INTERACTION OF TWO SULFONYLUREA HERBICIDES WITH SELECTED INSECTICIDES ON WHEAT

By

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CHAPTER I

INTRODUCTION

Wheat

Wheat (Triticum aestivum L.) is the major cultivated crop in the state of Oklahoma with a average of 2.15 million hectares harvested and 5.5 billion kilograms produced annually (24). Parathion (Table I) is the predominant insecticide used in Oklahoma on wheat for greenbug (Schizaphis graminum (Rondani)) control. Applications typically occur between November 1 and April 1, which frequently coincide with timing for application of broadleaf weed control herbicides. Therefore, tank mixes of methyl parathion and herbicides may be economically desirable to reduce application costs. However, it has been known for over 20 years that certain pesticide tank mixes can cause synergistic phytotoxicity and decrease yield (2,7). Such synergism was suspected to have occured in 1984 when a chlorsulfuron at 35 g/ha plus methyl parathion at 0.3 kg/ha, tank mixed and applied to Newton, Vona, and Tam 101 wheat varieties in early December, caused chlorosis and stunting. Although no yield reduction was confirmed the loss of wheat forage was an economic loss.

Chlorsulfuron

Chlorsulfuron (Table I) is a sulfonylurea herbicide used for annual ryegrass (Lolium temulentum L.) and broadleaf weed control in cereal crops. Its use in Oklahoma has increased steadily since it was labeled in 1980. The recommended use rate for chlorsulfuron in winter wheat is between 10 and 40 g ai/ha (18,27). Chlorsulfuron is absorbed by both roots and foliage of plants and is readily translocated. Death of susceptable plants is generally slow and is accompained by chlorosis, necrosis, and complete inhibition of plant growth (30,31). The inhibition of plant growth is the result of chlorsulfuron induced inhibition of biosynthesis of valine and isolucine (31). Chlorsulfuron does not directly affect photosysnthesis or respiration. Tolerant plant species, such as wheat, rapidly metabolize chlorsulfuron to a nonphytotoxic metabolite by hydroxylation of the benzene ring (38).

Metsulfuron

Metsulfuron is another sulfonylurea herbicide labeled for use on wheat in Oklahoma in 1985. It has been evaluated in the major cereal growing areas of the world since 1980.

TABLE I

COMMON AND CHEMICAL NAMES OF PESTICIDES

Common name	Chemical name
Acephate	O,S-dimethyl acetylphosphoramidothioate
Carbaryl	1-naphthyl-N-methylcarbamate
Chlorfenvinphos	2-chloro-1-(2,4-dichlorophenyl) ethenyl diethyl phosphate
Chlorproham	1-methylethyl 3 chlorophenylcarbamate
Chlorsulfuron	2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]-benzenesulfonamide
Dicamba	3,6-dichloro-2-methoxybenzoic acid
Dimethoate	O,O-dimethyl S-(methyl carbamoylmethyl) phosphorodithioate
Disulfoton	0,0-diethyl S-[(ethylthio)methyl] phosphorodithioate
Diuron	N'-(3,4-dichlorophenyl)-N,N-dimethylurea
Dyfonate	0-ethyl S-phenyl ethylphosphonodithioate
Fensulfothion	0,0-diethyl 0-[4-(methylsulfinyl)phenyl]-phosphorothioate

TABLE I (continued)

Guthion	0,0-dimethyl S-4-0x0-1,2,3 benzotriazin--3(4-h)-ylmethl)phosphldithioate
Linuron	N'-(3,4-dichlorophenyl)-N-methoxy-N-methylurea
Malathion	diethyl mercaptosuccinate, S-ester with O,O-Dimethyl phosphorodithioate
Methyl parathion	O,O-dimethyl O-p-nitrophenyl phosphorothioate
Metsulfuron	methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-trizin-2-yl)amino]carbonyl]-amino]sulfonyl]benzoate
Monuron	3-(p-chlorophenyl)-1,1-dimethylurea mono(trichloroacetate)
PCMC	p-chlorophenyl N-methylcarbamate
Phorate	0,0-diethyl S-[(ethylthio)methyl]phosphorodithioate
Phosphamidon	dimethyl phosphate, ester with 2-chloro-N,N-diethyl-3-hydroxycrotonamide
Propanil	N-(3,4-dichlorophenyl)pronanamide
Toxaphene	2,2,5-endo,6-exo,8,9,10-heptocholrobornane
Trichlorfon	O,O-dimethyl(2,2,2-trichloro-1-hydroxyethyl) phosphonate

In 1982 an extensive research program was begun in the United States to evaluate the mode of action and selectivity of metsulfuron (9). It was found that the mode of action is similar to that of chlorsulfuron, with absorption by both roots and foliage and rapid acropetal and basipetal translocation. Following uptake of metsulfuron by susceptable plants there is a rapid inhibition in the growing tips of the roots and shoots with visible die-back in the growing tips followed by chlorosis and necrosis. The selectivity of metsulfuron is similar to chlorsulfuron with rapid metabolism of the compound by the cereal plants.

Greenbugs

(*Schizaphis graminum* (Rondani))

The greenbug is a pest of small grains and sorghum in the Central, Northwestern, and Southeastern States. The first reported infestation of this insect in the United States was in Virginia in 1882. Since then, at least 19 major outbreaks have occurred. A serious outbreak occurred in the spring of 1976 on wheat, damage and control costs over $80 million in Oklahoma alone (35). The damage caused by the insect results from the greenbug sucking plant juices from grain plants while injecting an unknown toxin-like substance into the plant causing necrotic spots surrounded by chlorosis. Under heavy infestation, the leaves soon wither and the plant may die. The insects then move on to other plants. The greenbug is also an effective vector of virus diseases of small grains, corn, sorghum, and several wild grasses.

Greenbugs may be winged or wingless with all wingless types being female. Most of the wingless types give birth to living young and in the southern states reproduce continuously throughout the year. Further north there is some overwintering of the wingless females but these reproduce little during the winter. Infestations are thought to occur in the spring by movement of the winged females into the northern areas on wind currents from the south. When the greenbugs first appear they are pale green, when full grown, they have a dark-green stripe down the back. Greenbugs give birth to live young that may develop into winged or wingless adults, in 6 to 30 days, depending on the temperature. Females continue to reproduce for 20 to 30 days and produce 50 to 100 progeny. In Texas and Oklahoma there may be more than 20 generations in one year (35).

