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Interactive Effects of Weeds and Defoliating Insects in Soybean (Glycine Max).

Charles Frost Grymes

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INTERACTIVE EFFECTS OF WEEDS AND DEFOLIATING INSECTS IN
SOYBEAN (*Glycine max*)

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Plant Pathology and Crop Physiology

by

Charles F. Grymes
M.S., Texas A&M University, 1993
B.S., Texas A&M University, 1990
May 1997
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ABSTRACT

Field experiments were conducted to evaluate the influence of simulated insect defoliation and full season weed competition on soybean [Glycine max (L.) Merr.] growth and yield. Weeds were johnsongrass [Sorghum halepense (L.) Pers.], common cocklebur (Xanthium strumarium L.), and hemp sesbania [Sesbania exaltata (Raf.) Rybd. ex A.W. Hill] at 15, 3, and 12 plants/6 m of row. Simulated defoliation at R2 and R5 soybean growth stages was accomplished by removal of 0, 1, or 2 leaflets per soybean trifoliate, which approximated 0, 33, and 66% defoliation, respectively. Averaged across defoliation levels and stages, johnsongrass, common cocklebur, and hemp sesbania reduced soybean yields 30, 15, and 14%, respectively, in 1994 compared with no weed interference. In 1995, common cocklebur did not affect yield, whereas johnsongrass reduced yield 35%. As defoliation level increased, a linear decrease in soybean yield was observed. Averaged across weeds and defoliation stages, 33 and 66% defoliation reduced soybean yield 6 and 20% in 1994 and 12 and 33% in 1995, respectively. Defoliation at R5 resulted in 10% lower yield than defoliation at R2 in one of two years. Yield reduction due combinations of weeds and defoliation was additive.

Field experiments evaluated the influence of hemp sesbania and sicklepod [Senna obtusifolia (L.) Irwin and Barneby] on insecticide deposition within the soybean canopy and resultant soybean looper [Pseudoplusia includens (Walker)] control. Dye-sensitive cards placed in top, middle, and bottom portions of the soybean
canopy measured spray droplet deposition for the insecticide thiodicarb applied at 504 g ai/ha in 94 L/ha spray volume with a ground sprayer. Spray droplet deposition was highest on cards placed in the top of the soybean canopy, and weeds reduced deposition 26 to 43% compared with weed-free soybean. Thiodicarb deposition within the middle and bottom levels of the canopy was not reduced by weeds. Weeds, however, did not influence thiodicarb efficacy against soybean looper in the field or in laboratory feeding bioassays. Control of both weeds and defoliating pest is important; however, management strategies for soybean looper may not need to be altered when weeds are present.
CHAPTER I

INTRODUCTION

Soybean [Glycine max (L.) Merr.] is the dominant oilseed crop in the world accounting for 20 to 25% of the total fat and oil production (Smith and Huyser 1987). Soybean oil is commonly used in shortening and margarine and in a variety of other products. Meal is a major source of protein for livestock feed. Soybean was first grown in the United States in 1765 on a farm in Thunderbolt, Georgia (Hymowitz and Harlan 1983). In Louisiana, soybean has been an important cash crop since the 1960's (Morrison and McCormick 19%). In 1994, soybean was grown on approximately 465000 ha in Louisiana, with an estimated production value of $189 million (Anonymous 1995).

Soybean grown in the Gulf Coast states is exposed to stresses imposed by more species of pests, during longer periods of the year, and more frequently than in any other area of the United States (Newsom and Boethel 1985). Pest management strategies, however, have been primarily directed toward only a single class of pest such as weeds, insects, or pathogens, with little concern for interactions that may occur.

Adequate rainfall and soil moisture, warm temperatures and mild winters, along with nutrient-rich soils in Louisiana provide an environment conducive to growth of a broad spectrum of weed species (Jordan et al. 1987; Sanders 1996). Weeds primarily reduce crop yields by directly competing with the crop for limited supplies
of water, nutrients, and light (Ross and Lembi 1985). Some weeds can also have allelopathic properties whereby chemicals released into the rhizosphere inhibit the germination and/or growth of other plants. Competition and allelopathy are often collectively referred to as weed interference (Anderson 1996). The degree of interference and ultimately yield reduction associated with weeds are dependent on weed species and density. A single giant foxtail (Setaria faberi Herrm.) plant/30 cm of soybean row (30000/ha) resulted in a 13% yield reduction, whereas one smooth pigweed (Amaranthus hybridus L.) at the same density reduced yield 25% (Nave and Wax 1971). McWhorter and Hartwig (1972) reported 23 to 43% yield losses from johnsongrass [Sorghum halepense (L.) Pers.] competition, with differences dependent upon the soybean variety. Common cocklebur (Xanthium strumarium L.) reduced yields of the same varieties 63 to 75%. Mosier and Oliver (1995) reported yield losses of 57 and 60% with one common cocklebur plant/30 cm of row (32000/ha) under irrigated and non-irrigated conditions, respectively. Full season competition by common cocklebur populations of 3300, 6600, 13000, and 26000 plants/ha reduced soybean yields 10, 28, 43, and 52%, respectively (Barrentine 1974). Full season competition from hemp sesbania [Sesbania exaltata (Raf.) Rybd. ex A.W. Hill] at densities up to 5500 plants/ha did not reduce soybean yields, but populations of 8100 to 129000 plants/ha reduced yields 10 to 80% (McWhorter and Anderson 1979). In Arkansas, sicklepod [Senna obtusifolia (L.) Irwin and Barneby] spaced 10 and 30 cm apart (98000 and 32000/ha) reduced soybean yield 41 and
31%, respectively (Bozsa et al. 1989). Thurlow and Buchanan (1972) observed 19 to 35% soybean yield losses from sicklepod at densities of 7.7/m² (77000/ha). In general, if the crop can be maintained free of weeds for 4 to 5 weeks after emergence, later emerging weeds cause little or no yield loss (Ross and Lembi 1985), but can reduce harvest efficiency and crop quality. High weed populations may render mechanical harvest difficult. Elevated moisture and foreign material in harvested seed can lead to grade reductions that lower the value of the crop and reduce economic returns. Application of postemergence herbicides to wild poinsettia (*Euphorbia heterophylla* L.) did not increase weed control or soybean yield over that following only a preemergence application, but percent moisture and foreign material in the harvested soybean seed were reduced (Willard and Griffin 1993). Balloonvine (*Cardiospermum halicacabum* L.) produces a seed the same shape and size as soybean seed; therefore, it is difficult to separate from the crop seed (Jordan et al. 1987). Reduction in price received for soybean at the elevator due to high moisture and presence of foreign material or weed seed in many cases can justify the additional cost of herbicides.

