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INTERACTION OF BENTAZON (3-ISOPROPYL-IH-2,1,3-BENZOTHIADIAZIN-4(3H)-ONE 2,2-DIOXIDE) WITH DICLOFOP (2-(4-(2,4-DICHLOROPHENOXY) PHENOXY) PROPANOATE) AND SEVERAL ORGANOPHOSPHATE INSECTICIDES

presented by

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INTERACTION OF BENTAZON (3-ISOPROPYL-1H-2,1,3-BENZOTHIADIAZIN-4(3H)-ONE 2,2-DIOXIDE) WITH DICLOFOP (2-(4-(2,4-DICHLOROPHENOXY) PHENOXY) PROPANOATE) AND SEVERAL ORGANOPHOSPHATE INSECTICIDES

By

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ABSTRACT

INTERACTION OF BENTAZON (3-ISOPROPYL-1H-2,1,3-BENZO-THIADIAZIN-4(3H)-ONE 2,2-DIOXIDE) WITH DICLOFOP (2-(4-(2,4-DICHLORO-PHENOXY) PHENOXY) PROPANOATE) AND SEVERAL ORGANOPHOSPHATE INSECTICIDES

By

James Robert Campbell

The organophosphate insecticides malathion(O,O-dimethyl S-(1,2-dicarbethoxyethel)posphoridithionate), parathion(O,O-diethyl O-p-nitrophenyl phosphorothioate and diazinon (O,O-diethyl O-(2-isopropyl-4-methyl-6-pyrimidinyl)phosphorothioate) combined with bentazon (3-iso propyl-1H-2,1,3-benzothiadiazin-4 (3H)-one 2,2 dioxide) caused severe injury to soybean (Glycine max (L.) Merr. 'Corsoy') and navy bean (Phaseolus vulgaris L. 'Seafrer') as a postemergence spray. Postemergence tankmixture applications of bentazon with organophosphate or carbamate insecticides, or soil applied organophosphate insecticides prior to bentazon treatments did not interact with bentazon to injure corn (Zea mays L. 'Great Lakes Hybrid 4122'). Technical grade malathion interacted with bentazon similar to formulated malation. Malathion applications 48 hours before or after bentazon applications injured soybeans to the same extent as tankmixtures of the compounds.

Bentazon reduced the activity of diclofop (2-(4-(2,4-diclorophenoxy) phenoxy)propanoate) on annual grasses in tankmixtures. Bentazon did not reduce the activity of BAS 9052 (2-(1-(ethoxyimino)-butyl)-5-(2-

(ethylthio)propyl)-3-hydroxy-2-cyclohexene-1-one) in controlling annual grasses in greenhouse and field experiments.

The wettable powder formulation of bentazon as well as higher temperatures slighly reduced the antagonistic interaction of bentazon and diclofop. In greenhouse studies soybeans were injured by the diclofop bentazon combination. However, in field studies this injury was not sufficient to reduce soybean yield.

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INTRODUCTION

Modern agriculture requires increased economic efficiency in all areas of production. Pest management is an important aspect of crop production, the use of insecticides and herbicides have increased yields and decreased production cost. Application of pesticide combinations can further increase production efficiency, resulting in reduced fuel and labor costs, decreased soil compaction and more effecient equipment use.

Bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide] is a postemergence herbicide effective in controlling a number of broadleaved and sedge weeds including Compositae, Ambrosiaceae, Convolvulaceae, Polygonaceae and Cyperaceae (19). The control of grass weeds or insects could be facilitated by tank mixing other pesticides with bentazon. But indiscriminate mixing of pesticides is illadvised since many combinations have shown synergistic injury to the crop or antagonism of weed control (1,6,7,10,11,13,17).

Bentazon has been reported to exibit increased soybean injury when combined with the grass killing herbicide diclofop [2-(4-(2,4-dichloro phenoxy)phenoxy propanoate] (22). Increased crop injury has been reported when various organophosphate and carbamate insecticides were combined with a herbicide (1,6,10,11,17,21). In view of these interaction it would be desirable to know the extent of bentazon interactions with other pesticides. Our objectives were to a) evaluate the potential interaction of bentazon with several organophosphate and carbamate insecticides b) determine any interaction of bentazon with grass killing herbicides such as diclofop and BAS 9052 [2-(1-(ethoxyimino)-butyl)-5-(2-(ethlthio)-propyl)-3-hydroxy-2-cyclohexene-1-one] and evaluate

