soil activity and persistence studies. Herbicidal activity and persistence of activity was observed on germinating barnyardgrass seeds from soil applications of fluazifop-butyl (Figure 1). This observation is consistent with reports by Plowman et al. (13). Soil application of 0.07 kg/ha of fluazifop-butyl reduced barnyardgrass dry matter accumulation by 43% compared to the untreated control. Fluazifop-butyl applied to the soil at rates of 0.28 kg/ha or higher, resulted in 90% or greater reduction in barnyardgrass dry matter accumulation. Results also indicate persistence of activity from fluazifop-butyl in the soil. Application rates of 0.56 kg/ha provided 90% or greater control for 10 days after treatment (DAT) with no activity apparent at 30 DAT. Fluazifop-butyl applied to the soil at rates of 1.12 and 2.24 kg/ha provided 90% or greater control of germinating barnyardgrass seeds for 20 DAT and 30 DAT, respectively. No herbicidal activity from soil applications of fluazifop-butyl at rates of 2.24 kg/ha or lower was apparent 50 DAT (Figure 1).

Soil herbicidal activity was also examined on established barnyardgrass plants. The addition of vermiculite to the soil surface prior to herbicide application significantly reduced control of 4- to 6-cm tall barnyardgrass with fluazifop-butyl at rates of 0.07 and 0.14 kg/ha (Table 11). This response occurred under plant populations of both 3 plants/pot and 50 plants/pot. This indicates that herbicidal activity in the soil may contribute to barnyardgrass

Figure 1. Herbicidal activity and persistence of fluazifop--butyl following application to a sandy loam soil. The indicator was barnyardgrass planted and harvested at 10 day intervals. Herbicidal activity is reported as a reduction in dry matter accumulation compared to the untreated control.

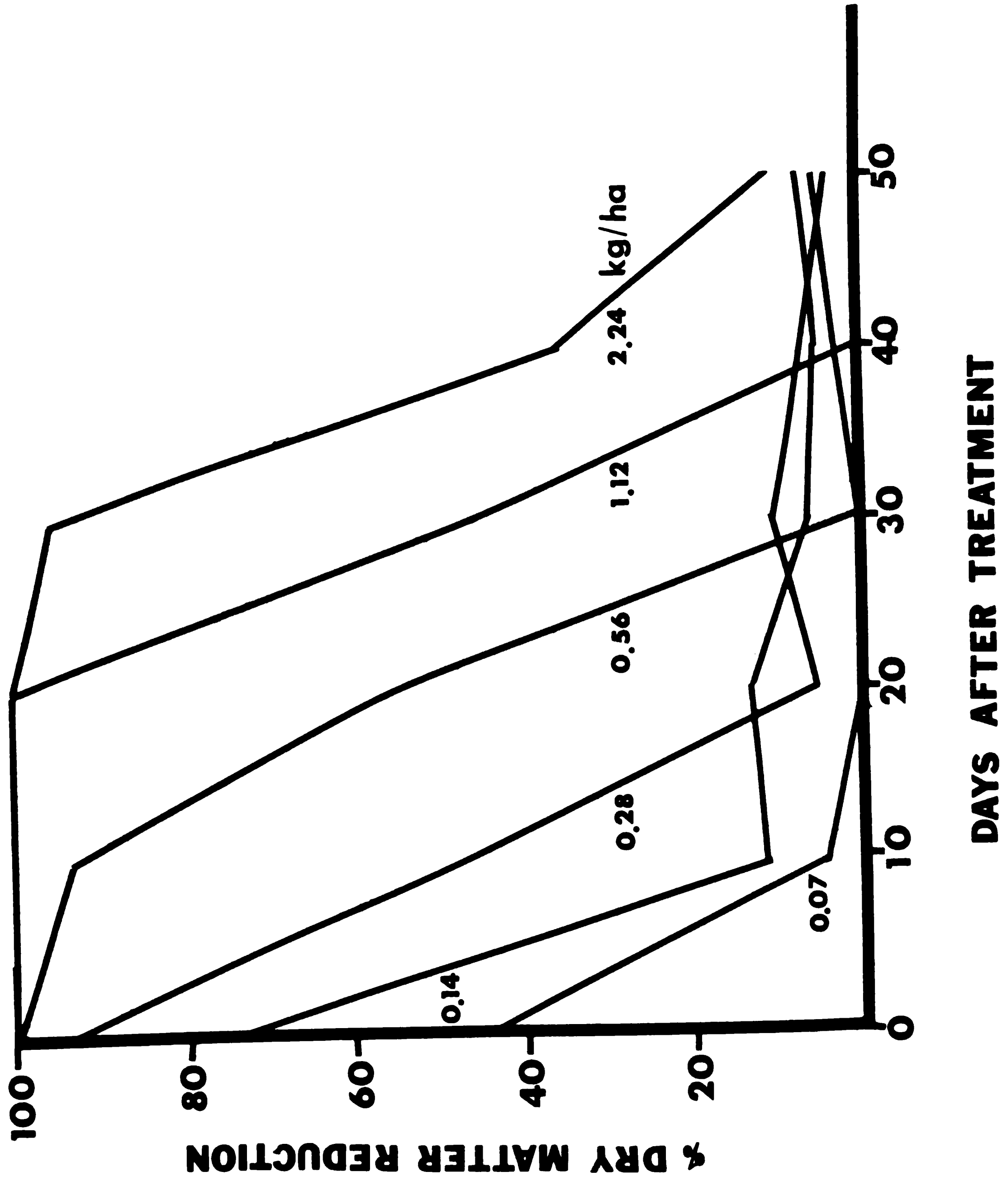
% DRY MATTER REDUCTION
100
80
60
40
20
0
10
20
30
40
50
DAYS AFTER TREATMENT
kg/ha
2.24
1.12
0.56
0.28
0.14
0.07

Table 11. The effect of herbicide rate, plant population, and herbicidal activity in the soil on barnyardgrass control with fluazifop-butyl in the greenhouse.[a]

Fluazifop-butyl rate[b]	Barnyardgrass control[e]			
	3 plants/pot[d]		50 plants/pot	
	+Ver[c]	-Ver	+Ver	-Ver
(kg/ha)	(%)			
0	0e	0e	0e	0e
0.07	22d	73b	33d	51c
0.14	73b	91a	58c	77b

[a]Means followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments included oil concentrate at 2.34 L/ha.

[c]Vermiculite was added to the soil surface prior to treatment and was removed after treatment.

[c]Number of plants in a 10-cm diameter plastic pot.

[e]Visually evaluated 2 weeks after treatment.

control with foliar applications of fluazifop-butyl. In this study, the loss of control from the addition of vermiculite to the soil surface could be overcome by increasing the rate of fluazifop-butyl from 0.07 to 0.14 kg/ha. In addition, barnyardgrass control from 0.14 kg/ha of fluazifop-butyl was lower under a plant density of 50 plants/pot compared to 3 plants/pot. This occurred with and without vermiculite and suggests that less spray reception by plants growing under high density may decrease control with selective postemergence herbicides, such as fluazifop-butyl (Table 11).

Herbicidal activity on quackgrass rhizomes was observed from soil applications of fluazifop-butyl at rates as low as 0.14 kg/ha (Table 12). Soil applications of fluazifop-butyl at rates of 0.28 kg/ha or higher provided 94% or greater quackgrass control 15 DAT. Quackgrass control from soil applications of fluazifop-butyl at 0.14 kg/ha was significantly less 45 DAT. This may be due to the dissipation of the herbicide allowing the plant to continue to grow. However, quackgrass control 45 DAT was 98% or greater from soil applications of fluazifop-butyl at rates of 0.56 kg/ha or higher. In addition, quackgrass rhizomes from these treatments were examined and found to be dead. Soil application of fluazifop-butyl at rates of 0.56 kg/ha or higher also reduced the number of quackgrass shoots present 45 DAT to 2% or less of the total number of quackgrass nodes planted compared to 71% for the untreated control (Table 12).

Table 12. Quackgrass control from soil applications of fluazifop-butyl to a sandy loam soil in the greenhouse.

Fluazifop-butyl rate[b]	Quackgrass control[c]		Quackgrass shoots[d]	
	15 DAT	45 DAT	15 DAT	45 DAT
(kg/ha)	(%)			
0	0e	0e	78a	71a
0.14	68c	23d	69a	42b
0.28	94b	68c	28b	32b
0.56	99a	98a	11c	2c
1.12	99a	100a	13c	0c
2.24	100a	100a	0c	0c

[a]Means within an evaluation followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments included X-77 surfactant at 0.5% (v/v).