Many insect pests feed on soybean during vegetative and reproductive growth stages (Turnipseed and Kogan 1987), but several species cause enough damage to justify control measures (Tynes and Boethel 1996). In Louisiana, soybean looper [*Pseudoplusia includens* (Walker)], velvetbean caterpillar [*Anticarsia gemmatalis* (Hübner)], and stink bugs [*Nezara viridula* (L.), *Acrosternun hilare* (Say)], and
Euchistus servus (Say)] frequently reach threshold levels that necessitate use of insecticides (Baldwin et al. 1996). Other important insect pests of soybean include corn earworm [Helicoverpa zea (Boddie)], bean leaf beetle [Ceratoma trifurcata (Forster)], and threecornered alfalfa hopper [Spissistilus festinus (Say)]. Soybean looper, velvetbean caterpillar, green cloverworm [Plathypena scabra (Fabricius)], Mexican bean beetle (Epilachna varivestis Mulsant), and bean leaf beetle all feed on soybean foliage. These pests reduce photosynthetically active leaf area of a plant, thereby reducing yield in some cases. Soybean looper larvae habitually feed in the lower half to two-thirds of the soybean canopy (Herzog 1980) and are most injurious to soybean from August to October (Steffey et al. 1994). A single soybean looper larva can consume up to 114 cm² of leaf tissue before pupation (Boldt et al. 1975; Reid and Greene 1973). Wier and Boethel (1996) reported soybean yield losses of 48 and 94% at defoliation levels of 74 and 94%, respectively, from full bloom (R2) to pod development (R5) (Fehr et al. 1971).

In approximately 90% of studies investigating the effect of defoliation on soybean yield, artificial injury was used to simulate actual insect defoliation (Ostlie and Pedigo 1984). Hinson et al. (1978) reported soybean seed yield losses of 8, 21, 31, and 30% with 67% leaf defoliation imposed 3, 17, 31, and 42 days after flowering, respectively, whereas yields were reduced only 4% with 33% defoliation. Defoliation of soybean 33, 66, and 100% at first bloom reduced yield 15, 20, and 36%, respectively, and 19, 37, and 67%, respectively, when defoliated 4 weeks
later (Todd and Morgan 1972). Most studies have shown soybean to be most tolerant to defoliation up to R3 (pod initiation) (Fehr et al. 1971), and prior to R3, soybean can tolerate up to 30% defoliation (Turnipseed and Kogan 1987). Research has been conducted using various simulated defoliation techniques including removal with a hole puncher or cork-borer, clipping portions of a leaflet (Poston et al. 1976), and excision of entire leaflets (Kalton et al. 1949; Todd and Morgan 1972). Even though the methodology has been refined, the hole puncher or clipping techniques are generally no more effective in representing a percentage defoliation than simply removing the entire leaflet (Turnipseed and Kogan 1987).

Soybean is also susceptible to many pathogens (Athow 1987; Ross 1987). Bean pod mottle virus, vectored by the bean leaf beetle, is common in Louisiana (Ross 1987). Bacterial blight \( Pseudomonas syringae \) pv. \( glycinea \) (Coerper) Young, Dye, Wilke is the major bacterial disease of soybean. A number of fungal pathogens can cause leaf defoliation of soybean. Common diseases include foliar blight \( (Rhizoctonia solani \) Kühn), frog-eye leaf spot \( (Cercospora sojina \) Hara), brown spot \( (Septoria glycines \) Hemmi), downy mildew \( (Peronospora manshurica \) (Naum.) Syd. ex Gäum], and red crown rot \( (Calonectria crotalariae \) (Loos) Bell and Sobers) (Berggren 1989; Phillips 1989; Whitam 1996). In Louisiana, frog-eye leaf spot and foliar blight have caused soybean yield losses as high as 20 and 80%, respectively (Whitam 1996).
In field situations, pests only rarely occur singly, but more commonly as complexes. The concept of integrated pest management (IPM) has been around since the 1950's with the original intent to promote judicious use of synthetic organic insecticides (Holtzer et al. 1996). The IPM concept emphasized the integration of multiple tactics for the management of pests in an ecologically and economically sound manner (Berry 1995). The most important aspects of an IPM program include use of pesticides, host plant resistance, biological control, and cultural practices (Holtzer et al. 1996). Researchers in the plant protection disciplines often fail to address interactions associated with multiple pest complexes that occur under field conditions. Consequently, such interactive effects are not considered in economic evaluations of pest management programs. While the IPM concept is familiar to scientists in many disciplines, investigations of pest complexes have been hindered by unfamiliarity of scientists with experimental methodology outside their respective disciplines (Higgins 1985). Furthermore, the complexity of dealing with a diversity of species can be overwhelming (Newsom and Boethel 1985). To conduct meaningful interactive research, Higgins (1985) suggested that pests with relatively simple life cycles and substantial data bases should be selected. This should enhance the possibility that integrated management practices could be developed.