CHAPTER 1

Enhanced Phytotoxicity of Bentazon with Several Organophosphate Insecticides

ABSTRACT

The organophosphate insecticides malathion [O,O-dimethyl S-(1,2-dicarbethoxyethel)phosphorodithionate], parathion (O,O-diethyl O-p-nitrophenyl phosphorothioate) and diazinon [O,O-diethyl O-(2 isopropyl-4-methyl-6-pyrimidinyl)phosphorothioate] combined with bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-4-(3H)-one 2,2-dioxide] caused severe injury to soybean (*Glycine max* (L.) Merr. 'Corsoy') and navy bean (*Phaseolus vulgaris* L. 'Seafarer'). Postemergence tank mixture applications of bentazon with organophosphate or carbamate insecticides, or soil-applied organophosphate insecticides prior to bentazon treatments did not interact with bentazon to injure corn (*Zea mays* L. 'Great Lakes Hybrid 4122'). Technical grade malathion interacted with bentazon to the same extent as formulated malathion. Malathion applications 48 h before or after bentazon applications were as injurious to soybean as tank mixtures of the two compounds.

INTRODUCTION

One of the management practices that allows for greater economic savings and production efficiency is the application of several pesticides at once as tank mixtures. Of potential interest would be the postemergence application of bentazon-insecticide combinations. However, there are numerous reports showing that certain herbicide-insecticide combinations may increase phytotoxicity to the crop (1, 3, 5, 6, 8, 9).

Bentazon has been reported to interact with the herbicide diclofop-methyl [methyl 2-(4(2,4-dichlorophenoxy)phenoxy)propanionic acid] when applied to soybean (11). Often these pesticide interactions are due to a change in uptake or metabolism of the herbicide (4, 10, 12).

The present study evaluates the potential interaction of bentazon with several organophosphate and carbamate insecticides.

MATERIALS AND METHODS

'Corsoy' soybean, 'Great Lakes Hybrid No. 4122' corn, and 'Seafarer' navy bean were seeded, five seeds per 946-ml wax cup, into greenhouse soil (1:1:1, v/v/v, soil:sand:peat). Seedlings were thinned to three uniform plants per pot 10 days later. Pesticides were applied with a link belt sprayer at 2.5 kg/cm^2 pressure with 280 L/ha spray volume. The plants were at the following leaf stage at application: the first trifoliolate leaf of soybean was one-half to fully expanded, the second leaf of the corn plant was emerging from the whorl, the second trifoliolate leaf of navy bean was fully expanded. Initial experiments with soybean and navy bean were placed in a greenhouse at 25 ± 5 C without supplemental lighting. Subsequent experiments with soybean and corn plants were grown out-of-doors.

Commercial formulations of the insecticides malathion emulsifiable concentrate (EC) at 1.12 kg/ha, parathion EC at 0.56 kg/ha, diazinon wettable powder (WP) at 2.24 kg/ha, carbaryl WP or carbaryl (1-naphthyl N-methylcarbamate) flowable liquid (FL) at 1.12 kg and carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) FL at 1.12 kg/ha were applied.

Herbicide-insecticide combination treatments were applied as tank mixtures. Due to the similarity of plant response of greenhouse and outdoor grown plants, the following experiments were conducted under greenhouse conditions.

Commercial granular formulations of terbufos [S-(((1,1 dimethylethyl) thio)methyl) O,O-diethylphosphorodithioate] at 1.12 kg/ha, carbofuran at 0.84 kg/ha and fonofos (O-ethyl-S-phenylethylphosphonodithioate) at 1.12 kg/ha were incorporated into the top 5 cm of a mixture of sand and soil (1:1, sandy loam:beach sand, v/v). Postemergence treatments of bentazon at 1.68 kg/ha were applied at two stages of growth, either as the first leaf or the fourth leaf was emerging from the whorl. To determine whether the active ingredient in an insecticide formulation was interacting with bentazon, formulated malathion (Malathion 50 Chevron Corporation) and technical grade malathion at 1.12 kg/ha were applied with and without bentazon at 1.68 kg/ha to soybean plants when the first trifoliolate leaves were expanding. The technical malathion was kept in suspension with water by constant agitation, application was with a thin layer chromatography plate sprayer. In a split application study formulated malathion was applied 48 or 3 h before as well as 3 or 48 h after an application of bentazon.