[c]Visual evaluations were made 15 and 45 days after treatment (DAT).

[d]Quackgrass shoots are reported as a percentage of the total number of nodes planted.

It is apparent that the soil component of herbicidal activity with fluazifop-butyl may contribute to both annual grass control and quackgrass control with this herbicide.

LITERATURE CITED

1. Anderson, R. N. 1976. Response of monocotyledons to HOE-22870 and HOE-23408. Weed Sci. 24:266-269.

2. Baird, D. D., R. P. Upchurch, W. B. Homesley and J. E. Fronz. 1971. Introduction of a new broad spectrum postemergence herbicide class with utility for herbaceous perennial weed control. Proc. N. Cent. Weed Contr. Conf. 26:64-68.

3. Betts, M. F. and I. N. Morrison. 1978. Anatagonism of diclofop activity by sequential treatments of bentazon or dinoseb applied to fababeans. Proc. North Central weed Control Conf. 33:72.

4. Campbell, J. R. and D. Penner. 1980. Factors affecting the activity of bentazon with diclofop and BAS-9052. Abstr. Weed Science Society Am., p. 13.

5. Dekker, J. H. and G. W. Anderson. 1982. Efficacy of several new postemergence grass herbicides. Abstr. Weed Sci. Soc. Am., p. 128.

6. Downs, J. P. and C. E. Rieck. 1978. The evaluation of HOE-29152 for selective johnsongrass control. Proc. South. Weed Sci. Soc. 31:53.

7. Hartzler, R. G. and C. L. Foy. 1982. Evaluation of BAS-9052-OH alone and in combination with aciflurofen or bentazon for control of large crabgrass (Digitaria sanquinalis). Abstr. Weed Sci. Soc. Am., p. 5-6.

8. Helms, R. L., W. J. Blackmon and B. D. Reynolds. 1980. Comparisons of BAS-9052, KK-80 and MBR-18337 for the control of johnsongrass and annual grasses in cotton. Proc. South. Weed Sci. Soc. 33:55.

9. Hill, L. V. 1980. KK-80 a topical postemergence herbicide for use in cotton & soybeans. Proc. South. Weed Sci. Soc. 33:338.

10. Linscott, D. L. 1970. The ten worst weeds in field crops. Quackgrass. Crops and Soils. 23:8-9.

11. Nalewaja, J. D., K. A. Adamczewski, L. Garcia-Torres, E. Pacholak and S. D. Miller. 1976. Factors affecting HOE-23408 phytotoxicity. Proc. North Central Weed Control Conf. 31:132-134.

12. Oliver, L. R., D. G. Mosier and O. W. Howe. 1982. A comparison of new postemergence herbicides for control of annual grasses. Abstr. Weed Sci. Soc. Am., p. 17.

13. Plowman, R. E., W. C. Stonebridge and J. N. Hawtree. 1980. Fluazifop-butyl--a new selective herbicide for the control of annual and perennial grass weeds. Proc. British Weed Control Conf. 17:29-37.

14. Ritter, R. L. and T. C. Harris. 1981. Interactions of postemergence soybean herbicides. Proc. Northeast. Weed Sci. Soc. 35:63.

15. Rogers, N. K., L. R. Oliver and R. E. Talbert. 1980. Response of several grass weeds to metriflufen. Weed Sci. 28:540-542.

16. Todd, B. G. and E. H. Stobbe. 1977. Selectivity of diclofop-methyl among wheat, barley, wild oat (*Avena fatua*) and green foxtail (*Setaria viridis*). Weed Sci. 25:382-385.

17. Veenstra, M. A., J. F. Vesecky and L. W. Hendrick. 1978. BAS-9052-OH, a new postemergence grass herbicide for soybeans. Proc. North Central Weed Control Conf. 33:69.

18. West, L. D., J. H. Dawson and A. P. Appleby. 1980. Factors influencing barnyardgrass (*Echinoloa crus-galli*) control with diclofop. Weed Sci. 28:366-371.

19. Westra, P. and D. L. Wyse. 1979. Quackgrass control in soybeans with BAS-9052 and KK-80. Proc. North Central Weed Control Conf. 34:34.

20. Woldetatios, T. and R. G. Harvey. 1977. Diclofop and bentazon interactions on soybeans and annual weeds. Proc. North Central Weed Control Conf. 32:42-43.

21. Wu, C. H. and P. W. Santelman. 1976. Phytotoxicity and soil activity of HOE-23408. Weed Sci. 24:601-604.

CHAPTER 3

ABSORPTION, TRANSLOCATION, AND ACTIVITY OF FLUAZIFOP-BUTYL AS AFFECTED BY PLANT GROWTH STAGE, TEMPERATURE, LIGHT, AND SOIL MOISTURE

ABSTRACT

Absorption and translocation of ^{14}C-fluazifop-butyl {(±)-butyl 2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy] propanoate} was compared in quackgrass [Agropyron repens (L.) Beauv.] and soybean [Glycine max (L.) Merr.]. Absorption was more rapid in soybeans with 75% of the recovered ^{14}C absorbed 6 h after treatment compared to 36% in quackgrass. Translocation of the radiolabel 144 h after treatment was 16.5% and 14.1% in soybeans and quackgrass, respectively. Data indicate that differential absorption and translocation did not contribute to the selectivity of fluazifop-butyl. Herbicidal activity of 0.56 kg/ha fluazifop-butyl was lower on quackgrass plants at the five- to six-leaf stage compared to those at the two- to three-leaf stage. Radioautographs indicated less extensive distribution of ^{14}C in the larger plants. Significantly more ^{14}C was removed in leaf washes 144 h after treatment from plants at the five- to six-leaf

stage than from those at the two-to three-leaf stage. Greater quackgrass control with 0.28 kg/ha fluazifop-butyl was observed at 30 C than at 20 C. Foliar absorption of ^{14}C-fluazifop-butyl was significantly greater at 30 C with 71.4% absorption of the applied ^{14}C 144 h after treatment compared to 45.3% abosprtion at 20 C. Radioautographs indicated more extensive distribution of ^{14}C at 30 C than at 20 C. Greatest herbicidal activity from 0.28 kg/ha fluazifop-butyl was observed on quackgrass plants exposed to 48 h of shade prior to treatment and full light after treatment. Plants exposed to full light translocated 17.9% of the applied ^{14}C 144 h after treatment compared to 14.1% in the shade. Moisture stress significantly reduced quackgrass control with 0.56 kg/ha fluazifop-butyl; however, no significant difference in absorption or translocation were observed.

INTRODUCTION

Quackgrass is a rhizomatous perennial grass that is well adapted to temperate regions of the world (6). It is a serious weed problem throughout the world, especially in the northern United States and southern Canada.

Successful chemical control of perennial weeds such as quackgrass requires that the biologically active compound is absorbed by the plant and translocated to the underground perennial tissue in sufficient concentration to cause death (7). Translocation has been observed with selective postemergence grass herbicides including diclofop-methyl {methyl 2-[4-(2',4'-dichlorophenoxy)phenoxy] propanoate} (1), sethoxydim {2-[1-(ethyloxyimino)butyl]-5-[2-(ethylothio)propyl]-3-hydroxy-2-cyclohexen-1-one}(2) and metriflufen {methyl 2-[4-(4'-trifluoromethyl phenoxy) phenoxy]propanoate} (9).

Environmental conditions influence translocation of foliar applied herbicides. For example, McWhorter (9) reported a two- to four-fold increase in translocation of ^{14}C-metriflufen in johnsongrass at 35 C compared to 18 C. High irradiance has been shown to promote translocation of ^{14}C-glyphosate [N-(phosphonomethyl)glycine] in johnsongrass [*Sorghum halepense* (L.) Pers.] (7).

Fluazifop-butyl is a selective postemergence herbicide which has excellent herbicidal activity on annual and perennial grasses in broadleaved crops (3,10). It is reported to be both xylem and phloem mobile (10).

The objectives of this study were to: (a) examine the absorption and translocation of ^{14}C-fluazifop-butyl in quackgrass and soybeans, (b) examine the role of quackgrass growth stage on absorption and translocation and activity of fluazifop-butyl, (c) examine the influence of environmental factors including temperature, light, and moisture stress on absorption, translocation, and activity of fluazifop-butyl.