Considerable research has addressed insect and disease interactions. Girdling of soybean stems by threecornered alfalfa hopper increased the severity of stem
anthracnose disease \textit{[Colletotrichum truncatum (Schw.)]} (Russin et al. 1987).  
Severity of stem canker disease \textit{[Diaporthe phaseolorum (Cke. & Ell.) Sacc. var. caulivora Ahow & Caldwell]} was greater when soybean was defoliated by soybean looper larvae (Russin et al. 1989a). In other studies, defoliation of soybean by soybean looper increased numbers of juvenile and cyst stages of soybean cyst nematode \textit{(Heterodera glycines Ichinohe)} in roots and soil (Russin et al. 1989b). Additionally, population densities of root-knot nematode \textit{[Meloidogyne incognita (Kofoid & White) Chitwood]} were greatest for plants defoliated by soybean looper (Russin et al. 1993). Padgett et al. (1994) reported that red crown rot incidence and stem canker severity were less on soybean defoliated by soybean looper, but stem canker severity was increased when soybean stems were girdled by the threecornered alfalfa hopper.

Research has also addressed interactions between weeds and pathogens. Some weeds can serve as alternate hosts for the soybean stem canker (Black et al. 1996b) and aerial blight (Black et al. 1996a) pathogens common in Louisiana soybean. The stem canker pathogen was isolated from hemp sesbania and hairy indigo \textit{(Indigofera hirsuta Harvey)}, but not from johnsongrass or barnyardgrass \textit{[Echinochloa crus-galli (L.) Beauv.]} (Black et al. 1996b). Berner et al. (1991) reported less mycelial growth by \textit{Calonectria crotalariae}, the causal agent of red crown rot, exposed to the herbicide glyphosate \textit{[N-(phosphonomethyl)glycine]}. Furthermore, incidence of red crown rot in the soybean field was reduced when glyphosate was applied preplant.
Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) herbicide prevented *Rhizoctonia solani* sclerotia production in laboratory studies and reduced *Rhizoctonia* foliar blight severity in field-grown soybean with high disease pressure (Black et al. 1996c).

The relationship between weeds and insects has been investigated to a lesser extent. Insect populations can be influenced by weeds. Collins and Johnson (1985) reported that oviposition by velvetbean caterpillar adult moths was almost three times greater in hemp sesbania, common cocklebur, and morningglory (*Ipomoea lacunosa* L. and *Ipomoea hederacea* (L.) Jacq.) infested soybean than in weed-free soybean. The nectar produced by morningglories (*Ipomoea* sp.) and hemp sesbania was a carbohydrate source required by soybean looper and velvetbean caterpillar for normal egg production. Altieri et al. (1981) observed lower populations of the predator *Geocoris* sp. in weed-free soybean in comparison with soybean infested with sicklepod. Conversely, velvetbean caterpillar and southern green stink bug (*Nezara viridula* (L.)) were more abundant in weed-free plots. The populations of velvetbean caterpillar and stinkbug may have been lower due to reduced soybean biomass under weedy conditions. Predator insects, *Coleomegilla maculata* (DeGeer), *Orius insidiosus* (Say), and *Nabis* spp., also were more abundant in weedy soybean, whereas Mexican bean beetle populations were higher in weed-free soybean (Shelton and Edwards 1983).
Herbicides also can affect insect populations. Soybean looper larvae survived for 13.8 days on soybean leaves treated with fluazifop-butyl [(\(\pm\))-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid] compared with 15 days for non-treated leaves (Angello et al. 1986b). Mexican bean beetle larvae reared on soybean plants treated with sethoxydim [2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] herbicide took longer to pupate than larvae on non-treated plants, while larvae reared on soybean plants treated with fluazifop-butyl had lower pupal weights (Angello et al. 1986a). Mexican bean beetle adults also preferred feeding on untreated soybean plants rather than plants treated with sethoxydim or fluazifop-butyl. Huckaba and Coble (1990) observed lower larval and adult soybean thrips [*Sericothrips variabilis* (Beach)] numbers on soybean treated postemergence with naphthalam [2-[(1-napthalenylamino)carbonyl] benzoic acid] plus dinoseb [2-(1-methylpropyl)-4,6-dinitrophenol]. Populations of flower bug [*Orius insidiosus* (Say)], damsel bugs (*Nabis* spp.), leafhoppers (Cicadellidae), and tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois) were reduced with two applications of MSMA (monosodium salt of methylarsenic acid) herbicide applied to cotton (Baker et al. 1985). Higher levels of sugarcane borer [*Diatraea saccharalis* (F.)] in sugarcane have been reported following an application of 2,4-D [(2,4-dichlorophenoxy)acetic acid] (Ingram et al. 1947). Less parasitism (18\%) of sugarcane borer eggs by *Trichogramma minutum* Riley occurred on plants treated with 2,4-D.
Little research has investigated the impact of both weeds and insects on soybean. Helm et al. (1992) observed soybean yield reductions resulting from defoliation by soybean looper or competition from velvetleaf (Abutilon theophrasti Medik.). In some plots, soybean yield reduction by combination of the two pests was additive. Higgins et al. (1984) investigated the influence of velvetleaf competition and simulated green cloverworm defoliation on soybean. They concluded that the economic injury level for green cloverworm did not change when velvetleaf was present. Robbins et al. (1990) investigated the relationships among soybean cyst nematode, threecornered alfalfa hopper, and three weeds (common cocklebur, pitted morningglory, or sicklepod). Yield loss attributed to each pest was additive.