All plants were fertilized with a solution containing 100 ppm (w/v) of N, P_2O_5 and K_2O. All experiments were in a completely randomized design, rerandomized several times throughout the experiment, having four or five replications per experiment and repeated at least once.

RESULTS AND DISCUSSION

Postemergence applications of bentazon or any of the insecticides alone did not result in injury to soybean measured as a reduction in soybean fresh weight (Table 1). Severe injury resulted from combination treatments of the organophosphate insecticides, malathion, parathion and diazinon combined with bentazon, as indicated by reduction in fresh weight. This injury appeared within 24 h as an interveinal water soaking, necrosis, followed by leaf abscission within a few days. The onset of injury was more rapid on soybeans grown outside than those grown in the greenhouse.

Only the combination of malathion and bentazon resulted in a corn fresh weight reduction from that of the control (Table 1). However, this combination treatment was not significantly different from malathion alone and the corn rapidly recovered from the injury.

Navy bean treated with bentazon or any of the insecticides alone were not injured (Table 1). Combination treatments of malathion, parathion, or diazinon with bentazon resulted in large reductions in fresh weight and severe leaf injury. This injury was either a rapid necrosis of the leaf tissue or a chlorosis which was not restricted to any veinal or interveinal portion of the leaf. It is noteworthy that with both the soybean and navy bean the phosphorothioate or phosphorodithioate type insecticides, parathion, diazinon and malathion, interacted with bentazon but the carbamate type insecticides, carbofuran and carbaryl did not, although all have been shown to be esterase inhibitors (7).

The interaction of the insecticides studied with bentazon was evaluated using Colby's (2) multiplicative model for interactions and the statistical significance between the expected and actual combination value calculated as outlined by Hamill and Penner (4). The analysis indicated significant synergism for the interaction with the number of insecticides showing significant synergistic decreases in plant fresh weight in the following decreasing sequence: soybean, navy bean, and corn, respectively (Table 2).

Soil application of the insecticides terbufos, carbofuran or fonofos followed by a postemergence application of bentazon to corn did not exhibit a significant reduction in fresh weight (data not presented). Yellow nutsedge (Cyperus esculentus L.) shoots treated with malathion at 1.12 kg/ha and bentazon at 1.12 kg/ha were not injured more severely than yellow nutsedge shoots treated with bentazon alone (data not presented).

The mixtures of formulated malathion or technical malathion with bentazon resulted in the same degree of injury to soybean. This indicated that the synergistic injury of malathion with bentazon was a result of the active ingredient in the malathion formulation (Table 3). Although bentazon alone caused a significant reduction in fresh weight the injury resulting from the combination treatment was much more severe.

Split application treatments of malathion and bentazon resulted in severe reductions in soybean fresh weight (Table 4). This response occurred when the malathion was applied 48 or 3 h before as well as 3 or 48 h after bentazon was applied. The split applications did not differ or differed only slightly from the malathion bentazon tank mixture. This injury indicates that the interaction was not
in the spray solution but on or within the leaf itself.

Table 1. Effect of insecticides and bentazon on the fresh weight of soybeans, corn and navy beans 14 days after application.

		Soybean fresh weight[a]		Corn fresh weight		Navy bean fresh weight	
Insecticide	Rate	-Bentazon[b]	+Bentazon	-Bentazon	+Bentazon	-Bentazon	+Bentazon
	(kg/ha)	———	———	% of control	———	———	———
Control		100 cd	107 cd	100 bcd	101 bcd	100 a	96 a
Malathion	1.12	109 d	42 a	89 abc	82 a	98 a	48 c
Parathion	0.56	105 cd	72 b	99 abcd	96 abcd	107 a	53 c
Diazinon	2.24	104 cd	82 b	99 abcd	96 abcd	95 a	72 b
Carbaryl	1.12	111 d	95 c	108 d	88 abc	100 a	96 a
Carbofuran	1.12	112 d	103 cd	105 cd	105 cd	103 a	92 a

[a] Means with a crop main heading followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] -Bentazon = without bentazon   +Bentazon = with bentazon at 1.68 kg/ha

Table 2. Calculations of expected interaction response by Colby's formula on soybean, navy bean and corn.