MATERIALS AND METHODS

General greenhouse procedures. Quackgrass rhizomes were collected in the field and four-node sections were planted in 10-cm diameter plastic pots, one section per pot, filled with either vermiculite, greenhouse potting soil (1:1:1 soil, sand, peat), or a sandy loam soil with 75% sand, 12% silt, 13% clay, 0.8% organic matter, and a pH of 7.8. Soybeans were also grown from seed in the greenhouse, one plant per pot, in 10-cm diameter plastic pots filled with vermiculite. Plants were grown under temperatures of approximately 25 C-day/20 C-night. Natural light was supplemented with metal halide lighting, with a 16-h photoperiod at an average photosynthetic photon flux density (PPFD) of $280 \mu E \cdot m^{-2} \cdot s^{-1}$. Relative humidity ranged from 30 to 60%. All plants, except those used in a moisture stress study, were surface irrigated as needed to maintain soil moisture at or near field capacity. On a weekly basis, 50 ml of a soluble fertilizer (22.5% N - 22.5% P_2O_5 - 22.5% K_2O, 2 g/l) was added to each pot containing soil. Plants growing in vermiculite received 50 ml of a modified Hoagland's solution (5) at 3-day intervals.

Plants were treated with foliar spray applications and visually evaluated for phototoxicity. Foliar applications of formulated fluazifop-butyl were made using a moving belt sprayer delivering 355 L/ha at a pressure of 206 kPa. Herbicidal activity was evaluated 2, 4 and 6 weeks after treatment. Additional plants were treated with ^{14}C-fluazifop-butyl to examine absorption and translocation. Soybeans were treated in the one-to two-trifoliolate growth stage. Quackgrass plants were treated in the two-to three-leaf stage and also in the five- to six-leaf stage.

Herbicidal activity experiments were conducted with four replications. Absorption and translocation studies with ^{14}C-fluazifop-butyl were conducted using a total of five replications with two replications used for radioautography. All studies were repeated and data presented are means of two experiments.

Laboratory procedure with ^{14}C-fluazifop-butyl. A stock treatment solution was prepared by adding 1.2 μl of technical grade fluazifop-butyl and 4.8 μl of blank formulation (Imperial Chemical Industries, LTD) to 50 μCi of uniformly ring labelled ^{14}C-fluazifop-butyl (specific activity of 61.2 mCi/mM) followed by the addition of 1.25 ml 0.5% (v/v) X-77[1]

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[1]X-77 is a non ionic surfactant composed of a mixture of alkylaryl-polyoxyethylene glycols, free fatty acids, and isopropanol produced by Chevron Chem. Co., San Francisco, CA.

surfactant. Agitation of the mixture extablished a stable emulsion. The treatment solution was stored frozen between treatment times. For each study conducted, plants were treated with formulated fluazifop-butyl at 0.56 kg/ha in combination with X-77 surfactant at 0.5% (v/v) with a moving belt sprayer as previously described. Uniform quackgrass plants with two connected shoots and soybeans in one- to two-trifoliolate growth stage were selected and treated with 0.40 μCi ^{14}C-fluazifop-butyl. Three μl of treatment solution [7.5 μl/μCi with 0.5% (v/v) X-77 surfactant] were applied with a microsyringe to a 2.0 cm^2 area in the center of the uppermost fully expanded quackgrass leaf or to the central leaflet of the first trifoliolate of soybean plants. The treated portion of the plants was removed and the plants were harvested. The treated portions were washed consecutively in two 150 ml beakers containing 100 ml 0.5% (v/v) X-77 surfactant. A 1-ml aliquot was added to 15 ml of liquid scintillation fluid for radioassay by liquid scintillation spectrometry. Treated plants were lyophilized and analyzed for radioactivity. Absorption and translocation were determined both qualitatively by radioautography (4) and quantitatively by combustion of plant parts followed by radioassay using liquid scintillation spectrometry.

Translocation was computed by comparing the radioactivity recovered in the entire plant, except the treated portion of the treated leaf, to the total activity applied or recovered. Absorption was computed by comparing the radioactivity recovered in the entire plant, including the treated portion of the treated leaf after being washed, to the total radioactivity applied or recovered. Total recovery was computed by adding the radioactivity in the leaf wash to the radioactivity in the entire plant, compared to the total radioactivity applied.

Comparison of species. Quackgrass and soybeans grown in vermiculite were treated with ^{14}C-fluazifop-butyl as previously described and were maintained in the greenhouse. Quackgrass was in two- to three-leaf stage and soybeans were in one- to two-trifoliolate growth stage. Plants were harvested 6, 48, and 144 h after treatment.

Comparison of quackgrass growth stages. Quackgrass plants grown in vermiculite in two- to three-leaf stage and five- to six-leaf stage were treated with ^{14}C-fluazifop-butyl. Plants were harvested 144 h after treatment. In a second study, quackgrass plants grown in greenhouse potting soil were treated at the two- to three-leaf or five- to six-leaf stage with fluazifop-butyl at 0.14 to 1.12 kg/ha and evaluated for phytotoxicity. Additional plants were treated at both the two- to three-leaf and five- to six-leaf stage.

Effect of temperature. Forty-eight hours prior to treatment, quackgrass plants in the two- to three-leaf stage grown in vermiculite were placed in growth chambers containing both incandescent and fluorescent lights that provided a 16-h photoperiod with an average PPFD of $146 \mu E \cdot m^{-2} \cdot s^{-1}$. Temperature was maintained at 20 or 30 C. Plants treated with ^{14}C-fluazifop-butyl were harvested 144 h after treatment. Additional quackgrass plants were treated with 0.28 and 0.56 kg/ha fluazifop-butyl and evaluated for phytotoxicity.

Effect of light. A shading cloth was used over a greenhouse bench to provide shaded conditions. Irradiance under the shading cloth was $53\mu E{\cdot}m^{-2}{\cdot}s^{-1}$. Irradiance without the shading cloth on the same bench was $280\mu E{\cdot}^{-2}{\cdot}s^{-1}$. Forty-eight hours prior to treatment, quackgrass plants grown in vermiculite were selected and placed in shade or full light. Plants treated with ^{14}C-fluazifop-butyl were harvested 144 h after treatment. Additional plants were treated with 0.28 or 0.56 kg/ha fluazifop-butyl. After treatment, plants either remained in the same irradiance as before treatment or were moved to the opposite condition. Plants were visually evaluated for phytotoxicity.

Effect of soil moisture. Quackgrass rhizomes were grown in the greenhouse in a sandy loam soil previously described. Following emergence of quackgrass shoots, plants were exposed to conditions of moisture stress or adequate moisture throughout the duration of the experiment. Soil moisture was maintained at or near field capacity [21% (w/w) moisture] for plants grown under adequate moisture. Plants under moisture stress were maintained under conditions of 6% to 10% (w/w) soil moisture. When plants reached the two- to three-leaf stage, uniform plants were selected for treatment with ^{14}C-fluazifop-butyl and harvested 144 h after treatment. Additional plants were treated with a foliar application of fluazifop-butyl at 0.28 or 0.56 kg/ha in combination with 0.5% (v/v) X-77 surfactant or oil concentrate at 2.34 L/ha and evaluated for phytotoxicity.

RESULTS AND DISCUSSION

Comparison of species. Absorption and translocation of ^{14}C-fluazifop-butyl occurred in both soybeans, a tolerant broadleaved plant and quackgrass, a susceptible grass (Figures 1, 2). Absorption was significantly greater in soybeans than in quackgrass 6 h after treatment with 75% of the recovered ^{14}C absorbed by soybeans compared to 36% absorption in quackgrass. Additional ^{14}C was absorbed between 6 h and 48 h after treatment by both species. No significant increase in absorption was observed between 48 h and 144 h after treatment. No significant difference in absorption between quackgrass and soybeans was apparent 48 or 144 h after treatment (Figure 1).

Translocation 6 h after treatment was observed in both species with 1.5% and 2.3% of the recovered ^{14}C translocated in quackgrass and soybeans, respectively (Figure 2). Additional translocation occurred between 6 h and 144 h after treatment for both species. Considerable translocation and accumulation of ^{14}C was observed 144 h after treatment in both species with 16.5% of the recovered ^{14}C translocated in soybeans compared to 14.1% translocation in quackgrass (Figure 2). Radioautographs of treated plants indicate

Figure 1. Absorption of ^{14}C following application of ^{14}C-fluazifop-butyl to quackgrass and soybeans.