Parathion

Parathion is an organophosphate insecticide applied postemergence to wheat and is metabolized in the wheat plant by hydroxylation by carboxyesterase enzymes (5) followed by a demethylation process (18). The pimary use for methyl parathion in Oklahoma is for the control of greenbugs on wheat. In 1981 over 81,000 kilograms of methyl parathion were applied to 121,000 hectares of wheat for control of greenbugs in Oklahoma (26). Tank mixes of sulfonylurea herbicides and organophosphate insecticides might be anticipated to be necessary with increasing frequency in the future. Since isolated farmer reports of wheat phytotoxicity due to such combinations have been reported, this research was undertaken to determine the effect of two sulfonylurea herbicides with selected insecticides on wheat grain yield and to determine the effect of these combinations on the photosynthetic activity of wheat.

CHAPTER II

LITERATURE REVIEW

Winter Wheat

Wheat is the most extensively grown crop in the world and produces more grain than any other crop (10). The most abundant species of wheat grown is hard red winter wheat (Triticum aestivum L.). It is economically important to Oklahoma farmers not only for grain production but also for utilization of wheat forage by livestock. Thus both forage and grain yield may be considered during variety selection (32,36). The optimum seeding date in central Oklahoma for forage production is August 22, with a reduction in forage yields from 672 to 1120 kg/ha for each two week delay (20). The optimum seeding date for grain yield is between September 15 and October 15 (17).

Herbicide - Insecticide Interaction

There has been little research on the effects of herbicide by insecticide combinations on wheat. However there are many reports of significant synergistic interactions between herbicides and insecticides.

Malathion, phosphamidon, guthion, or trichlorfon applied to rice did not cause leaf burn, however when the insecticides were tanked mixed with propanil there was an increase in leaf burn and decrease in yield (2). An increase in diuron persistance in the soil occured when diuron was applied serially with phorate and disulfoton resulting in synergistic phytotoxicity to oats (Avena sativa L.), corn (Zea mays L.), and cotton (Gossypium hirsutum L.) (23). Phytotoxicity of monuron and diuron was increased when either herbicide was applied to cotton seedlings grown in soil treated with either phorate or di-syston (39). Phorate used as seed treatment on cotton seeds caused a synergistic reaction with monuron or diuron applied preemergent resulting in reduced growth followed by peripheral necrosis of the cotyledons, desication, and death (12).

Certain herbicide by insecticide combinations can influence metabolism of a pesticide by a plant species or soil microorganism (16). Simultaneous application of monuron with carbaryl inhibited monuron degradation to 1-(p-chlorophynyl)-3-methylurea and p-chlorophynylurea by inhibiting progressive demethylation and subsequent hydrolysis in cotton (37). In wheat, metabolism of dicamba, chloropham, and linuron was inhibited by dyfonate, chlorfenvinphos, malathion, fensulfothion, and disulfoton (7). Propanil metabolism in tomato (Lycopersicon esculentum Mill. cv John Baer) was strongly inhibited by certain carbamate and organophosphate insecticides (7). The carbamate insecticides carbaryl, carbofuron, and PCMC inhibited aryl acylamidase enzymes from metabolizing propanil in tomato (7,11). Herbicides can also inhibit insecticide metabolism in certain plants. Linuron and propanil inhibited metabolism of dyfonate and malathion in bean (Phaseolus vulgaris L.) tissue (6). Hydroxylation of the N-methyl group to N-hydroxymethyl carbamate of carbaryl was inhibited in tomato by linuron (6). Inhibition of phenylcarbamate herbicide metabolism in soil occured when selected methylcarbamate insecticides were applied (16). The first step in metabolism of dicamba and propanil by plants is hydroxylation of the benzene ring by aryl acylamidase exzymes (2,4,8). Metabolism of dicamba in wheat was inhibited by malathion, chlorfenvinphos, fensulfothion, and disulfoton (7,21).

Chlorsulfuron

Chlorsulfuron (Figure 1) is a sulfonylurea herbicide developed primarily for the control of annual ryegrass and

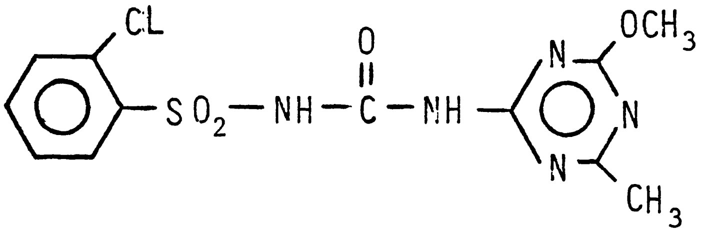

Figure 1. Chlorsulfuron

broadleaf weeds found in a number of cereal crops (18). Chlorsulfuron is synthesized by adding an equivalent of 2-chlorobenzenesulfonyl isocyanate to a suspension of 2-amino-4-methoxy-6-methyl-1,3,5-triazin (18). Chlorsulfuron is absorbed by both roots and foliage of plants and is readily translocated. Selectivity in crops such as wheat is primarily related to the metabolism of chlorsulfuron by hydroxylation of the benzene ring (Figure 2) after which the 5-OH derivative is conjugated to form the 5-glycoside of chlorsulfuron (Figure 3) (38). Chlorsulfuron's primary mode of action in plants is the inhibition of the biosynthesis of the amino acids, valine and isolucine (31). Photosynthesis, respiration, RNA synthesis, and protein synthesis are not initially affected when plant cell division is strongly inhibited (30,31). Wheat metabolizes chlorsulfuron and metsulfuron through the enzyme acetolactate synthase followed by the hydroxylation of the benzene ring (9,30,31).