Bentazon[a] plus insecticide	Rate	Soybean fresh weight Expected	Soybean fresh weight Actual	Navy bean fresh weight Expected	Navy bean fresh weight Actual	Corn fresh weight Expected	Corn fresh weight Actual
	(kg/ha)	(% of control)					
Malathion	1.12	103**	38**	106**	41**	79	80
Parathion	0.56	102**	52**	123**	52**	90	91
Diazinon	2.24	115**	61**	99	80	97	97
Carbaryl	1.12	109**	79**	103	100	101*	81*
Carbofuran	1.12	91	86	115*	84*	104	104

[a] Bentazon rate was 1.68 kg/ha

[b] Means followed by double asterisk (**) are significant at the 1% level; means followed by (*) are significantly different at the 5% level.

Table 3. Effect of malathion formulation on the interaction with bentazon on soybeans 7 days after application

Treatment	Rate	Soybean fresh weight
	(kg/ha)	(% of control)
Untreated		100 d
Bentazon	1.68	74 b
Malathion-formulated[b]	1.12	79 b
Malathion-technical	1.12	88 c
Bentazon+malathion-formulated	1.68 + 1.12	26 a
Bentazon+malathion-technical	1.68 + 1.12	31 a

[a] Numbers followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] Malathion formulation was a 50% emulsifiable concentrate.

Table 4. The effect of split applications of malathion and bentazon on the fresh weight of greenhouse-grown soybeans 7 days after application.

Treatment	Rate	Soybean fresh weight[a]
	(kg/ha	(% of control)
Untreated	----	100 cd
Bentazon	1.68	92 c
Malathion	1.12	103 d
Malathion 48 h before bentazon	1.12 + 1.68	49 b
Malathion 3 h before bentazon	1.12 + 1.68	37 a
Malathion 3 h after bentazon	1.12 + 1.68	40 ab
Malathion 48 h after bentazon	1.12 + 1.68	42 ab
Malathion -bentazon tank mix	1.12 + 1.68	37 a

[a] Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

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CHAPTER 2

Factors Influencing the Compatibility of Diclofop and BAS 9052 OH [2-(1-(ethoxyimino)-butyl)-5-(2-(ethylthio)-propyl)-3-hydroxy-2-cyclohexene-1-one] with Bentazon

ABSTRACT

BAS 9052 [2-(1-(ethoxyimino)-butyl)-5-(2-(ethylthio)-propyl)-3-hydroxy-2-cyclohexene-1-one] effectively controlled annual grasses in soybeans alone or in combination with bentazon [3-isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] in greenhouse and field experiments. The activity of diclofop [2-(4-(2,4-dichlorophenoxy)phenoxy)propanoate] on annual grasses was reduced if combined with bentazon in a tank mixture. The wettable powder formulation of bentazon as well as higher temperatures slightly reduced the antagonistic interaction. In greenhouse studies soybeans (*Glycine max* Merr. (L.) 'Corsoy') were injured by the diclofop-bentazon combination. However, in field studies this injury was not sufficient to reduce grain yields.

Additional index words Interaction, antagonism, synergism.

INTRODUCTION

Diclofop has been shown to be effective for postemergence control of annual grasses in soybean and offers potential for wild oat (*Avena fatua* L.) control in wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). BAS 9052, also a postemergence herbicide, is effective on both annual and perennial grasses, including bermudagrass [*Cynoden dactylon* (L.) Pers.], quackgrass [*Agropyron repens* (L.) Beauv.] and johnsongrass [*Sorghum halapense* (L.) Pers.] (2, 7, 8, 9). If both monocotyledonous and dicotyledonous weeds are present in soybean, it would be desirable to obtain broad spectrum weed control by combining the postemergence application of these herbicides with bentazon. Unfortunately not all pesticide combinations are compatible (10). Dortenzio and Norris (4) have reviewed a number of diclofop-herbicide interactions in which diclofop activity was reduced. Further, the combination of diclofop and bentazon has been reported to increase phytotoxicity to soybean (12) and the combination of diclofop with metamitron (4-amino-4,5-dihydro-3-methyl-6-phenyl-1,2,4-triazin-5-one) to increase phytotoxicity to sugarbeet (Beta vulgaris L.).

The objectives of this study were to (a) ascertain the application rate at which the diclofop-bentazon combination failed to control grasses and injured soybeans, (b) determine the influence of light, temperature and bentazon formulation on the diclofop-bentazon interaction, (c) determine whether combinations of BAS 9052 with bentazon showed similar interactions as the diclofop-bentazon combination.