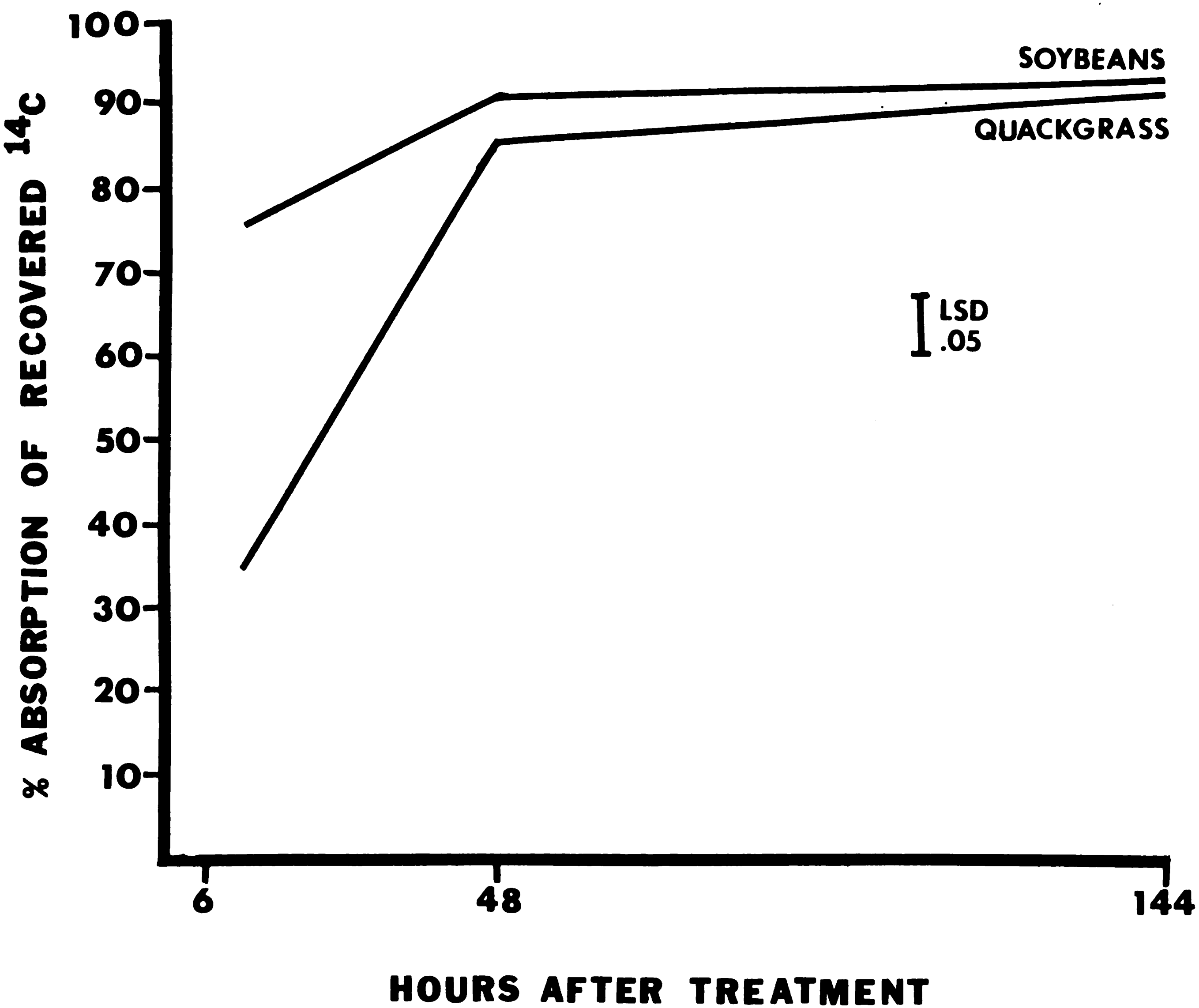

SOYBEANS
QUACKGRASS
LSD .05
100
90
80
70
60
50
40
30
20
10
% ABSORPTION OF RECOVERED ^{14}C
6
48
144
HOURS AFTER TREATMENT

Figure 2. Translocation of ^{14}C following application of ^{14}C-fluazifop-butyl to quackgrass and soybeans.

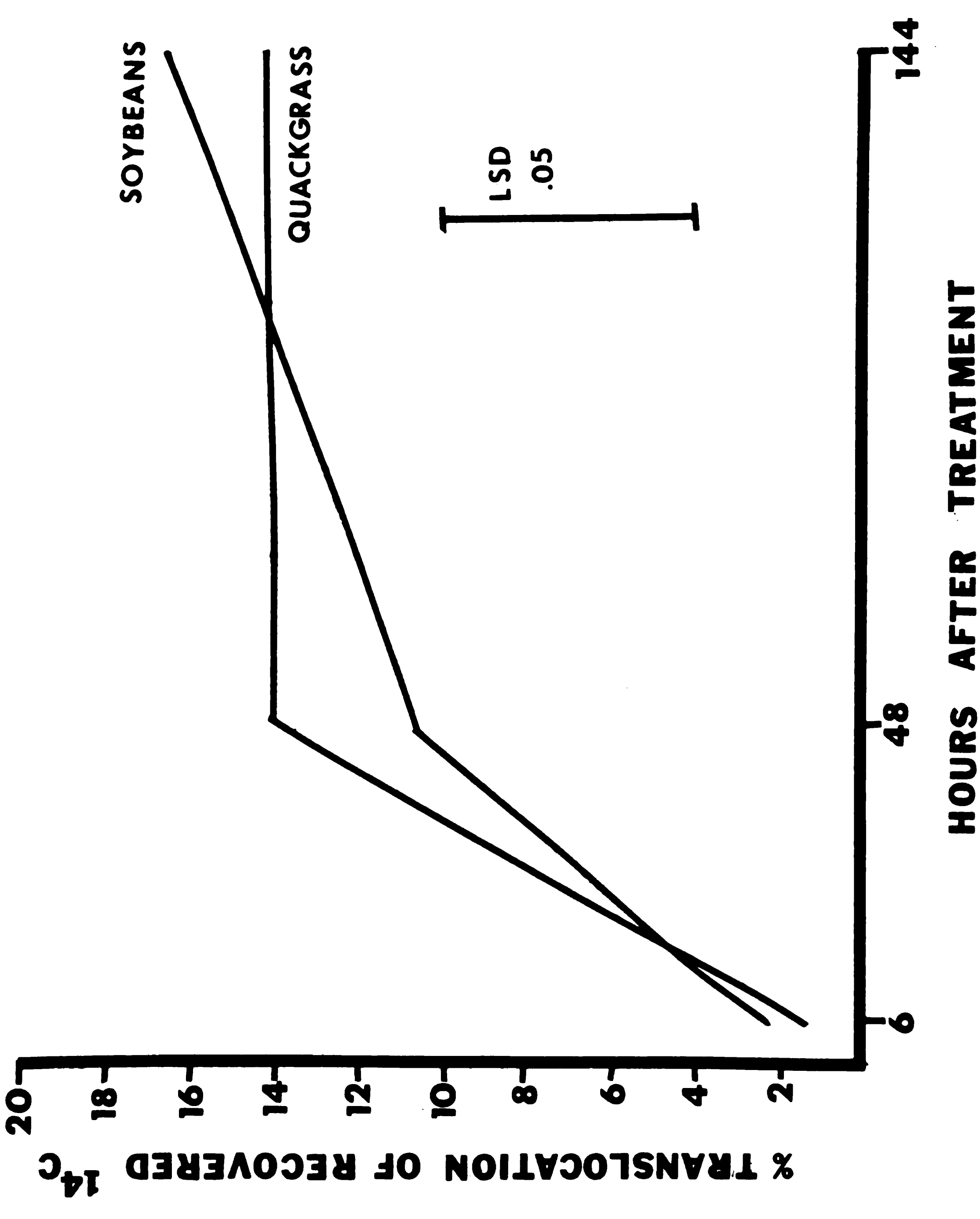
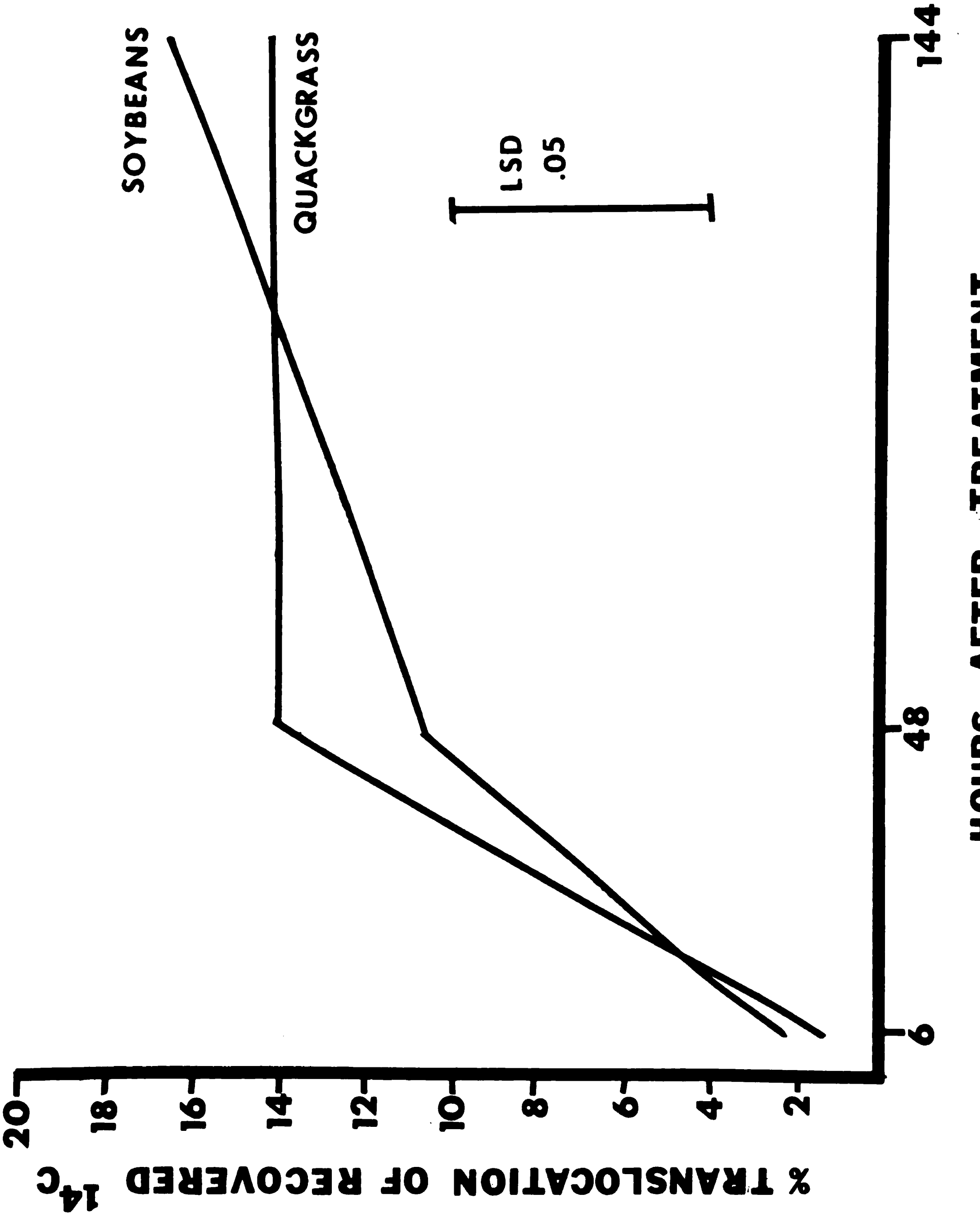