Herbicides, insecticides, and fungicides are commonly applied to prevent pests from reaching levels of economic consequence. The effectiveness of a pesticide is related to many environmental, chemical, and physical factors (Johnstone 1985). Temperature and humidity affect the stability of a spray droplet containing the pesticide. Wind coupled with small spray droplet size is conducive to pesticide drift, resulting in poor control of the pest and possible injury to non-target crops. The herbicide 2,4-D can injure susceptible plants several kilometers downwind of the target area (Matthews 1992). To achieve optimum pest control, good coverage of the target weed (Field and Bishop 1988), insect (Hutchins and Pitre 1985), or pathogen (Royal et al. 1990; Walker and Huitink 1989) is often critical. Greater soybean looper mortality with permethrin [(3-phenoxyphenyl)methyl(±)-cis. trans-
3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate] insecticide in the upper one-third of the soybean canopy was associated with greater pesticide coverage in this region (Hutchins and Pitre 1985). Walker and Huitink (1989) reported greater propiconazole [1-[[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1H-1,2,4-triazole] fungicide coverage provided greater control of sheath blight \textit{(Rhizoctonia solani} Kühn) on rice \textit{(Oryza sativa} L.). Surfactants and crop oil concentrates have improved herbicide effectiveness by increasing droplet spread across the leaf, thereby enhancing leaf surface penetration (Ashton and Monaco 1991). Variations in sprayer speed, spray volume and pressure, nozzle type and orientation, and droplet size are among the many factors investigated as a means to improve pesticide distribution within the crop canopy (Carlton et al. 1982; Kirk et al. 1994; Salyani and Whitney 1989; Walker and Huitink 1989). Soybean looper mortality with permethrin insecticide was greater when insecticide was applied with ground equipment than by airplane (Hutchins and Pitre 1985). This difference was associated with increased spray droplet deposition in the target area with the ground equipment.

These studies were conducted under weed-free conditions and the impact of weeds on insecticide deposition and subsequent pest control were not considered. Leaves and stems of tall growing weeds potentially could intercept insecticide spray droplets resulting in less insecticide coverage within the crop canopy. Royal et al. (1990) reported that chlorothalonil (tetrachloroisophthalonitrile) fungicide deposition into...
peanut decreased and disease incidence increased with increasing densities of sicklepod, Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.], or common cocklebur. Hutchins and Pitre (1984) observed less coverage with methomyl [S-methyl-N-[(methylcarbamoyl)oxy]thioacetimidate] and methyl parathion [O,O-dimethyl O-p-nitrophenyl phosphorothioate] insecticides within the median one-third of the canopy in narrow-row (17.8 cm spacing) soybean compared with wide-row (96.5 cm spacing). Soybean looper larval mortality also was reduced in the median one-third of the canopy in the narrow-row soybean in relation to the wide row soybean. Parrot et al. (1973) reported greater deposits of azinphos-methyl [O,O-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl) methyl] phosphorodithioate] insecticide along with higher boll weevil (*Anthonomus grandis grandis* Boheman) mortality on fregu bract cotton in relation to normal bract cotton.

Weed and insect pests frequently occur together in the same field. Development of integrated pest management strategies, however, has been most often directed toward a single class of pest such as weeds or insects. When a multiple pest complex is present, both individual and interactive effects on crop yield may occur. To economically produce crops in the Southern United States, weeds, insects, and diseases must be managed. A decision to apply a pesticide is based on the economic return expected from controlling a specific pest without consideration of the subsequent impact on other pests that may be present. Interactions among pests should be considered before economic thresholds for pest complexes can be developed.
This dissertation addresses the combined stresses of weed competition and defoliation on weed and soybean growth and soybean yield. Previous research investigating interactive effects of weeds and insects was conducted in Iowa (Higgins et al. 1984) and Illinois (Helm et al. 1992) with indeterminate soybean and velvetleaf. However, in Louisiana determinate soybean is grown and velvetleaf is of minor importance. The agreement of these studies in respect to the additive response to defoliation and weed interference on soybean yield would be of significance considering the differences in environment and weed spectrum. Additionally, the effect of weeds on thiodicarb \( \text{[dimethyl-N,N'-[thiobis[(methylimino)carbonyloxy]] bis[ethanimidothioate]]} \) insecticide deposition into the soybean canopy and subsequent soybean looper control is investigated. Results of this research will help delineate the possible interactive effects of multiple pests in soybean and help justify use of multiple pest control measures to maximize economic returns in a soybean production system.

**LITERATURE CITED**


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Wier, A. T. and D. J. Boethel. 1996. Symbiotic nitrogen fixation and yield of soybean following defoliation by soybean looper (Lepidoptera: Noctuidae) during pod or seed development. J. Econ. Entomol. 89:525-535.

CHAPTER II

SOYBEAN (Glycine max) RESPONSE TO WEED INTERFERENCE AND DEFOLIATION

INTRODUCTION

Soybean [Glycine max (L.) Merr.] in the Gulf Coast states is exposed to stress imposed by more species of pests, during longer periods of the year, and more frequently than any other area of the United States (Newsom and Boethel 1985). Development of integrated pest management strategies has been most often directed toward a single class of pest such as weeds, insects, or pathogens. Weeds reduce soybean yield through competition for water, nutrients, and light. Williams and Hayes (1984) reported soybean yield reductions of 59 to 88% from johnsongrass [Sorghum halepense (L.) Pers.] competition. McWhorter and Hartwig (1972) reported yield losses of 23 to 43% from johnsongrass competition with differences attributed to soybean variety. Common cocklebur (Xanthium strumarium L.) reduced yields of the same varieties 63 to 75%. Full season competition by common cocklebur populations of 3300, 6600, 13000, and 26000 plants/ha reduced yields 10, 28, 43, and 52%, respectively (Barrentine 1974). Full season competition from hemp sesbania [Sesbania exaltata (Raf.) Rybd. ex A.W. Hill] at densities up to 5500 plants/ha did not reduce soybean yields; however, populations of 8100 to 129000 plants/ha reduced yield 10 to 80% (McWhorter and Anderson 1979).

In Louisiana, insects requiring control measures most frequently include the soybean looper [Pseudoplusia includens (Walker)] and velvetbean caterpillar.
[Anticarsia gemmatalis (Hübner)] (Baldwin et al. 1994). These two pests in their larval stage are most injurious to soybean from August to October (Steffey et al. 1994). A single soybean looper larva can consume up to 114 cm$^2$ of leaf tissue before pupation (Boldt et al. 1975; Reid and Greene 1973). In approximately 90% of studies investigating the effect of defoliation on soybean yield, artificial injury was used to simulate actual insect defoliation (Ostlie and Pedigo 1984). Hinson et al. (1978) observed soybean seed yield losses of 8, 21, 31, and 30% with 67% artificial defoliation at 3, 17, 31, and 42 days after flowering, respectively, whereas yields were reduced only 4% with 33% defoliation. Turnipseed and Kogan (1987) reported that most studies have shown soybean to be most tolerant to defoliation up to R3 (pod initiation) (Fehr et al. 1971), and that prior to R3, soybean can tolerate up to 30% defoliation.