Metsulfuron

The herbicide metsulfuron (Figure 4) differs from chlorsulfuron only by replacement of the chlorine molecule on the benzene ring of chlorsulfuron with a benzoic acid

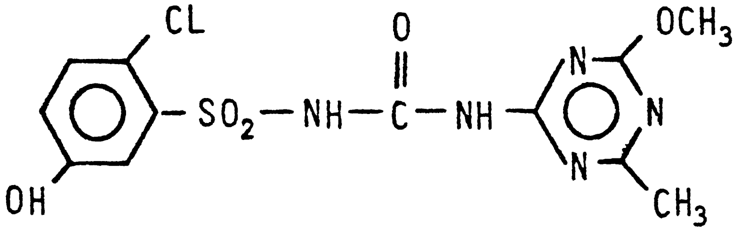

Figure 2. Hydroxylation of Chlorsulfuron

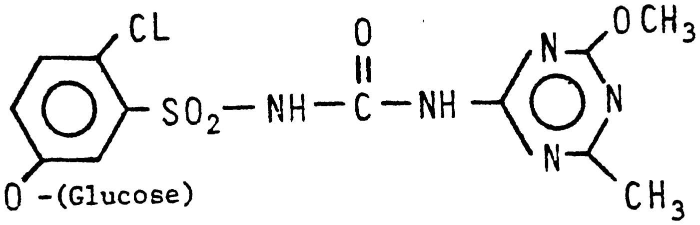

Figure 3. Chlorsulfuron as Metabolite A

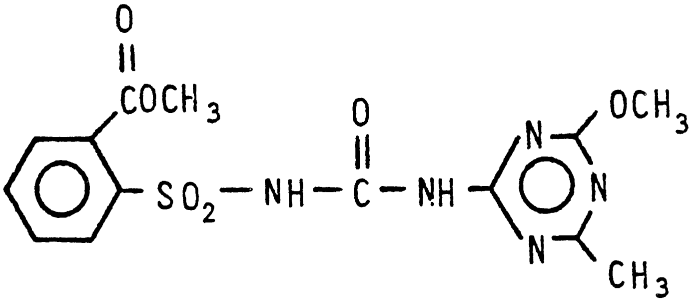

Figure 4. Metsulfuron

side chain (Figure 1,4). The mode of action of metsulfuron is similar to that of chlorsulfuron (9,30). Metsulfuron is absorbed both through the roots and foliage. Translocation within the plant is fairly rapid with both acropetal and basipetal translocation occuring (9). The effects of metsulfuron on susceptible plants include rapid inhibition of growing tips of the roots and foliage followed by visible die-back in the growing tips, chlorosis, and necrosis. Plants which do not die are severly stunted and considered to be much less competitive to the cereal crop (9). As with chlorsulfuron, cereal selectivity is due to the rapid metabolism of the molecule by the cereal plant (9).

CHAPTER III

METHODS AND MATERIALS

Effect of Chlorsulfuron and Metsulfuron with Selected Insecticides on Wheat Yield

Two field experiments were established on the Agronomy Research Station, Stillwater, Oklahoma and one on the Agronomy Research Station, Perkins, Oklahoma to examine the effect of two sulfonylurea herbicides with selected insecticides on wheat yield. The experimental design used for each experiment was a split-plot with four replications and a 3m by 3m plot size. Statistical analysis of the yield data was obtained using a split-plot analysis of variance with herbicide treatments as the main plot and the insecticide treatments as the subplot. Treatment affects were compared using L.S.D.'s at the .05 level of significance unless otherwise stated. One experiment was established on the Agronomy Research Station, Stillwater, Oklahoma in November, 1983 and one experiment in October, 1984 on a Kirkland clay loam (Sa=33%, Si=35%, Cl=32%) (Udertic Paleustoll) with 1.1% organic matter, pH=5.7, and a soil buffer index of 6.9. In both experiments, Chisholm wheat was sown in 25 cm rows with a hoe drill at 76 kg/ha. Seeding dates were November 15, 1983 and October 29, 1984. Herbicide and insecticide treatments were applied on March 7, 1984 and March 19, 1985 with a tractor mounted small plot sprayer. Herbicide treatments were applied first with insecticide treatments applied across the herbicide treatment strips immediately afterward. The herbicide treatments were chlorsulfuron (75 DF) at 12, 23, and 35 g ai/ha, metsulfuron (60 DF) at 12, 23, and 35 g ai/ha, and a no herbicide check. The insecticide treatments were acephate, malathion, and trichlorfon, each at 1.1 kg ai/ha; carbaryl, and toxaphene, each at 1.7 kg ai/ha; dimethoate at 0.4 kg ai/ha; and a no insecticide check. Each insecticide was applied at its highest recommended use rate (25). All treatments were applied at the three to four tiller growth stage of the wheat. Futher treatment particulars are in Table II. Harvested plot size was 1.4m by 2m. Grain yield was obtained with a self propelled small plot combine. Grain was cleaned with a Clipper M2B seed cleaner with clean grain yield analysis reported.

The experiment established on the Agronomy Research Station, Perkins, Oklahoma, was on a Teller loam (Sa=49%, Si=28%, Cl=23%) (Udic Agriustoll) with 0.7% organic matter

Table II

CONDITIONS FOR ESTABLISMENT OF THE FIELD EXPERIMENTS AT STILLWATER (1983-1984 AND 1984-1985)

Location:	Agronomy Research Station, Stillwater, Oklahoma	
Soil:	Kirkland clay loam (Sa=33%, Si=35%, Cl=32%) OM=1.1%, pH=5.7 Udertic Paleustoll	
Application equipment:	Compressed nitrogen tractor sprayer	
Carrier volume (l/ha):	187	
Spray boom:	Eight 11004 nozzle tips on 50 cm spacing	
Planting dates:	November 15, 1983 October 29, 1984	
Planting method:	Hoe drill with 25 cm row spacing	
Wheat variety:	Chisholm	
Seeding rate:	78.6 kg/ha	
Treatment particulars:		
Experiment year:	1983-1984	1984-1985
Application stage:	3 to 4 tiller	3 to 4 tiller
Date:	March 7, 1984	March 19, 1985
Air temp (°C):	12	16
Soil temp (°C):	18	10
Soil moisture:	Good	Good
Sun:	Bright	Bright
Wind (km/h):	0-3.2	0-4.8

and pH=6.1. Chisholm wheat was seeded as previously described, on October 29, 1984. Chlorsulfuron and metsulfuron, each at 12, 23, and 35 g ai/ha, were applied alone and in combination with acephate, malathion, and trichlorfon, each at 1.1 kg ai/ha; toxaphene at 1.7 kg ai/ha; dimethoate at 0.4 kg ai/ha; and methyl parathion at 0.3 kg ai/ha. Chemical treatments were applied to wheat at the three to four leaf growth stage on November 29, 1984. At application the air temperature was 11^{0}C, the soil temperature was 14^{0}C and the wind speed was 0 km/h. Visual ratings of chlorosis were obtained on December 20, 1984, using a rating scale of 1 to 100 where 100 equals complete crop kill. The experimental design used, application of chemical treatments, harvested plot size, harvesting, and cleaning of grain, were the same as previously described.