SOYBEANS
QUACKGRASS
LSD
.05
% TRANSLOCATION OF RECOVERED ^{14}C
20
18
16
14
12
10
8
6
4
2
6
48
144
HOURS AFTER TREATMENT

Figure 2. Translocation of ^{14}C following application of ^{14}C-fluazifop-butyl to quackgrass and soybeans.



SOYBEANS
QUACKGRASS
LSD
.05
HOURS AFTER TREATMENT
6
48
144
% TRANSLOCATION OF RECOVERED ^{14}C
2
4
6
8
10
12
14
16
18
20

basipetal translocation in both species 6 h after treatment (Figures 3, 4). After 144 h the radiolabel was distributed throughout all plant parts of both species, including the adjacent shoot in quackgrass. Radioautographs also indicate accumulation of ^{14}C in meristematic areas of both plants (Figures 3, 4). These data indicate that absorption and translocation are not selectivity mechanism for fluazifop-butyl between quackgrass and soybeans.

Recovery of ^{14}C following application of ^{14}C-fluazifop-butyl decreased over time in both species (Figure 5). Recovery of applied ^{14}C 144 h after treatment was significantly greater in soybeans compared to quackgrass with 79.2% and 66.2% recovery, respectively. This observation may be related to the more rapid rate of absorption by soybeans (Figure 1).

Comparison of quackgrass growth stages. In the greenhouse, quackgrass control with 0.56 kg/ha fluazifop-butyl was significantly greater when treatments were applied to plants in the two- to three-leaf stage compared to plants in the five- to six-leaf stage (Table 1). Quackgrass plants treated with ^{14}C-fluazifop-butyl at the two- to three-leaf stage translocated 12.4% of the applied ^{14}C 144 h after treatment compared to 10.0% translocation in plants at the five- to six-leaf stage; however, this difference was not significant (Table 2). Significantly more ^{14}C was removed in the leaf wash from treated leaves of the plants at the five- to six-leaf stage. This indicates a difference in

Figure 3. Translocation and distribution of ^{14}C-fluazifop-butyl in quackgrass. Plant and corresponding radioautograph following harvest 6 h after treatment (A) and 144 h after treatment (B). Plant left, radioautograph right. The treated portion of the treated leaf is marked with an arrow.

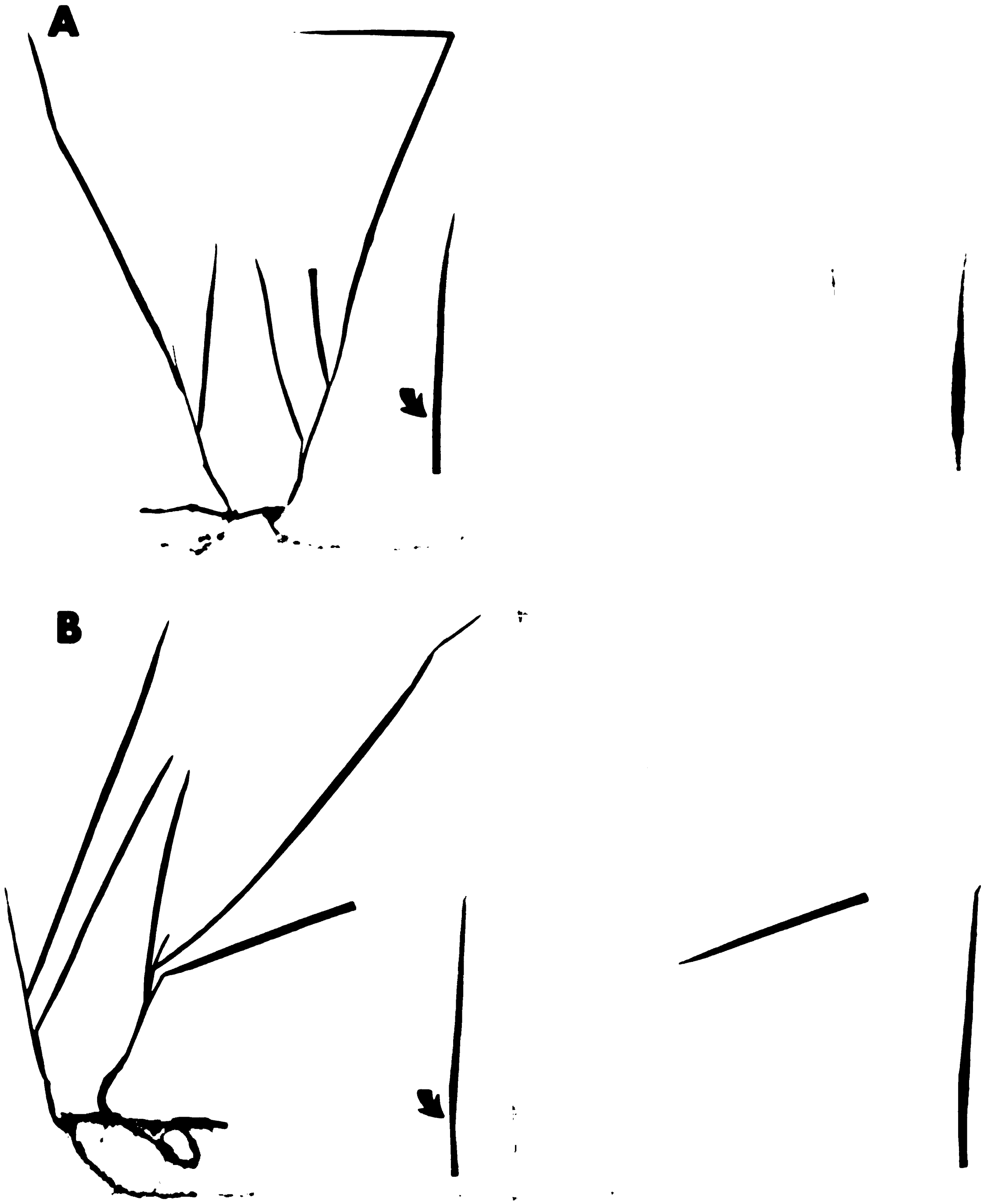

A
B

Figure 4. Translocation and distribution of ^{14}C-fluazifop-butyl in soybeans. Plant and corresponding radioautograph following harvest 6 h after treatment (A) and 144 h after treatment (B). Plant left, radioautograph right. The treated portion of the treated leaf is marked with an arrow.