Little research has addressed weed and insect relationships. Collins and Johnson (1985) reported that oviposition by velvetbean caterpillar adult moths was increased nearly three-fold when exposed to hemp sesbania, common cocklebur, and morningglory [Ipomoea lacunosa L. and Ipomoea hederacea (L.) Jacq.] infested soybean compared with weed-free soybean. Helm et al. (1992) observed soybean yield reductions from defoliation by both soybean looper and velvetleaf (Abutilon theophrasti Medicus) competition, and combinations of the two had an additive effect in some plots. Higgins et al. (1984a) investigated the influence of velvetleaf competition and simulated green cloverworm [Plathypena scabra (Fabricius)]
defoliation on soybean. Simulated defoliation was achieved by removing leaf area with cork borers during the same time period green cloverworms were defoliating surrounding fields. They concluded that economic injury levels for green cloverworm did not change when velvetleaf was present. Robbins et al. (1990) investigated the relationships among soybean cyst nematode, threecornered alfalfa hopper, and one of three weeds [common cocklebur, pitted morningglory (Ipomoea lacunosa L.), or sicklepod [Senna obtusifolia (L.) Irwin and Barneby]]. The yield loss attributed to each pest was additive.

To manage the diverse pest problems of soybean in Louisiana, both herbicides and insecticides are used. Research to delineate the effects of weeds and defoliating insects alone and in combination will help justify pest control practices. Previous research investigating interactive effects of weeds and insects were conducted in Iowa (Higgins et al. 1984a) and Illinois (Helm et al. 1992) with indeterminate soybean and velvetleaf. However, in Louisiana determinate soybean is grown and velvetleaf is of minor importance. The objective of this research was to determine the effect of full-season johnsongrass, common cocklebur, and hemp sesbania interference and simulated insect defoliation on weed and soybean growth parameters and soybean yield.

**MATERIALS AND METHODS**

Field experiments were conducted at the Ben Hur Research Farm near Baton Rouge, Louisiana in 1994 and 1995 on a Mhoon silty clay loam soil (fine-silty.
mixed nonacidic, thermic Fluventic Haplaquepts). 'Asgrow 6785', a determinate group VI soybean, was planted 16 June 1994 and 14 June 1995 in rows spaced 76 cm apart. Metalochlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] at 1.1 kg ai/ha and glyphosate [N-(phosphonomethyl) glycine] at 1.8 kg ai/ha were broadcast as a tank mix over the entire experimental area immediately after planting both years to control emerged weeds and to provide residual control of annual grasses. Seeds of johnsongrass, common cocklebur, and hemp sesbania were planted in peat pellets in a greenhouse the same day that soybean was planted in the field. Two weeks after planting, seedlings were transplanted five cm from soybean in each row of the four-row plot. The plastic wrap was removed from each peat pellet prior to transplanting to facilitate weed root growth. Plots were maintained free of other weeds by hand removal and mechanical cultivation both years. Methyl-parathion (O,O-dimethyl-O-p-nitrophenyl phosphorothioate) and thiodicarb [dimethyl-N,N'-[thiobis[(methylimino) carbonyloxy]] bis[ethanimidothioate]] insecticides were applied as needed to control insects.

The experimental design was a randomized complete block with a factorial arrangement of treatments replicated four times. Plots were four rows wide and 6 m in length. Weed treatments (Factor A) consisted of johnsongrass, common cocklebur, and hemp sesbania at densities of 15, 3, and 12 plants/6 m of row, respectively, and a weed-free control. These densities were selected because they
were sufficient to reduce soybean yield approximately 20% in previous studies (Barrentine 1974; McWhorter and Anderson 1979; McWhorter and Hartwig 1972; Oliver 1988; Williams and Hayes 1984). The intent was to evaluate low to moderate weed densities that economically may not justify control measures. Hemp sesbania and some common cocklebur did not survive transplanting the second year. Therefore, hemp sesbania was not evaluated and cocklebur was limited to one row per plot in 1995. Defoliation levels (Factor B) were imposed by removing 0, 1, or 2 leaflets per soybean trifoliate to approximate 0, 33, and 66% defoliation, respectively. No preference was given to removing lateral or center leaflets from each trifoliate. Simulated defoliation (Factor C) was initiated at R2 (full bloom) or R5 (beginning seed development) soybean growth stages (Fehr et al. 1971), which is when soybean loopers commonly defoliate soybean (Steffey et al. 1994). Soybean plants were manually defoliated at R2 on 16 to 18 August 1994 and 14 to 16 August 1995. Defoliation at R5 was performed on 7 to 9 September 1994 and 11 to 13 September 1995. All treatments were defoliated by replication because several days were required to complete the procedure. Soybean from only the two center rows of each plot was defoliated. At each defoliation stage, soybean plants from a one-m section of row was removed from selected plots to determine actual leaf area removal for each defoliation level. Leaf area was measured on a Li-Cor LI-3100 Area Meter. Measurements revealed that removal of one leaflet per trifoliate

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1LICOR, Inc. Lincoln, NE 68504.
resulted in a reduction in leaf area of 31 to 36% and two leaflet removal a 64 to 69% reduction.