MATERIALS AND METHODS

'Corsoy' soybean, barnyardgrass [Echinochola crus-galli (L.) Beauv.], and yellow foxtail [Setaria lutescens (Weigel) Hubb.] were planted in a greenhouse mix of soil, sand and peat (1:1:1, v/v/v) and later thinned to three soybean or ten barnyardgrass or yellow foxtail per 946-ml pot. Greenhouse temperatures were 25 ± 5 C. When the soybeans were at the early second trifoliolate leaf stage and the barnyardgrass and yellow foxtail in the third to fourth leaf stage, application by a belt link sprayer at 2.45 kg/cm^2 pressure and 284 L/ha spray volume was made.

Commercial formulations of the herbicides were applied in all experiments except for the experimental wettable powder (WP) bentazon and the emulsifiable liquid BAS 9052. All combination treatments were tank mixtures.

To evaluate the effect of sunlight on weed control by the diclofop-bentazon combination, potted plants were grown outside under full sun or under wire mesh screens. Three intensity levels of sunlight were used, full intensity (1750 μE m^{-2} sec^{-1}), medium intensity (70% of full intensity), and a low intensity of light (28% of full intensity).

At the reduced sunlight levels two subtreatments were included, pretreatment (Pre) with medium or low sunlight was followed by full sunlight after herbicide application or a pretreatment with full sunlight followed by growth under low or medium sunlight (Post) after the herbicides were applied. Phytotoxicity was measured as the reduction in the percent moisture content since barnyardgrass moisture was independent of the level of sunlight but influenced by herbicide treatments. Plants were harvested 14 days after application of the herbicides.

To determine the influence of temperature on the diclofop-bentazon interaction, barnyardgrass was grown in the greenhouse for 7 to 10 days, then transferred to growth chambers with temperatures of 15/10, 21/15 and 30/25 C day/night with a 14-h photoperiod at 280 μE m^{-2} sec^{-1}. Plants were grown until they had reached the third leaf stage, then herbicide treatments of diclofop at 1.12 kg/ha, bentazon at 1.12 kg/ha and diclofop at 1.12 kg/ha plus bentazon at 1.12 kg/ha were applied and plants were then returned to the growth chambers. After 10 days the plants were harvested and shoot fresh and dry weight determined. Data presented from all of these studies are the means of two experiments with three or four replications each.

To determine whether the interactions observed in the previous studies in the greenhouse occurred under field conditions, 'Hark' soybeans were planted into a Capac fine-loamy, mixed, mesic Aeric Ochraqualfs soil at the Crop Science Research Center in East Lansing in May of 1979. Herbicide treatments were applied 20 days after planting with a small plot tractor sprayer at 2.45 kg/cm^2 pressure with 730308 TeeJet nozzles (Spray Systems Co.) and 215 L/ha spray volume when the soybeans were in the early second trifoliolate leaf stage. Annual grasses present were barnyardgrass and giant foxtail (Setaria faberi Herrm.). To evaluate the possible effect of the time of day on herbicide effectiveness, applications were sprayed at pre-dawn, midday, and shortly after sunset. Weed control was visually rated and weeds were harvested from three 1000 cm^2 quadrats per plot and total weed fresh weight determined. Plot size was 3 by 6.1 m with three replications.

To evaluate the effect of the stage of grass growth on efficacy of the herbicide combination treatments, ten barnyardgrass per plot at four-leaf and eight-leaf stage were tagged with strings the day after application. Twenty-six days later these tagged plants were recovered from the plots and fresh and dry shoot weight determined.

To evaluate the effect of the herbicide combinations on soybean injury and yield, the soybeans were grown under weed-free conditions. To eliminate weed competition that might have reduced soybean yields, plots were kept weed-free by hand hoeing only. Plot size was 3 by 9.1 m. Crop injury was visually rated and yield was determined by harvesting the three 2.1 m lengths of row from the center rows of the plot.

RESULTS AND DISCUSSION

Postemergence application of diclofop at 0.19, 0.34, or 0.67 kg/ha reduced the shoot fresh weight and moisture content of barnyardgrass, but when combined with bentazon at 0.56 or 1.68 kg/ha, there was an antagonistic interaction and barnyardgrass injury was significantly reduced (Table 1). The antagonistic interaction was more evident on barnyardgrass desiccation than on barnyardgrass growth as measured by fresh weight accumulation. The characteristics of the antagonistic interaction was similar on yellow foxtail (Table 2).