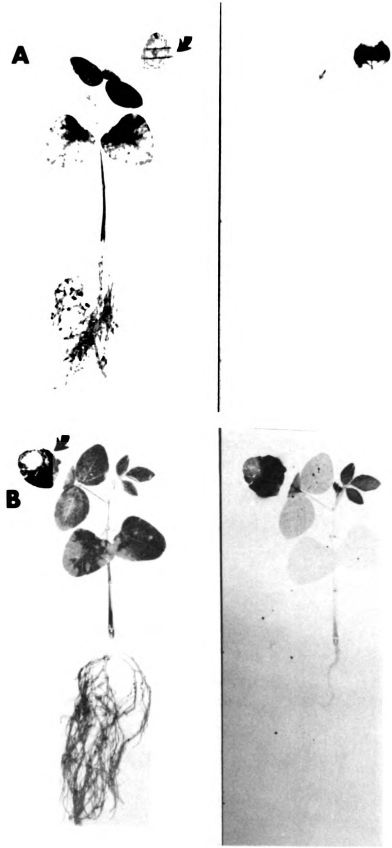

A
B

Figure 5. Recovery of ^{14}C following application of ^{14}C-fluazifop-butyl to quackgrass and soybeans.

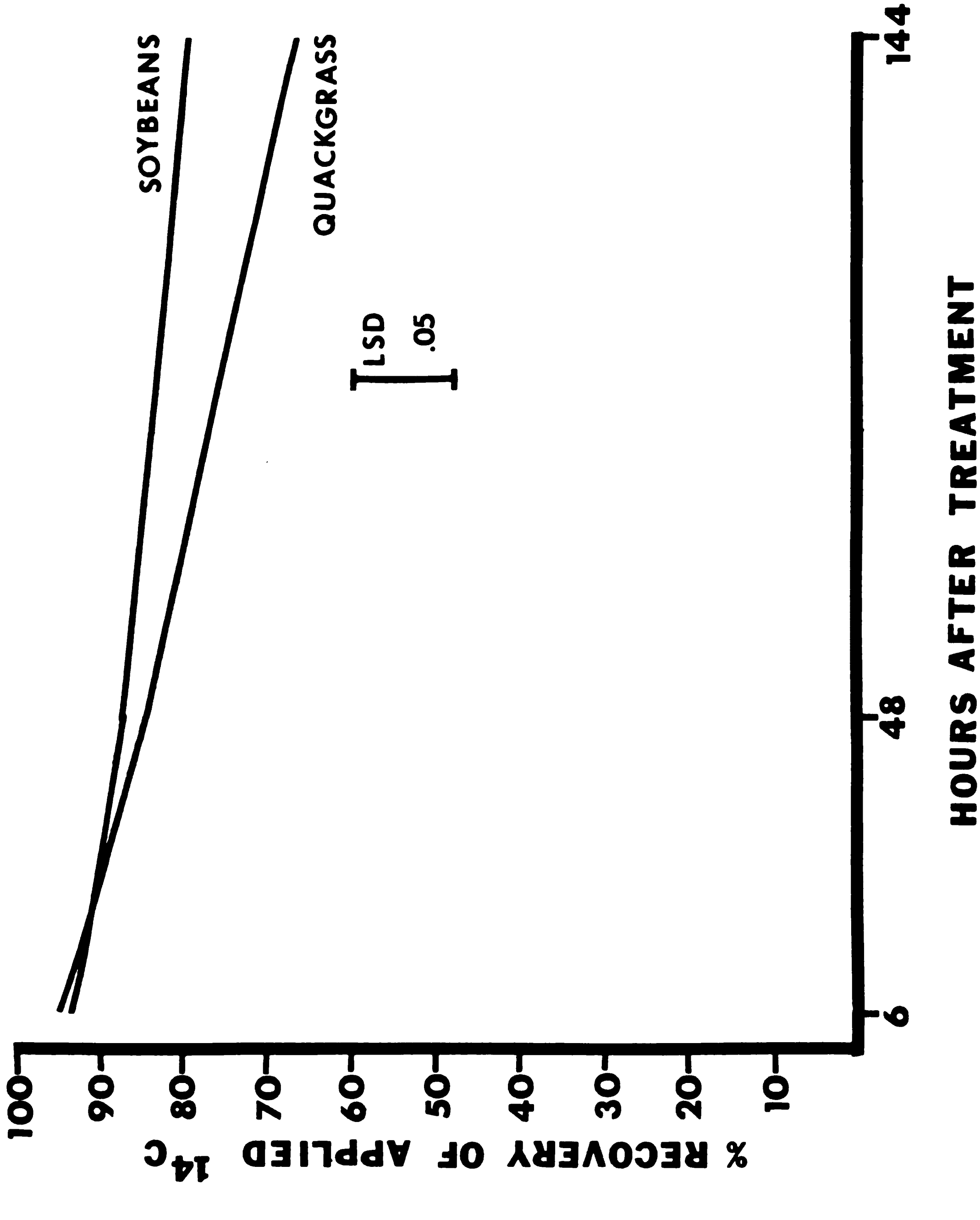

SOYBEANS
QUACKGRASS
LSD .05
% RECOVERY OF APPLIED ^{14}C
100
90
80
70
60
50
40
30
20
10
6
48
144
HOURS AFTER TREATMENT

Table 1. The effect of time of treatment and sequential applications on quackgrass phytotoxicity with fluazifop-butyl in the greenhouse 4 weeks after treatment.[a]

Fluazifop-butyl rate[b]	Quackgrass control		
	EP[c]	LP	EP + LP
(kg/ha)	(%)		
0	0f	0f	0f
0.14	28e	25e	
0.28	35de	35de	40de
0.56	75ab	53cd	63bc
1.12	80ab	65bc	88a

[a]Means followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]All herbicide treatments included X-77 surfactant at 0.5% (v/v).

[c]Early postemergence (EP) and late postemergence (LP) treatments were applied to quackgrass plants in the two- to three-leaf and five- to six-leaf stage, respectively.

the characteristics of the cuticle with different maturities of quackgrass. No differences in recovery or translocation were observed (Table 2). Radioautographs of treated plants suggest that, although total translocation was similar, distribution throughout the plant was more extensive in plants in the two- to three-leaf stage with much of the translocated ^{14}C in the plants at the five- to six-leaf stage remaining in the proximal untreated portion of the treated leaf (Figure 6). These differences may partially explain the loss of control with fluazifop-butyl observed in the greenhouse when applied to plants at the five- to six-leaf stage.

Effect of temperature. Significantly greater quackgrass phytotoxicity with 0.28 kg/ha fluazifop-butyl was observed with plants under 30 C compared to 20 C (Table 3). However, this response was not observed when the application rate was increased to 0.56 kg/ha. With quackgrass plants treated with ^{14}C-fluazifop-butyl, no significant difference in translocation was observed bewteen 20 C and 30 C (Table 2). However, absorption was significantly greater at 30 C with 71.4% absorption of the applied ^{14}C compared to 45.3% absorption at 20 C. In addition, leaf washes removed more than six times more ^{14}C from plants at 20 C compared to 30 C. No quantitative differences in translocation or recovery were observed (Table 2). Although no quantitative difference in total translocation occurred, radioautographs indicate more extensive distribution of ^{14}C in plants under

Table 2. The effect of plant growth stage, temperature, light, and moisture stress on absorption, translocation, and recovery of ^{14}C-fluazifop-butyl in quackgrass 144 h after treatment.[a]

Variable	% of Applied ^{14}C Recovered	Leaf wash	Absorbed	Translocated
	(%)			
Growth Stage				
5 to 6 leaf	68.8a	9.3a	59.5a	10.0a
2 to 3 leaf	71.8a	4.4b	67.4a	12.4a
Temperature				
20C	74.8a	29.5a	45.3b	8.8a
30C	75.7a	4.3b	71.4a	8.4a
Illuminance[b]				
Light	73.4a	6.1a	67.3a	17.9a
Shade	67.9a	6.0a	61.9a	14.1b
Moisture Stress[c]				
Moist soil	73.7a	3.0a	70.7a	18.4a
Dry soil	68.1a	4.9a	63.2a	14.3a

[a]Means within a variable and column followed by a common letter are not significantly different at the 5% level of probability.