Soybean and weed heights were measured three weeks after defoliation at R5. Soybean, common cocklebur, and hemp sesbania heights were measured from the ground to the apex of the plant, whereas johnsongrass was measured from the ground to the tip of the longest leaf. Above-ground portions of weeds were harvested on 21 October 1994 and 17 October 1995, dried, and weighed. Soybean was harvested on 2 November 1994 and 26 October 1995 using a plot combine. Soybean seed moisture and 100-seed weight were measured after harvest. Seed yield was adjusted to 13% moisture. Data were subjected to the General Linear Models procedure (SAS Institute 1988) to test for main treatment effects and interactions among treatments. For soybean seed yield, weed by year and defoliation stage by year interactions were observed, so all data are presented separately for 1994 and 1995. Means were separated using Fisher’s Protected LSD at the 0.05 probability level. Defoliation level responses were further evaluated using single degree-of-freedom contrasts.

RESULTS AND DISCUSSION

Johnsongrass, common cocklebur, and hemp sesbania height and dry weight were not affected by defoliation level or defoliation stage (Table 2.1). It was anticipated that additional light interception by weeds in defoliated soybean would increase weed growth. Higgins et al. (1984b) also reported no significant
Table 2.1. Weed height three weeks after defoliation at R5 and dry weight at soybean maturity as influenced by soybean defoliation level and stage in 1994 and 1995.

<table>
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<tbody>
<tr>
<td></td>
<td>Height cm</td>
<td></td>
<td></td>
<td>Dry weight g/plant</td>
<td></td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
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<tr>
<td></td>
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<td>177 a*</td>
<td>174 a</td>
<td>65 b</td>
<td>97</td>
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<tr>
<td></td>
<td>Common cocklebur</td>
<td>127 b</td>
<td>114 b</td>
<td>215 a</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td>Hemp sesbania(^b)</td>
<td>168 a</td>
<td>-</td>
<td>55 b</td>
<td>-</td>
</tr>
<tr>
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<td>160</td>
<td>144</td>
<td>112</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>158</td>
<td>141</td>
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<td>143</td>
<td>114</td>
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<tr>
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<td>R5</td>
<td>159</td>
<td>143</td>
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<td>0.7628</td>
<td>0.0671</td>
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<td>0.9796</td>
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<td>Weed by level by stage</td>
<td>0.2799</td>
<td>0.2638</td>
<td>0.9093</td>
<td>0.9843</td>
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*Means followed by the same letter within a column are not significantly different using Fisher’s Protected LSD at P<0.05.

*bData available for 1994 only.

Fehr et al. 1971
differences in velvetleaf dry weight in response to simulated green cloverworm defoliation. They did, however, observe linear increases in velvetleaf leaf area and leaf number as soybean defoliation level increased. In another study, shading of three week old velvetleaf plants reduced height, leaf number, and dry weight (Bello et al. 1995). Since weeds in the present study were taller than soybean at defoliation, light interception was not a limiting factor to weed growth. Mosier and Oliver (1995) observed that most of the leaf area of common cocklebur competing with irrigated soybean was in the upper portion of the plant 12 weeks after planting. Differences in height and dry weight were observed among weeds. Johnsongrass was taller than common cocklebur both years, but dry weight of common cocklebur was 3.3 times that of johnsongrass in 1994 (Table 2.1). For weed height and dry weight, none of the possible interactions were significant indicating that weeds responded similarly to defoliation.

Soybean height three weeks after defoliation at R5 was not influenced by weed interference, defoliation level, or defoliation stage either year (Table 2.2). Soybean yield response to weed interference and defoliation was additive both years. No interaction was observed between weeds, defoliation levels, or defoliation stages (Table 2.2). In 1994, averaged across defoliation levels and stages, johnsongrass, common cocklebur, and hemp sesbania reduced soybean yield 30, 15, and 14%, respectively, compared with weed-free soybean. In 1995, johnsongrass reduced yield 35%, but common cocklebur interference resulted in yield equivalent to weed-
Table 2.2. Soybean height three weeks after defoliation at R5 and soybean yield and 100-seed weight as influenced by weed interference and soybean defoliation level and stage in 1994 and 1995.

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<tr>
<td></td>
<td></td>
<td>cm</td>
<td>cm</td>
<td>kg/ha</td>
<td>kg/ha</td>
<td>g/100</td>
<td>g/100</td>
</tr>
<tr>
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<td>86</td>
<td>90</td>
<td>2720</td>
<td>a</td>
<td>12.72</td>
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<tr>
<td></td>
<td>Johnsongrass</td>
<td>87</td>
<td>91</td>
<td>1910</td>
<td>c</td>
<td>12.67</td>
<td>10.55</td>
</tr>
<tr>
<td></td>
<td>Common cocklebur</td>
<td>88</td>
<td>92</td>
<td>2310</td>
<td>b</td>
<td>12.53</td>
<td>10.60</td>
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<tr>
<td></td>
<td>Hemp sesbania&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>90</td>
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<td>91</td>
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<td>2280</td>
<td>12.78</td>
<td>10.62</td>
</tr>
<tr>
<td></td>
<td>66</td>
<td>87</td>
<td>90</td>
<td>2030</td>
<td>2010</td>
<td>11.87</td>
<td>9.78</td>
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<tr>
<td>Contrast</td>
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<td>Quadratic (P = F)</td>
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<th>90</th>
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<td>R5</td>
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<td>2180</td>
<td>12.59</td>
<td>10.49</td>
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*Means followed by the same letter within a column are not significantly different using Fisher's Protected LSD at $P<0.05$. 
Data available for 1994 only. 
Fehr et al. 1971
free soybean. The lack of response for common cocklebur the second year is not apparent, but may be related to the lower yield for the weed-free control that year. The weed densities selected for this study were expected to reduce soybean yield approximately 20% (Barrentine 1974; McWhorter and Anderson 1979; McWhorter and Hartwig 1972; Oliver 1988; Williams and Hayes 1984). It is possible that greater differences and interactions may have been observed if higher weed densities had been included. Contrast analysis revealed a linear relationship between soybean seed yield and defoliation level both years (Table 2.2). Defoliation levels of 33 and 66% reduced yield 6 and 20%, respectively, in 1994 and 12 and 23%, respectively, in 1995. These data agree with those of Turnipseed (1972) and Todd and Morgan (1972) in which soybean yield decreased as defoliation level increased. In the present study, soybean yield in 1994 was equivalent for defoliation at R2 and R5, but in 1995 defoliation at R5 resulted in 10% less yield than defoliation at R2. Fehr et al. (1977) also reported greater yield losses with defoliation at R5 than R2. In another study, soybean yield was reduced 40% with 100% defoliation at temporal mid-point of seed filling (R6.3), but only 20% at three-quarter point of seed filling (R6.6), (Board et al. 1994). Soybean defoliated at R2 in 1995 in the current study may have compensated for the reduction in photosynthetic leaf area by delaying senescence and by delaying the decline of photosynthetic rates associated with aging (Higley 1992). These responses would result in sustained photosynthate production later into the growing season.
Regrowth in the early-defoliated plants may also help explain why yield was equivalent for the defoliation stages the first year and greatest for defoliation at R2 the second year. By the time soybean was in the R5 growth stage, during seed fill, plants had compensated for defoliation at R2 by producing new leaf area. Regrowth was not measured in this study, however, additional growth was visually apparent in the defoliated plots. In a study where soybean was defoliated 30% by soybean looper at V11, leaf area of defoliated soybean was equivalent to leaf area of non-defoliated soybean 22 days after defoliation (Russin et al. 1989), indicating regrowth.