Effect of Chlorsulfuron with Methyl Parathion on Wheat

A second experiment was established on the Agronomy Research Station, Perkins, Oklahoma to determine whether different wheat varieties varied in their response to chlorsulfuron and methyl parathion. Seeding was completed in the manner described above on October 29, 1984. The chemical treatments included chlorsulfuron at 23 and 35 g ai/ha; methyl parathion at 300 g ai/ha; chlorsulfuron plus mehtyl parathion at 23 plus 300 g ai/ha; and a check. The wheat varieties selected were Centurk, Chisholm, Osage, TAM W 101, TAM W 105, and Vona. The experiment was established on the same soil type as previously described. The experimental design used was a split-plot with four replications and a 3m by 4m plot size. Harvested plot size was 1.4m by 3m. Chemical treatments were applied to the wheat varieties at the 3 to 4 leaf growth stage. Application of chemical treatments, harvesting, and cleaning of grain, were the same as previously described.

Effect of Greenbug Infestation, Prior to Chemical Treatment, on Chlorophyll Fluorescence of Wheat

Laboratory experiments were conducted to determine whether the effects of a greenbug infestation on wheat could be detected by use of a chlorophyll fluorometer and to determine whether such an infestation would affect the response of the wheat to subsequent pesticide treatments. In the greenhouse 560 ml styrofoam containers were filled with 400 grams of an air dried Teller loam (Sa=49%, Si=28%, Cl=23%) (Udic Agriustoll) with 0.7% organic matter and pH=6.1. Four Chisholm wheat seeds were planted in each container 2.5 cm deep. Each container was then subirrigated to capacity then allowed to drain. After seedling emergence the wheat in each container was thinned to one plant per container and transferred to the laboratory. Containers were place under fluorescent lights (300 $\mu E \cdot m^{-2} \cdot sec^{-1}$) with a 24 h daylength and 32°C mean temperature. Soil moisture was maintained by adding 30 ml of half-strength Hoagland solution (13) every 48 h and subirrigating to capacity with tap water every sixth day. When the plants reached the three to four leaf stage of growth, half of the plants were infested with 20 biotype E adult greenbugs for a period of 72 hours. Greenbug infestation was maintained by surrounding each plant with a controlled environment cylinder. Each cylinder was constructed from clear plastic 5.8 cm in diameter and 25.4 cm in length. One end of the cylinder was covered with a 100 mesh screen with one circle opening 5 cm in diameter cut into the side of the cylinder 12.7 cm from the end also covered with a 100 mesh plastic screen. The purpose of the openings were to facilitate air movement and temperature control. Measurements of chlorophyll fluorescence were obtained with a fluorometer (29,33) every 24 h during infestation. At the end of the infestation period, treatments of chlorsulfuron, at 23 g ai/ha, and/or methyl parathion, at 0.3 kg ai/ha, were applied using a CO_2 hand sprayer with a carrier volume of 13.8 l/ha. Greenbugs were manually removed from plants not receiving an insecticide treatment (34). Measurements of chlorophyll fluorescence were obtained 24, 48, and 72 h after chemical application.

Chlorophyll Fluorescence Measurements

In the laboratory, measurements of chlorophyll fluorescence were obtained with the use of a model SF-20 plant productivity fluorometer. Using the procedure described by Shaw (33), a sensing probe was placed over the adaxial surface of the second leaf of actively growing wheat plants. The light-emitting diode of the probe, centered around 670 nm, was adjusted to provide an intensity of 7 $\mu m \cdot m^{-2} \cdot sec^{-1}$. The leaves were illuminated for 30 seconds and chlorophyll fluorescence signals were collected every 10 msec, stored and displayed graphically using a Northstar high-speed, computer-controlled data acquisition system.

The ratio of the inflection point (I) to that of the variable fluorescence peak (P) was determined for each plant at all time intervals (29,33). Chlorophyll fluorescence of a normal plant begins at a low initial level (O) and increased rapidly to an inflection point (I). Fluorescence emission continues to rise to maximum peak (P) and then declines to a lower level (S). More slowly, fluorescence increases to a terminal level (T). Treatment with a herbicide or insecticide that inhibits photosynthesis significantly influences these parameters. At the onset of illumination, a very rapid rise to a maximal level is observed, with little difference between the height of I and P and little decay from the maximal (P) level. Therefore, a ratio of I:P can be a good indicator for photosynthetic inhibition (Figure 5).

Effect of Methyl Parathion and Malathion with and without Chlorsulfuron on Chlorophyll Fluorescence of Wheat

Since methyl parathion was not used in the field experiments, a laboratory experiment was established to compare the effects of malathion and methyl parathion, alone