Combinations of diclofop at 0.17, 0.34, or 0.67 kg/ha and bentazon at 1.68 kg/ha resulted in increased injury to soybean as measured by reduction in shoot fresh weight (Table 1). The predominant injury symptom evident was necrosis of the exposed leaves within 5 days after treatment. Nine days later regrowth of the soybean was apparent with no indication of injury to the new growth.

BAS 9052 at rates of 0.056 and 0.224 kg/ha alone or in combination with bentazon at rates as high as 2.24 was highly injurious to barnyardgrass with no antagonistic interaction of the combination treatment evident (Table 3). Only at very low rates of BAS 9052, 0.028 kg/ha, was there any indication that the effectiveness of BAS 9052 was reduced with the addition of bentazon at 0.56, 1.12 or 2.24 kg/ha. In contrast to diclofop, the combination of BAS 9052 and bentazon did not result in increased injury to soybean as measured by soybean fresh weight accumulation. The effects of the combination were measured over a rate range of 0.028 to 0.224 kg/ha for the BAS 9052 and 0.56 to 2.24 kg/ha for the bentazon.

The possibility that the bentazon formulation was involved in the antagonistic interaction was investigated. Substituting the wettable powder formulation of bentazon for the liquid formulation decreased but did not eliminate the antagonistic interaction (Table 4).

Varying the light intensity before and after the application of the combination of diclofop and bentazon did not affect the antagonistic interaction of these two herbicides on barnyardgrass (Table 5). Barnyardgrass plants grown under Pre low light intensity appeared to be more sensitive to diclofop than those grown under full sunlight (Table 5). This is in contrast with the report of Rao and Sweet (11) that diclofop activity was greatest under long days and high light intensity in the growth chamber.

As temperatures increased from 15/10 C day/night to 30/25 C day/night, the antagonistic interaction of the diclofop-bentazon combination treatment became less pronounced (Table 6). This was indicated by a reduction in both percent shoot moisture content and fresh weight of the barnyardgrass. At the lowest temperature regime studied, 15/10 C day/night, the antagonistic interaction of diclofop and bentazon was not evident (Table 6). The action of diclofop applied alone was temperature dependent, increasing with increasing temperature.

Field experiments showed that the activity of diclofop at 1.12 kg/ha on annual grasses was also substantially reduced by the addition of 1.12 kg/ha bentazon to the spray mixture, confirming the greenhouse studies. The antagonistic interaction was measured by both visual control ratings and weed shoot fresh weight (Table 7). BAS 9052 at 0.56 kg/ha was effective on annual grasses and showed no interaction when combined with bentazon at 1.12 kg/ha, confirming greenhouse studies.

The potential of decreasing the antagonistic interaction of diclofop and bentazon was also investigated by applying the combination treatments at various times in the day. However no significant differences in the interaction were apparent between predawn, midday, or after-sunset applications of the combination treatment.

Another factor which could conceivably influence the antagonistic interaction due to diclofop-bentazon combination is the physiological stage of growth of the plant. To test the possibility the herbicides were applied alone and in combination to barnyardgrass seedlings growing in the field at four-leaf and eight-leaf stages. However, the antagonistic interaction was equally apparent at both leaf stages (Table 8), although barnyardgrass is susceptible to diclofop at these stages (1). Again the BAS 9052-bentazon combination did not show any antagonistic interactions.

There was no significant difference in soybean grain yield in weed-free plots between plants treated with diclofop, BAS 9052 or either herbicide combined with bentazon and those plants not treated with a herbicide (Table 7). Although visual ratings of soybean injury by diclofop at 1.12 kg/ha or BAS 9052 at 0.56 kg/ha were higher when either herbicide was combined with bentazon at 1.12 kg/ha, this injury was not sufficient to decrease soybean yields. This agrees with the report of Hagood _et al_. (6) that early-season soybean injury which did not persist did not reduce soybean yields.

The reduction in diclofop activity by bentazon has occurred under both greenhouse and field conditions. This interaction is not completely elevated by changes in temperature, light intensity, bentazon formulation or the time of day of the spray application. Combinations of BAS 9052 with bentazon appear to be fully compatible under both greenhouse and field conditions.