Soybean seed weight was not influenced by weed interference either year (Table 2.2). Yield loss may be partially explained by reductions in seed weight caused by defoliation. As with yield, a linear decrease in seed weight was observed as defoliation level increased. Seed weight was reduced at least 4.6 and 11.4% by 33 and 66% defoliation, respectively. In 1995, seed weight was also 3.3% lower in soybean defoliated at R5 than at R2. As with soybean yield, 100-seed weight was equivalent for defoliation stages in 1994. Turnipseed (1972) also reported seed weight reductions for soybean defoliated 33% at pod-fill, but not when defoliated at bloom stage. Board et al. (1994) reported seed weight reductions of 34% with complete defoliation at R6.3, however, only a 14% reduction was observed at R6.6. In other studies, yield loss by defoliation during the early reproductive stages up to R4 was primarily related to reduced pod numbers (Board and Harville 1993: Goli and
Weaver 1986), whereas defoliation during R5 and R6 was related to reduced seed weight (Goli and Weaver 1986).

Results of this study indicate that weeds and defoliation each can negatively influence soybean yield when both stresses were imposed. Johnsongrass, common cocklebur, and hemp sesbania reduced soybean yield 14 to 30% when compared with no weed interference. The degree of yield reduction was dependent on the weed and defoliation level, and to a lesser extent on defoliation stage. Soybean yield response to weed interference and simulated insect defoliation was additive in this study. Velvetleaf competition and insect defoliation have also resulted primarily in additive responses on soybean yield in Iowa (Higgins et al. 1984a) and Illinois (Helm et al. 1992) studies. Furthermore, in Arkansas soybean yield losses with combinations of a nematode, threecornered alfalfa hopper, and weeds were additive (Robbins et al. 1990). The agreement of these studies, especially with the diversity in soybean type and environmental conditions, clearly show the importance of controlling both weeds and defoliating insects in soybean pest management programs.

LITERATURE CITED


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CHAPTER III
HEMP SESBANIA AND SICKLEPOD INFLUENCE ON INSECTICIDE DEPOSITION AND SOYBEAN LOOPER CONTROL

INTRODUCTION

Weed and insect control can be major expenses in soybean [Glycine max (L.) Merr.]. Depending on location and agronomic practices, Louisiana soybean producers annually spend from 62 to 86 dollars/ha for herbicides and from none to 32 dollars/ha for insecticides (Wegenhoft 1996). Weeds reduce soybean yield through competition for water, nutrients, and light. Hemp sesbania [Sesbania exaltata (Raf.) Rybd. ex A.W. Hill] and sicklepod [Senna obtusifolia (L.) Irwin and Barneby] are among the most troublesome weeds in several southern states (Bridges and Baumann 1992). Hemp sesbania is an erect, annual, herbaceous plant that will reach a height of four m (Anonymous). Full season competition from hemp sesbania at densities up to 5500 plants/ha did not reduce soybean yields, but populations of 8100 to 129000 plants/ha reduced yield 10 to 80%, respectively (McWhorter and Anderson 1979). Sicklepod is an annual, herbaceous plant that grows up to two m tall (Anonymous). Densities of 32000 and 98000 sicklepod/ha reduced soybean yield 31 and 41%, respectively (Bozsa et al. 1989).

In Louisiana, soybean loopers [Pseudoplusia includens (Walker)] occasionally reach population levels requiring the use of insecticides (Baldwin et al. 1996). Soybean loopers are defoliating insects that habitually feed in the lower one-half to two-thirds of the soybean canopy (Herzog 1980). This pest reduces the
photosynthetically active leaf area of a plant, thereby reducing yield in some cases. Wier and Boethel (1996) observed 48 and 95% yield losses when soybean looper defoliated 'Clark' soybean 74 and 94%, respectively, during full bloom to pod development (R2 to R5) (Fehr et al. 1971).

Even though weeds and insects frequently coexist in the same field, development of integrated pest management strategies has been most often directed toward a single class of pest. Furthermore, a decision to apply a pesticide is based on the economic return expected from controlling a specific pest without consideration of the subsequent impact on other pests that may be present.