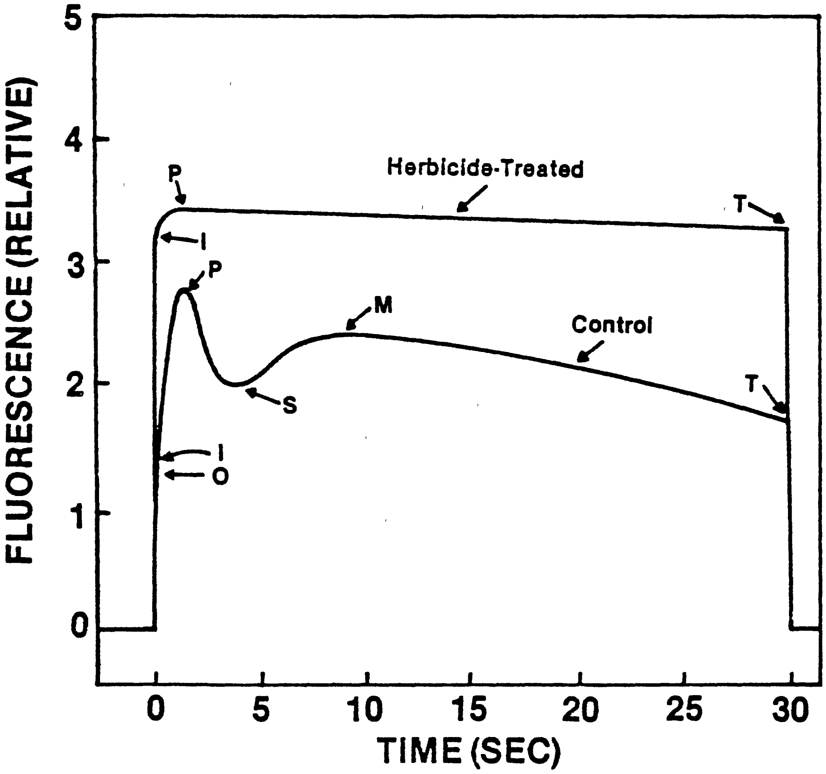

Figure 5. Chlorophyll Fluorescence Curve for Control and Herbicide Treated Oat Plant. Shaw et. al. (33).

and in combination with chlorsulfuron, on chlorophyll fluorescence of wheat. In this experiment, wheat seedlings were grown as previously described. When the plants reached the three to four leaf stage of growth, treatments of malathion at 1.1 kg ai/ha and methyl parathion at 0.3 kg ai/ha were applied separately and in combination with chlorsulfuron at 23 g ai/ha. Separate chlorsulfuron and check treatments were included in this experiment. All chemical treatments were applied with a CO_2 hand sprayer with a carrier volume of 13.8 l/ha. Measurements of chlorophyll fluorescence were obtained as described above 4, 24, 48, and 72 h after chemical application.

Effect of Chlorosulfuron and Metsulfuron with Insecticides on Chlorophyll Fluorescence of Wheat

In order to further examine the effect of the chemical treatments used in the field experiments on chlorophyll fluorescence, a third laboratory experiment was conducted. Wheat plants were established as previously described. When the plants reached the three to four leaf stage of growth chlorsulfuron, at 23 g ai/ha and metsulfuron, at 23 g ai/ha, were applied alone and in combination with acephate, malathion, and trichlorfon, each at 1.1 kg ai/ha, carbaryl and toxaphene, each at 1.7 kg ai/ha, and dimethoate, at 0.4 kg ai/ha. A no herbicide and a no insecticide check was included. All chemical treatments were applied using a CO_2 hand sprayer as previously described. Measurements of chlorophyll fluorescence were obtained 4, 8, 24, 48, and 72 h after chemical application.

Chapter IV

RESULTS AND DISCUSSION

Effect of Chlorsulfuron and Metsulfuron with Insecticides on Wheat Yield

Statistical analysis of the 1984 grain yields from the Agronomy Research Station, Stillwater, Oklahoma, revealed no herbicide by insecticide interaction. However, averaged over insecticide treatments, metsulfuron at 23 and 35 g ai/ha (Table III) significantly reduced yield by more than 300 kg/ha. Averaged over herbicide treatments all insecticide treatments except carbaryl reduced yield by more than 280 kg/ha.

In 1985, metsulfuron at all rates, significantly reduced yield from 244 to 439 kg/ha, averaged over insecticide treatments (Table IV). Averaged over herbicide treatments all insecticide treatments reduced yield by more than 297 kg/ha. However, the yield from carbaryl treated plots was again higher than the yield from plots treated with other insecticides.

Statistical analysis of the visual ratings from Perkins indicated no significant herbicide by insecticide

TABLE III

EFFECT OF CHLORSULFURON AND METSULFURON WITH SELECTED INSECTICIDES ON WHEAT YIELD (1984)

Insecticide treatment	Herbicide treatment							
	Chlorsulfuron			Metsulfuron				
	(g ai/ha)							
	12	23	35	12	23	35	Check	Means
	(kg/ha)							
Acephate	3911	4410	3903	4320	3864	3831	3913	[4023]
Carbaryl	4671	4371	4583	4611	4024	4232	4876	[4482]
Dimethoate	3975	3983	4268	3868	4250	3936	4154	[4062]
Malathion	4232	4199	4359	4098	3565	3551	4560	[4081]
Toxaphene	4077	3984	4024	3884	4068	3940	4572	[4048]
Trichlorfon	4010	4020	3942	3749	3756	4142	4151	[3968]
Check	4727	4396	4330	4326	3967	4357	4572	[4383]
Means	(4230)	(4196)	(4202)	(4124)	(3929)	(3999)	(4368)	

L.S.D. .05 for comparing herbicide treatment means averaged across insecticides, in()= (349)

L.S.D. .05 for comparing insecticide treatment means averaged across herbicides, in[]= [297]

Table IV

EFFECT OF CHLORSULFURON AND METSULFURON WITH SELECTED INSECTICIDES ON WHEAT YIELD (1985)

	Herbicide treatments							
	Chlorsulfuron			Metsulfuron				
	(g ai/ha)							
Insecticide treatment	12	23	35	12	23	35	Check	Means
	(kg/ha)							
Acephate	2867	2869	3092	2512	2724	2651	3240	[2852]
Carbaryl	3122	3419	3194	2655	3273	3104	3079	[3122]
Dimethoate	2817	2860	3161	2602	2870	2895	2911	[2875]
Malathion	2667	2384	2914	2253	2782	2871	2808	[2669]
Toxaphene	2862	3144	3243	2422	2903	2926	3414	[2982]
Trichlorfon	3213	2947	3415	2585	2768	2698	3195	[2975]
Check	4158	3790	3757	2912	2998	3345	4240	[3601]
Means	(3102)	(3060)	(3255)	(2564)	(2904)	(2928)	(3271)	

L.S.D. .05 for comparing herbicide treatment means averaged across insecticides, in()= 280

L.S.D. .05 for comparing insecticide treatment means averaged across herbicides, in[]= 104 interaction, however, averaged over insecticide treatments, metsulfuron clearly caused some chlorosis on the wheat. Among the insecticides, malathion was the only one that caused significant visual injury (Table V).