[b]Irradiance in light and shade was $280\mu E \cdot m^{-2} \cdot s^{-1}$ and $53\mu E \cdot m^{-2} \cdot s^{-1}$, respectively.

[c]Soil moisture was field capacity [21% (w/w)] for moist soil and 6 to 10% (w/w) for dry soil.

Figure 6. The influence of quackgrass growth stage on translocation and distribution of ^{14}C-fluazifop-butyl in quackgrass. Plant and corresponding radioautograph of quackgrass plants in the two- to three-leaf stage (A) and the five- to six-leaf stage (B). Plant left, radioautograph right. The treated portion of the treated leaf is marked with an arrow.


A
B

Table 3. The influence of temperature, light, and moisture stress on quackgrass phytotoxicity with fluazifop-butyl 4 weeks after treatment.[a]

	Quackgrass control									
	Temperature		Light[b]		Shade		X-77[c]		O.C.[d]	
Rate	20C	30C	Light	Shade	Light	Shade	Moist soil[e]	Dry soil[f]	Moist soil	Dry soil
(kg/ha)	(%)									
0	0d	0d	0d	0d	0d	0d	0e	0e	0e	0e
0.28	67c	74b	50c	59bc	78ab	42c	36cd	23d	19d	21d
0.56	85a	83a	80ab	90a	87a	100a	54ab	33cd	64a	43bc

[a]Means within an environmental factor followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]Irradiance in light and shade was $280 \mu E \cdot m^{-2} \cdot s^{-1}$ and $53 \mu E \cdot m^{-2} \cdot s^{-1}$, respectively.

[c]X-77 surfactant was added to the spray mixture at 0.5% (v/v).

[d]Oil concentrate was added to the spray mixture at 2.34 L/ha.

[e]Moist soil was maintained at or near field capacity [21% (w/w)].

[f]Dry soil was maintained between 6 and 10% (w/w) moisture.

30 C compared to 20 C (Figure 7). Increased absorption and more extensive distribution in plants under 30 C compared to 20 C may partially explain the lower phytotoxicity of fluazifop-butyl on quackgrass plants exposed to 20 C.

Effect of light. No significant difference in herbicidal activity from fluazifop-butyl at 0.28 kg/ha was observed between quackgrass plants maintained in constant shade or full light (Table 3). However, greatest control was observed on plants exposed to shade for 48 h prior to treatment and to full light following treatment. In addition, early evaluations of treated plants indicate that phytotoxicity occurred more rapidly with plants exposed to shade before treatment and full light after treatment. The effect of light was overcome by increasing the rate of fluazifop-butyl to 0.56 kg/ha (Table 3). Translocation of ^{14}C in quackgrass following application of ^{14}C-fluazifop-butyl was significantly greater under full light compared to shade (Table 2). Plants exposed to full light translocated 17.9% of the applied ^{14}C compared to 14.1% translocation under shaded conditions. No significant differences in absorption or recovery were observed (Table 2). Radioautographs of treated plants indicate no difference in distribution of ^{14}C between plants in full light and plants in shade (Figure 8). Data suggest that translocation of ^{14}C-fluazifop-butyl is influenced by photosynthate movement in the phloem. Reduced translocation under lower irradiance may influence herbicidal activity of fluazifop-butyl under certain conditions.

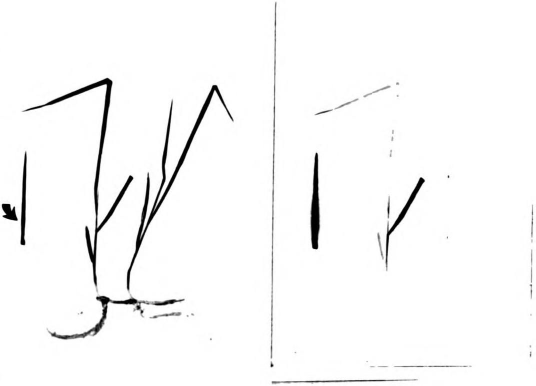
Figure 7. The influence of temperature on translocation and distribution of ^{14}C-fluazifop-butyl. Plant and corresponding radioautograph of quackgrass maintained at 20 C (A) and 30 C (B). Plant left, radioautograph right. The treated portion of the treated leaf is marked with an arrow.

A

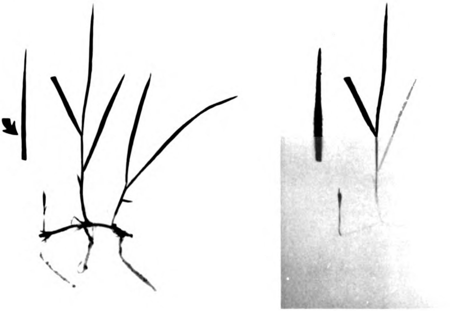
B

Figure 8. The influence of irradiance on translocation and distribution of ^{14}C-fluazifop-butyl in quackgrass. Plant and corresponding radioautograph of quackgrass maintained under light irradiance of $280 \mu E \cdot m^{-2} \cdot s^{-1}$ (A) and $53 \mu E \cdot m^{-2} \cdot s^{-1}$ (B). Plant left, radioautograph right. The treated portion of the treated leaf is marked with an arrow.

A



B



Effect of moisture stress. Herbicidal activity of fluazifop-butyl at 0.56 kg/ha was significantly greater when application was made to plants maintained under adequate moisture compared to plants under moisture stress (Table 3). This observation agrees with findings on johnsongrass reported by Ready and Wilkerson (11). This response was observed when either X-77 at 0.5% (v/v) or oil concentrate at 2.34 L/ha were included in the spray mixture. No significant difference in control with fluazifop-butyl was observed between X-77 and oil concentrate as spray additives (Table 3). Translocation of ^{14}C in quackgrass following application of ^{14}C-fluazifop-butyl was 18.4% in plants under adequate moisture compared to 14.3% in plants under moisture stress; however, this difference was not significant (Table 2). No significant differences in absorption or recovery were observed. However, radioautographs of treated plants suggest that more extensive distribution of ^{14}C occurred in plants grown under adequate moisture (Figure 9).

In another study, absorption of ^{14}C 144 h after treatment was significantly greater when a foliar application prior to treatment with the radiolabel included oil concentrate at 2.34 L/ha compared to 0.5% (v/v) X-77 surfactant as is shown in Table 1 of the appendix. No significant differences in absorption or translocation were observed with spray mixtures of fluazifop-butyl with bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] or acifluorfen [sodium 5-2-chloro-4-(trifluoromethyl)-phenxoy-2-nitrobenzoate].

Figure 9. The influence of soil moisture on translocation and distribution of ^{14}C-fluazifop-butyl. Plant and corresponding radioautograph of quackgrass maintained at 6 to 10% (w/w) soil moisture (A) and 21% (w/w) soil moisture (B). Plant left, radioautograph right. The treated portion of the treated leaf is marked with an arrow.

Herbicidal activity of fluazifop-butyl on quackgrass is influenced by several variables including plant growth stage, temperature, light, and moisture stress. The effect of these variables on absorption, translocation and distribution of fluazifop-butyl in quackgrass may partially explain the influence of these variables on herbicidal activity.

LITERATURE CITED

1. Boldt, P. F. and A. R. Putnam. 1980. Selectivity mechanisms for foliar application of diclofop-methyl. I Retention, absorption, translocation and volatility. Weed Sci. 28:474-477.

2. Campbell, J. R. and D. Penner. 1981. Absorption and translocation of BAS-9052 OH (2-[1-(ethoxyimino)-butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexen-1-one). Abstr. Weed Sci. Soc. Am., p. 13.

3. Colby, S. R., J. R. Bone and A. A. Akhavein. 1982. PP009, a selective herbicide for control of perennial and annual grasses. Abstr. Weed Sci. Soc. Am., p. 14-15.

4. Crafts, A. S. and S. Yamaguchi. 1964. The autoradiography of plant materials. California Agric. Exp. Sta. Manual 35. 143 pp.