Table 1. Effect of diclofop and bentazon on barnyardgrass and soybean 14 days after application under greenhouse conditions.

Herbicide rate		Barnyard grass[a]			Soybean
Diclofop	Bentazon	Moisture	Injury rating[b]	Fresh weight	Fresh weight
-------(kg/ha)-------		---------(%)-----------		------(%)of control --------	
0.00	0.00	88 g	0 g	100 h	100 de
0.00	0.28	88 g	0 g	91 h	89 bcd
0.00	0.56	88 g	1 g	95 h	96 cde
0.00	1.68	89 g	3 g	90 h	96 cde
0.17	0.00	45 cd	65 c	7 def	100 cde
0.17	0.28	51 de	60 cd	6 cde	107 e
0.17	0.56	55 e	51 ef	6 cdef	83 bc
0.17	1.68	69 f	46 f	11 g	72 ab
0.34	0.00	32 ab	81 a	5 abc	93 cde
0.34	0.28	42 cd	67 bc	6 cde	92 cde
0.34	0.56	48 cde	54 de	7 cdef	84 bcd
0.34	1.68	75 f	54 de	9 efg	61 a
0.67	0.00	26 a	86 a	4 a	90 bcd
0.67	0.28	33 ab	82 a	4 ab	86 bcd
0.67	0.56	40 bc	73 b	6 bcd	84 bcd
0.67	1.68	69 f	61 cd	9 fg	59 a

[a] Means within a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] The injury rating was performed 7 days after application.

Table 2. Effect of diclofop and bentazon on yellow foxtail moisture content and fresh weight 7 days after application under greenhouse conditions.

Herbicide rate		Yellow Foxtail	
Diclofop	Bentazon	Moisture	Fresh weight
--------(kg/ha)--------		--(%)--	----(g)----
0.00	0.00	91 a	100 d
0.00	0.56	91 a	90 cd
0.00	1.12	91 a	91 cd
0.00	1.68	91 a	87 c
0.84	0.00	68 de	13 ab
0.84	0.56	73 cd	17 ab
0.84	1.12	79 b	24 b
0.84	1.68	81 b	17 ab
1.40	0.00	60 f	6 a
1.40	0.56	64 ef	10 a
1.40	1.12	75 bc	14 ab
1.40	1.68	77 bc	14 ab

[a] Means within a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Table 3. Effect of BAS 9052 and bentazon on barnyardgrass fresh weight 14 days after application under greenhouse conditions.

Herbicide rate		Barnyardgrass[a] fresh weight
BAS9052	Bentazon	
--------(kg/ha)---------		(% of control)
	0.00	
0.000	0.00	100 a
0.000	0.56	107 a
0.000	1.12	107 a
0.000	2.24	87 b
0.028	0.00	14 def
0.028	0.56	55 c
0.028	1.12	58 c
0.028	2.24	50 c
0.056	0.00	10 def
0.056	0.56	11 def
0.056	1.12	17 d
0.056	2.24	15 de
0.224	0.00	3 f
0.224	0.56	4 f
0.224	1.12	6 ef
0.224	2.24	6 ef

[a] Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Table 4. Effect of bentazon formulation on the interaction with diclofop applied to barnyardgrass 14 days after application under greenhouse conditions.

Herbicide	Rate	Barnyardgrass Moisture content[a]
	(kg/ha)	(%)
Untreated		85.9 d
Bentazon SL[b]	1.68	86.7 d
Bentazon WP	1.68	85.7 d
Diclofop EC	1.12	37.4 a
Bentazon SL+diclofop EC	1.68 + 1.12	58.8 c
Bentazon WP+diclofop EC	1.68 + 1.12	41.2 b

[a] Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] Formulations: SL = soluble liquid, WP = wettable powder, and EC = emulsifiable concentrate.

Table 5. Effect of light intensity and herbicides on the moisture content of barynardgrass 14 days after application.

		Barnyardgrass shoot moisture content[a]						
		Sunlight						
		Full	Medium			Low		
Herbicide	Rate	Contin-uous	Contin-uous	Pre[b]	Post	Contin-uous	Pre	Post
	(kg/ha)	(%)						
Untreated		87 hij	88 ij	87 hij	88 ij	90 j	89 j	90 j
Diclofop	0.56	70 cd	70 cd	71 cd	73 d	68 bc	64 ab	75 de
Diclofop + bentazon	0.56 + 1.12	81 fg	81 fg	82 fgh	81 fg	82 fgh	86ghij	81 fg
Bentazon	1.12	88 ij	89 j	88 ij	88 ij	91 j	90 j	90 j

[a] Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] Pre = grown under reduced light intensity until herbicide treatments.
Post = grown under full sunlight until herbicide treatment.