Statistical analysis of the 1985 grain yields from Perkins again revealed no significant herbicide by insecticide interaction. A significant insecticide treatment main effect was present, however, there were no significant differences in insecticide treatments compared to the check (Table VI). The yield from the toxaphene treated plots was higher than the yield from plots treated with acephate, dimethoate, methyl parathion, or trichlorfon. Also the yield of malathion treated plots was higher than that of methyl parathion treated plots.

Statistical analysis of the percent dockage revealed a significant insecticide main effect. Although there was a significant decrease with toxaphene, compared to methyl parathion, there were no significant differences between insecticide treatments compared to the check (Table VII).

TABLE V

CHLOROSIS OF WHEAT AS AFFECTED BY CHLORSULFURON AND METSULFURON WITH SELECTED INSECTICIDES (PERKINS FALL 1984)

Insecticide Treatment	Herbicide treatment							Means
	Chlorsulfuron			Metsulfuron			Check	
	12	23	35	12	23	35		
	(Percent chlorosis)							
Acephate	1	1	5	10	13	13	0	[6]
Dimethoate	5	1	5	9	11	13	0	[6]
Malthion	16	14	13	16	20	24	6	[16]
Methyl para[1]	10	4	6	11	18	16	0	[9]
Toxaphene	6	3	3	13	13	11	2	[7]
Trichlorfon	3	0	4	9	11	11	0	[5]
Check	6	6	3	10	16	15	0	[7]
Means	(6)	(4)	(5)	(11)	(14)	(15)	(1)	

L.S.D. .05 for comparing insecticide treatment means averaged over herbicide treatments, in [ ]= 2

L.S.D. .05 for comparing herbicide treatment means averaged over insecticide treatments, in ( )= 4

---

[1] refers to methyl parathion

TABLE VI

EFFECT OF FALL APPLICATION OF CHLORSULFURON AND METSULFURON WITH SELECTED INSECTICIDES ON WHEAT YIELD (PERKINS 1985)

Insecticide Treatment	Herbicide treatment							Means
	Chlorsulfuron			Metsulfuron			Check	
	12	23	35	12	23	35		
	(kg/ha)							
Acephate	1232	1241	1308	1333	1267	965	998	[1191]
Dimethoate	1233	1299	1129	1119	1244	1068	946	[1148]
Malathion	1292	1356	1399	1269	1495	1370	1158	[1334]
Methyl para[1]	1162	965	1241	1237	1202	1097	1035	[1134]
Toxaphene	1737	1551	1434	1507	1525	1367	1206	[1475]
Trichlorfon	1332	1410	1078	1205	1272	1124	1124	[1221]
Check	1260	1148	1246	1487	1478	1304	1325	[1321]

L.S.D. .05 for comparing insecticide treatment means, averaged over herbicide treatments, in [ ]= 192

---

1. refers to methyl parathion

TABLE VII

PERCENT DOCKAGE OF WHEAT FOR CHLORSULFURON AND METSULFURON WITH SELECTED INSECTICIDES (PERKINS 1985)

Insecticide treatment	Herbicide treatment							
	Chlorsulfuron			Metsulfuron			Check	Means
	(g ai/ha)							
	12	23	35	12	23	35		
	(% dockage)							
Acephate	23.3	20.3	20.1	15.8	21.0	17.2	26.8	[20.6]
Dimethoate	20.9	20.9	26.5	22.2	20.3	15.0	23.8	[21.4]
Malathion	24.9	23.5	16.8	16.3	17.3	17.4	21.0	[19.6]
Methyl parathion	23.3	26.2	25.1	23.5	25.6	20.8	24.1	[24.1]
Toxaphene	18.5	18.6	17.7	14.8	15.5	17.1	19.0	[17.3]
Trichlorfon	18.8	18.4	20.5	17.9	20.5	20.8	24.7	[20.2]
Check	23.0	25.7	21.8	19.0	20.5	20.3	26.4	[22.4]

L.S.D. .05 for comparing insecticide treatment means averaged over herbicide treatments, in [ ]= 4

Effect of Chlorsulfuron and Methyl Parathion on Wheat

Statistical analysis of the yield data revealed no pesticide by varietial interaction. However, there was a significant pesticide treatment affect indicated, although when compared to the check there were no significant differences among the pesticide treatments (Table VIII). Methyl parathion with and without chlorsulfuron reduced dockage by more than 2.8 percent compared to the check (Table IX).

Effect of Greenbug Infestation, Prior to Chemical Treatment, on Chlorophyll Fluorescence of Wheat

Analysis of chlorophyll fluorescence data revealed that infestion of wheat with greenbugs for a period of 72 h before chemical treatment did not affect the I:P ratio. Also, such prior greenbug infestations had no effect on the influence of the pesticides on I:P ratios (Table X). Chlorsulfuron caused no significant increase in the I:P

TABLE VIII

EFFECT OF CHLORSULFURON AND METHYL PARATHION ON SELECTED WHEAT VARIETIES

	Chemical treatments				
	Chlorsulfuron		MP[1]	Chlor[2] + MP	Check
	(g ai/ha)				
Wheat varieties	23	35	300	23 + 300	
	(kg/ha)				
Centurk	1566	1900	1690	1741	1847
Chisholm	1845	2076	1441	1509	1783
Osage	1651	1901	1607	1297	1552
TAM W 101	1575	1442	1479	1590	1384
TAM W 105	1118	1335	1206	1265	1051
Vona	1586	1670	1372	1417	1746
Means	(1557)	(1725)	(1466)	(1469)	(1560)

L.S.D. .05 for comparing chemical treatment means averaged over varieties, in()= 174

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[1] refers to methyl parathion

[2] refers to chlorsulfuron

TABLE IX

PERCENT DOCKAGE AS AFFECTED BY CHLORSULFURON AND METHYL PARATHION ON WHEAT

	Chemical treatments				
	Chlorsulfuron		MP[1]	Chlor[2] + MP	Check
	(g ai/ha)				
Wheat varieties	23	35	300	23 + 300	
	(Percent Dockage)				
Centurk	9.5	7.7	6.6	6.1	7.5
Chisholm	8.9	14.0	10.1	12.5	15.1
Osage	8.5	10.1	9.8	3.2	13.1
TAM W 101	8.9	9.2	9.4	11.4	11.4
TAM W 105	17.2	10.0	14.7	10.8	16.7
Vona	12.0	9.9	8.6	10.7	12.6
Means	(10.9)	(10.1)	(9.8)	(9.1)	(12.7)