5. Hoagland, D. R. and D. I. Arnon. 1950. The water culture method for growing plants without soil. California Agric. Exp. Sta. Circ. 347. 32 pp.

6. Holm, L. G., D. L. Plucknett, J. V. Poncho, and J. P. Herberger. 1977. The World's Worst Weeds. University Press of Hawaii, Honolulu, Hawaii. 609 pp.

7. Kells, J. J. and C. E. Rieck. 1979. Effect of illuminance and time on accumulation of glyphosate in johnsongrass. Weed Sci. 27:235-237.

8. Linscott, D. L. 1970. The ten worst weeds in field crops. Quackgrass. Crops and Soils 23:-8-9.

9. McWhorter, C. G. 1981. The effect of temperature and relative humidity on translocation of ^{14}C-metriflufen in johnsongrass (_Sorghum halepense_) and soybean (_Glycine max_). Weed Sci. 27:42-47.

10. Plowman, R. E., W. C. Stonebridge and J. N. Hawtree. 1980. Fluazifop-butyl--a new selective herbicide for the control of annual and perennial grass weeds. Proc. British Weed Control Conf. 17:29-37.

11. Ready III, E. L. and J. Wilkerson. 1982. Postemergence control of rhizome johnsongrass [_Sorghum halepense_ (L.) Pers.] with PP009 as effected by drought stress. Abstr. Weed Sci. Soc. Am., p. 15.

12. Sprankle, P., W. F. Meggitt, and D. Penner. 1975. Absorption, action, and translocation of glyphosate. Weed Sci. 23:235-240.

CHAPTER 4

SUMMARY AND CONCLUSIONS

Studies were conducted in the field to evaluate the efficacy of several selective postemergence grass herbicides in soybeans and to examine factors influencing grass control with these herbicides. Greenhouse and laboratory studies were conducted to examine factors affecting absorption, translocation, and herbicidal activity of fluazifop-butyl.

Several herbicides were found to provide excellent control of quackgrass and annual grasses with little injury to soybeans. In all cases the rate necessary for annual grass control was less than for quackgrass. For control of quackgrass the time of application was an important factor with each of the compounds tested. In 1980, late treatments applied to 16- to 22-cm tall quackgrass provided greater midseason quackgrass control and regrowth control than early treatments applied to 7- to 13-cm tall plants with most of the herbicides tested. In 1981, no differences in control were observed between early and late treatments; however, quackgrass regrowth control the following spring was greater from early treatments with most of the herbicides tested. This indicates less translocation to the perennial tissue of the larger plants. Data indicate that a window of maximum control exists in terms of quackgrass growth stage. The time of application was more critical for certain herbicides than others. For example, quackgrass control with RO-13 8895 appeared to be the most sensitive to plant growth stage while control with NCI-96683 and Dowco 453 was influenced much less by plant growth stage. Soil herbicidal activity may explain in part the reduced influence of plant growth stage on quackgrass control with NCI-96683 and Dowco 453. Sequential applications of each of the herbicides tested provided equal or greater quack-grass control and regrowth control than single applications of the same total rate regardless of the time of application. From a practical standpoint the optimum time of application may not be a critical issue since it is likely that these herbicides will be applied in sequential applications for quackgrass control. Plant growth stage was much less critical for annual grass control in the field compared to quackgrass.

Herbicide antagonisms on annual grasses were consistently observed only with diclofop-methyl. Quackgrass control with several postemergence grass herbicides was significantly reduced when acifluorfen or bentazon was added to the spray mixture. The intensity of these antagonisms varied between compounds and could be overcome in part by increasing the rate of the grass herbicide. Greenhouse and laboratory data indicate that the antagonism between fluazifop-butyl and bentazon is not related to absorption or translocation of fluazifop-butyl. An understanding of these antagonisms by herbicide applicators is important in order to avoid loss of control with certain herbicide combinations.

Herbicide injury to soybeans from each of the compounds tested was minimal with the greatest injury observed with NCI-96683 and NCI-96721. Injury was always significantly greater when acifluorfen was included in the spray mixture. However, herbicide injury was not persistent and plants were able to recover. Data indicate that herbicide injury did not result in a significant yield reduction. Yield data also indicate that complete eradication of grasses may not be necessary in order to eliminate competition with the crop.

Greenhouse studies with fluazifop-butyl indicate herbicidal activity on barnyardgrass and quackgrass from applications to the soil. Herbicidal activity from fluazifop-butyl applied to the soil at 1.12 kg/ha persisted for 30 days after treatment. Soil herbicidal activity contributed to control of 4- to 6-cm tall barnyardgrass from foliar applications of fluazifop-butyl in the greenhouse. Activity and persistence of fluazifop-butyl in the soil may be an important factor in effective control, especially in control of grasses that germinate after treatment.

Greenhouse and laboratory experiments with ^{14}C-fluazifop-butyl indicate that the herbicide is absorbed, translocated, and distributed throughout the plant in both quackgrass and soybeans. Absorption occurred more rapidly in soybeans, a tolerant species. These results indicate that absorption and translocation are not selectivity mechanisms for fluazifop-butyl.

Several environmental factors affected absorption, translocation of herbicidal activity of fluazifop-butyl in the greenhouse. Data suggest that greater herbicidal activity on quackgrass plants at the two- to three-leaf stage compared to those at the five- to six-leaf stage may be related to greater absorption and distribution in the younger plants. Greater herbicidal activity was observed with quackgrass plants maintained at 30 C compared to 20 C. This may be related to much greater absorption and more complete distribution of the radiolabel at 30 C compared to 20 C. Significantly greater translocation of ^{14}C following application of ^{14}C-fluazifop-butyl occurred in quackgrass plants exposed to light irradiance of $280\mu E \cdot m^{-2} \cdot s^{-1}$ compared to $53\mu E \cdot m^{-2} \cdot s^{-1}$. This suggests that light may influence quackgrass control in the field with fluazifop-butyl, especially when minimal rates are used. Herbicidal activity of fluazifop-butyl was significantly reduced with plants grown under moisture stress. However, no significant differences in absorption or translocation were observed.

The chemistry of herbicides examined in this study offer some interesting comparisons. Each of the herbicides with known chemistry except sethoxydim are either diphenyl-ether structures or are closely related to diphenyl-ethers. General herbicidal activity of each of the compounds is similar. Diclofop-methyl, metriflufen, difenopenten, and RO-13 8895 are diphenyl-ethers. Of these four herbicides, diclofop-methyl is the only compound that lacks herbicidal activity on quackgrass. It is also the only compound that does not have a trifluoromethyl group in its structure. In addition development of each of the four herbicides except diclofop-methyl has been discontinued by the respective companies. CGA 82725, fluazifop-butyl, and Dowco 453 are each (2-pyrindinyl)oxy-phenoxy-propanoate herbicides. Of these three herbicides, CGA-82725 has much less herbicidal activity on quackgrass and is the only herbicide of this group which does not have a trifluoromethyl group in its structure. The only compound evaluated with known chemistry which has herbicidal activity on quackgrass and does not contain a trifluoromethyl group is sethoxydim.

In conclusion, selective postemergence grass control in broadleaved crops represents a new concept in chemical weed control. Herbicides in this class are expected to provide a valuable mechanism for quackgrass control in broadleaved crops such as soybeans. In addition, these herbicides provide considerable flexibility in postemergence control of annual grasses. The role that each of these herbicides will fill in a weed control program will be dependent upon several factors including the cropping rotation, the spectrum of weeds present, and the cost of the herbicides to the producer.

APPENDIX

Table 1. Absorption, translocation, and recovery of ^{14}C-fluazifop-butyl in quackgrass 144 h after treatment as affected by pretreatment with herbicide additives and herbicide combinations.[a]

Herbicide Pretreatment[b]	Recovered	Leaf wash	Absorbed	Translocated
	% of applied ^{14}C			
	(%)			
Fluazifop-butyl+ X-77	71.8c	4.4b	67.4c	12.4a
Fluazifop-butyl+ O.C.	85.5a	8.6a	76.9a	12.8a
Fluazifop-butyl+ acifluorfen	72.7c	10.0a	62.7bc	10.8a
Fluazifop-butyl+ bentazon+O.C.	79.7b	5.9b	73.8ab	12.8a

[a]Means within a column followed by a common letter are not significantly different at the 5% level of probability according to Duncan's multiple range test.

[b]Fluazifop-butyl, X-77 surfactant, oil concentrate (OC), acifluorfen, and bentazon were applied at 0.56 kg/ha, 0.5% (v/v), 2.34 L/ha, 0.56 kg/ha, and 0.84 kg/ha, respectively.