Table 6. Effect of temperature during growth and herbicides on the moisture content and fresh weight of barnyardgrass 10 days after application.

		Barnyardgrass[a]					
		Moisture content			Fresh weight		
		Temperature day/night C					
Herbicide	Rate	15/10	21/15	30/25	15/10	21/15	30/25
	(kg/ha)	(%)			(% of control)		
Untreated		89 a	85 ab	86 ab	100 a	100 a	100 a
Bentazon	1.12	89 a	87 ab	86 ab	74 c	85 b	101 a
Diclofop	1.12	80 b	64 c	30 e	45 d	12 e	6 e
Bentazon + diclofop	1.12 + 1.12	80 ab	81 ab	54 d	37 d	14 e	9 e

[a] Means followed by the same letter within the moisture content or fresh weight heading are not significantly different at the 5% level as determined by Duncan's multiple range test.

Table 7. Effect of bentazon diclofop and BAS 9052 on annual grass control, soybean injury and grain yield

Herbicide	Rate	Annual grasses[a] Weed control[b]	Annual grasses[a] Fresh weight	Soybean Injury	Soybean Yield Weeds present	Soybean Yield Weed free
	(kg/ha)	-------(%)---------		(%)	------(kg/ha)------	
Untreated		0	100 bc	0	1190 d	3297 a
Diclofop	1.12	86 c	39 ab	12 ab	1647 cd	3308 a
Diclofop + bentazon	1.12 + 1.12	44 b	292 d	23 c	1805 cd	3119 ab
BAS	0.56	94 b	21 a	6 a	1906 cd	3037 ab
BAS bentazon	0.56 + 1.12	89 c	2 a	17 bc	2201 c	3165 ab
Bentazon	1.12	2 a	158 c	6 a	1627 de	2822 abc

[a] Means within a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

[b] 100 = perfect weed control or complete crop kill; 0 = no weed control or no crop injury.

Table 8. Effect of bentazon, diclofop and BAS 9052 on barnyardgrass fresh weight at two leaf stages under field conditions.

Treatment	Rate	Barnyardgrass fresh weight	
		Four-leaf	Eight-leaf
	(kg/ha)	(% of control)	
Untreated		100	100
Bentazon	1.12	178 b	138 b
Diclofop	1.12	28 a	32 a
Diclofop + bentazon	1.12 + 1.12	110 b	95 b
BAS 9052	0.56	11 a	9 a
BAS 9052 + bentazon	0.56 + 1.12	16 a	8 a

[a] Means within a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

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CHAPTER 3

Summary and Conclusions

Postemergence combinations of bentazon with organophosphate insecticides were very injurious to soybean and navy bean. It is uncertian whether the injury was due to the bentazon or the insecticide, or whether other organophosphate insecticides would induce the same effect with bentazon. The carbamate insecticides carbaryl and carbofuran were compatable with bentazon in all crops studied. Since the interaction of bentazon with the organophosphates occured even if applications were split by 48 hours it is likely that the insecticides were interfering with bentazon metabolism and that this phenomėnon was not a result of a chemical change in the spray mixture. The combination of the organophosphate or carbamate insecticides with bentazon were compatable when applied either as preplant incorporated granules or postemergence sprays applied to corn. Bentazon did not interfere with the activity of BAS 9052, indicating the suitability of this combination for broad-spetrum postemergence weed control in soybean. Bentazon reduced diclofop activity on annual grasses. This undesirable interaction could not be moderated by application of the combination at a paticular time of day or applications to very young plants. Applications using the wettable powder formulation of bentazon with diclofop resulted in less interaction on grass control but it is uncertian whether a concomitant reduction in bentazon activity would also result. Application of bentazon with diclofop at higher temperatures, 30 C, resulted in less interaction and increased grass control.

In greenhouse studies bentazon-diclofop combinations induced severe injury to soybean. But field studies indicated that soybean plants were more tolerent to the combination outdoors and that the slight injury that resulted was insufficient to reduce soybean yield. The more important aspect of the bentazon-diclofop interaction was the reduction in grass control.

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