L.S.D. .05 for comparing dockage means for chemical treatments averaged over varieties, in ()= 2.8

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1. refers to methyl parathion
2. refers to chlorsulfuron

Table X

EFFECT OF GREENBUG INFESTATION, PRIOR TO TREATMENT, ON CHLOROPHYLL FLUORESCENCE OF WHEAT

Time after chemical application	Pesticide treatment			
	Chlor[1]	MP[2]	Chlor + MP	Check
	(I:P ratio)			
24 h				
Without greenbugs[3]	.56	.68	.74	.53
With greenbugs	.58	.62	.69	.55
(Means)	(.57)	(.65)	(.72)	(.54)
48 h				
Without greenbugs	.60	.64	.73	.58
With greenbugs	.60	.61	.68	.55
(Means)	(.60)	(.63)	(.71)	(.56)
72 h				
Without greenbugs	.53	.58	.55	.63
With greenbugs	.60	.60	.64	.56
(Means)	(.56)	(.59)	(.59)	(.59)
Treatment means	[.58]	[.62]	[.67]	[.57]

L.S.D. .05 for comparing treatment means by time, in()= .05
L.S.D. .05 for comparing treatment means averaged over time, in[]= .05

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1. refers to chlorsulfuron
2. refers to methyl parathion
3. greenbugs were applied for 72 h prior to pesticide application

ratio 24, 48 or 72 h after treatment, however, methyl parathion at 0.3 kg ai/ha increased the I:P ratio at 24 and 48 h after treatment, but not at 72 h. The combination of chlorsulfuron at 23 g ai/ha plus methyl parathion increased the I:P ratio at 24 and 48 h after treatment more than methyl parathion alone (Table X). After 72 h, the chlorsulfuron plus methyl parathion treatment was no longer affecting the I:P ratio. Thus it would appear that although methyl parathion and chlorsulfuron reacted synergistically in regard to initial affect on I:P ratios, chlorsulfuron does not appear to delay the plants ability to overcome the effect of methyl parathion on the I:P ratio.

Effect of Methyl Parathion and Malathion, with and without Chlorsulfuron, on Chlorophyll Fluorescence of Wheat

There was a significant increase in the I:P ratio of plants treated with either malathion or methyl parathion from 4 to 72 h after application. Chlorsulfuron alone had no effect on chlorophyll fluorescence, but in combination with either insecticide, fluorescence was increased more than the increase from the insecticides alone (Table XI).

Table XI

EFFECT OF CHLORSULFURON WITH MALATHION AND METHYL PARATHION ON CHLOROPHYLL FLUORESCENCE OF WHEAT

	Time after chemical application							
	4 h		24 h		48 h		72 h	
Treatment	Chlor[1]	Check	Chlor	Check	Chlor	Check	Chlor	Check
	(I:P ratio)							
Malathion	.77	.64	.86	.72	.86	.72	.79	.67
M. para.[2]	.78	.66	.88	.74	.88	.74	.81	.68
Check	.56	.57	.59	.60	.58	.59	.58	.60

L.S.D. .05 for herbicide by insecticide by time interaction= .05

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1. refers to chlorsulfuron
2. refers to methyl parathion

The I:P ratio had not returned to normal after 72 h in this experiment. However, the I:P ratio of plants treated with both malathion and malathion plus chlorsulfuron decreased between 48 and 72 h, again indicating that chlorsulfuron does not decrease the rate of malathion detoxification. Data for methyl parathion and methyl parathion plus chlorsulfuron at 48 and 72 h after treatment also indicates that chlorsulfuron does not inhibit methyl parathion detoxification.

Effect of Chlorsulfuron and Metsulfuron with Insecticides on Chloropyll Fluorescence of Wheat

Analysis of chlorophyll fluorescence data revealed a significant herbicide by insecticide by time after application interaction. Chlorsulfuron caused no significant increase the I:P ratio. All insecticide treatments 4, 8, 24, and 48 h after application increased the I:P ratio. Only malathion was still increasing the I:P ratio 72 h after application. Among the combinations, chlorsulfuron with acephate, dimethoate, malathion, toxaphene, and trichlorfon increased the I:P ratio 4, 8, 24, and 48 h in a similar fashion as the insecticides above. At

72 h after application the I:P ratio with malathion plus chlorsulfuron had not decreased significantly from that recorded at 48 h, but the I:P ratio at 72 h with malathion alone was significantly less than the I:P ratio from that treatment at 48 h. The combination of chlorsulfuron and carbaryl decreased the the I:P ratio compared to carbaryl alone, from 4 to 48 h after treatment. After 72 h, carbaryl alone no longer affected the I:P ratio (Table XII).

Metsulfuron increased the I:P ratio of wheat at 4 and 8 h after treatment. By 24 h the effect was diminished and by 48 h was no longer present. This indicates much more rapid detoxification of metsulfuron than of insecticides. There were no apparent metsulfuron by insecticide interactions. Measurements of chlorophyll fluorescence 24, 48, and 72 h following metsulfuron application revealed no significant increase in the I:P ratio. All combinations of metsulfuron with insecticides increased the I:P ratio 4, 8, 24, and 48 h after application. Fluorometer measurements taken 72 h after metsulfuron plus insecticides were applied revealed that only the metsulfuron with acephate and malathion to have a significant increase in the I:P ratio (Table XII).

Table XII

EFFECT OF CHLORSULFURON AND METSULFURON WITH SIX SELECTED INSECTICIDES ON CHLOROPHYLL FLUORESCENCE OF WHEAT

	Time after application				
Treatment	4 h	8 h	24 h	48 h	72 h
	(I:P ratio)				
Acephate					
Chlorsulfuron	.72	.73	.71	.75	.54
Metsulfuron	.76	.79	.67	.70	.65
Check	.65	.69	.68	.74	.60
Carbaryl					
Chlorsulfuron	.54	.55	.53	.56	.56
Metsulfuron	.69	.71	.80	.80	.55
Check	.72	.74	.77	.75	.61
Dimethoate					
Chlorsulfuron	.67	.68	.68	.74	.56
Metsulfuron	.75	.76	.76	.78	.57
Check	.72	.74	.72	.77	.57
Malathion					
Chlorsulfuron	.75	.77	.79	.79	.69
Metsulfuron	.70	.71	.76	.76	.64
Check	.70	.71	.73	.76	.64
Toxaphene					
Chlorsulfuron	.70	.72	.74	.73	.57
Metsulfuron	.72	.74	.79	.80	.57
Check	.73	.74	.77	.81	.51
Trichlorfon					
Chlorsulfuron	.71	.73	.71	.75	.56
Metsulfuron	.72	.74	.73	.75	.57
Check	.68	.69	.70	.79	.51
Check					
Chlorsulfuron	.52	.53	.53	.49	.56
Metsulfuron	.74	.75	.65	.58	.54
Check	.53	.54	.55	.56	.52

L.S.D. .05 for herbicide by insecticide by time interaction= .11

CHAPTER V

SUMMARY

In the field there were no significant herbicide by insecticide interactions. Although chlorsulfuron did not reduce yield, in 1984 metsulfuron at 23 and 35 g ai/ha and in 1985 at 12, 23, and 35 g ai/ha significantly reduced yield. In 1984, all insecticide applications, except carbaryl, significantly reduced yield. All insecticide treatments, including carbaryl, significantly reduced yield in 1985, however, carbaryl did not reduce yield as much as the other insecticides.

In laboratory experiments, greenbugs did not affect chlorophyll fluorescence before chemical application. After chemical application there was no affect up to 72 hours. Chlorsulfuron did not affect chlorophyll fluorescence, as determined by measuring the I:P ratio at any time after application, however, methyl parathion significantly increased the I:P ratio. The combination of chlorsulfuron and methyl parathion increased the I:P ratio more than methyl parathion alone. Methyl parathion and malathion significantly increased the I:P ratio from 4 to 72 h after application. The combination of chlorsulfuron with methyl parathion and malathion significantly increased the I:P ratio over that of the insecticide application alone. There was no significant difference in the effect on the I:P ratio between the two insecticides. Metsulfuron increased the I:P ratio from 4 to 24 h after application, indicating that metabolism of metsulfuron at the rate applied required more than 24 h. Metsulfuron, applied in combination with acephate, carbaryl, dimethoate, malathion, toxaphene, and trichlorfon, significantly increased the I:P ratio from 4 to 48 h after treatment. After 72 h only malathion, malathion with both chlorsulfuron and metsulfuron, and acephate with metsulfuron were significantly increasing the I:P ratio. Chlorsulfuron did not affect chlorophyll fluorescence at any time after application. However, acephate, dimethoate, malathion, toxaphene, and trichlorfon, applied alone and in combination with chlorsulfuron, significantly increased the I:P ratio from 4 to 48 h after treatment. Carbaryl with chlorsulfuron reduced the I:P ratio from 4 to 72 h after treatment compared to carbaryl alone.

Based on field experiments it is suggested that the use rate of metsulfuron be reduced to the current labeled use rate of 5.8 g/ha. Results from the laboratory experiments indicate a possible inhibition of photosynthesis in wheat due to insecticide application with a possible reduction in the metabolizm of the herbicides. Therefore it is suggested that to avoid possible interactions insecticides should be applied at least 72 h before subsequent herbicide application.

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APPENDIX

Table XIII

RAINFALL DATA (QUANTITIES OVER 1 CM) AND DATE OF INITIATION OF EXPERIMENTS -AGRONOMY RESEARCH STATION, STILLWATER, OKLAHOMA (JULY 1, 1983 - JUNE 30, 1985)

Date	Centimeters	Date	Centimeters
August 19, 1983	2.2	October 27	6.5
September 13	2.8	November 1	1.3
September 20	1.5	November 17	1.7
October 20	6.1	November 18	2.2
October 21	8.2	December 5	1.1
November 19	1.6	December 14	2.2
November 23	1.7	December 15	2.1
March 7, 1984 -iniation of exp-		December 16	4.0
March 12,	1.0	January 1, 1985	5.2
March 23	3.8	January 27	1.1
March 24	2.6	February 21	3.9
March 28	2.0	February 24	6.4
March 31	1.3	March 4	3.3
April 8	2.4	March 19 -iniation of exp-	
April 11	1.3	March 20	2.1
April 27	1.7	March 21	1.5
May 8	2.4	March 27	1.7
May 11	1.3	March 30	2.7
May 20	1.6	April 22	1.7
May 26	2.1	April 27	5.2
June 12	2.0	April 29	1.0
June 20	2.7	April 30	4.3
June 26	5.4	May 13	1.2
June 28	1.2	June 2	2.0
July 12	1.0	June 5	4.1
August 11	1.5	June 7	1.9
September 28	1.4	June 11	1.4
October 16	1.5	June 22	1.3
October 21	1.3	June 27	4.3
October 25	2.1		

TABLE XIV

RAINFALL DATA (QUANTITIES OVER 1 CM) AND DATE OF INITIATION OF EXPERIMENTS - AGRONOMY RESEARCH STATION, PERKINS, OKLAHOMA (JULY 1, 1984 - JUNE 30, 1985)

Date	Centimeters	Date	Centimeters
August 9, 1984	1.7	Feburary 23	8.7
September 2	1.0	March 4	6.0
October 16	1.1	March 20	2.6
October 25	2.2	March 21	2.2
October 27	4.2	March 30	3.3
October 29 (exp. intiated)		April 22	2.5
November 1	1.0	April 27	3.9
November 17	1.5	April 30	7.6
November 18	2.9	May 1	1.0
December 5*	0.6	May 8	1.2
December 14	2.8	May 13	1.3
December 15	2.9	May 14	2.0
December 16	5.3	June 5	8.6
December 31	2.1	June 11	1.0
January 1, 1985	3.7	June 22	1.4
February 21	3.4	June 27	5.1

* first rainfall following pesticide application

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