Weed presence in a soybean field may influence insecticide deposition into canopy resulting in reduced insecticide efficiency. This may be especially important for weeds such as hemp sesbania and sicklepod, which are tall-growing and capable of producing a canopy over soybean late in the growing season. Weed leaves and stems potentially could intercept the insecticide spray droplets before reaching the crop, resulting in less insecticide deposition. Decreased insecticide coverage of soybean planted in narrow rows compared with wide rows (18 vs. 97 cm) has resulted in a reduction in soybean looper control (Hutchins and Pitre 1984). Methomyl [S-methyl-N-[(methylcarbamoyl)oxy]thioacetimidate] and methyl parathion \((O,O\text{-dimethyl}-O-p\text{-nitrophenyl phosphorothioate})\) insecticide coverage of soybean was lower within the median one-third of the canopy in narrow-row soybean spacing than in wide-row spacing. No differences in coverage between row
spacings were noted in the terminal or lower-thirds of the canopy. Furthermore, in their study soybean looper larval mortality also was reduced in the median one-third of the canopy in the narrow-row soybean. Royal et al. (1990) reported that chlorothalonil (tetrachloroisophthalonitrile) fungicide deposition into peanut decreased with increasing density of sicklepod, Florida beggarweed (*Desmodium tortuosum* (Sw.) DC.), or common cocklebur (*Xanthium strumarium* L.). Four sicklepod or Florida beggarweed/7.6 m of row reduced chlorothalonil deposition by 10%, while four common cocklebur plants/7.6 m resulted in a 20% reduction. Furthermore, late season disease incidence also increased with increasing weed density.

In order to manage the diverse pest problems in soybean, herbicides and insecticides are often needed. Herbicide use may be even more important if weeds alter insecticide efficiency. Furthermore, insecticide programs may need revision when weed control programs fail. The objective of this research is to evaluate insecticide deposition into the soybean canopy and soybean looper control when hemp sesbania and sicklepod are present.

**MATERIALS AND METHODS**

Field experiments were conducted at the Macon Ridge location of the Northeast Research Station near Winnsboro, Louisiana and at the Northeast Research Station near St. Joseph, Louisiana in 1995 and 1996. Soil type was a Gigger silt loam (finesilty, mixed nonacidic, thermic Typic Fragiudalfs) at Winnsboro and a Commerce
silty clay loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquents) at St. Joseph. Soybean fields with natural infestations of hemp sesbania and sicklepod were used. To ensure adequate densities, fields were overseeded with each weed species at soybean planting with a hand spreader. Soybean varieties were 'DPL 3627' and 'Asgrow 6785' in the 1995 and 1996 experiments, respectively. Soybean was planted at Winnsboro on 5 June 1995 and 28 May 1996 and at St. Joseph on 12 June 1995 and 23 May 1996. The experimental design was a randomized complete block replicated four times at Winnsboro and five times at St. Joseph. Plot size was four 102-cm rows wide and 12 m long at Winnsboro and 9 and 11 m long at St. Joseph in 1995 and 1996, respectively. Treatments consisted of either weeds, hemp sesbania and sicklepod, or no weeds in combination with no insecticide or thiodicarb [dimethyl-N,N'-[thiobis[(methylimino)carbonyloxy]]bis [ethanimidothioate]] [Larvin 3.21 Flowable (F), 504 g (ai)/ha] applied to control soybean looper. Within five weeks after planting, all plots were cultivated once so that any desired weeds were present only in the non-cultivated band. All weeds were hand-removed from the weed-free plots and weeds other than hemp sesbania and sicklepod from the weedy plots. Weed-free plots were maintained the remainder of the season by hand removal. Methyl-parathion was applied in early August to reduce the native predator and parasitoid populations across the test sites. This treatment has been shown to increase population densities of soybean loopers to economic damage.

1Rhone-Poulenc Ag Company, Research Triangle Park, NC 27709.
levels (Shepard et al. 1977). Soybean looper populations were then monitored weekly using a 38-cm diameter sweep net until larval numbers reached economic threshold levels (Baldwin et al. 1996). Soybean was at R4 (Fehr et. al 1971) growth stage when populations reached this level in all experiments, except St. Joseph in 1996 where this level was reached at R5.

Number of larvae in each plot was determined before insecticide application by placing a 91-cm ground cloth between the two center rows and shaking plants on both sides over the cloth (Kogan and Pitre 1980). This same procedure also was used to estimate larval mortality three days after treatment (DAT). Bean leaf beetle (Ceratoma trifurcata (Forster)) populations were also determined at St. Joseph in 1996 using this same technique. Light penetration within the soybean canopy was measured using a Decagon Sunfleck Ceptometer positioned between the two center rows, parallel to the row, and 30 cm above ground level. Light readings also were measured above the soybean canopy to give an estimate of full sunlight. These measurements were made on the day of or the day before thiodicarb application between 1230 and 1330 hours when no clouds were present to reduce variation in light intensity due to cloud cover and sun position. Measurements from 30 cm above ground level were compared to the above-canopy measurements and expressed

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2Abbreviations: DAT, days after treatment; PAR, photosynthetically active radiation.

3Decagon Devices Inc., Pullman, WA 99163.
as reduction in photosynthetically active radiation (PAR)² penetrating the canopy. Cloudy weather occurred at the time soybean was sprayed at Winnsboro in 1996 and no PAR data were collected.

Thiodicarb was applied with nozzles maintained at a height to allow spray deposition on both the weed and soybean foliage. This height was 180 cm above the soil surface and approximately 101 to 111 cm above the top of the soybean canopy in three of the four experiments. Because the predominate weed species was sicklepod at Winnsboro in 1996, the nozzle height was 155 cm above the soil and approximately 53 cm above the soybean canopy. An additional control treatment included insecticide application with the nozzle height 48 cm above a weed-free soybean canopy, which is more typical for on-farm applications. Thiodicarb applications were made using a high clearance sprayer equipped with a four-row boom with 51-cm nozzle spacing and calibrated to deliver a spray volume of 94 L/ha. Nozzles used were TX-8⁴ hollow cone in all experiments except St. Joseph in 1995 where TX-12⁴ nozzles were used. Data collected at each application date are presented in Table 3.1.

Before insecticide application, 10.5 x 14-cm Kromekote⁵ dye-sensitive cards were placed in the top, middle, and bottom-thirds of the soybean canopy to measure spray deposition. Top level cards were placed at the average soybean terminal height for

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⁴Spraying Systems Company, Wheaton, IL 60189-7900.

⁵Champion International Corp., Stanford, CT 06921.
Table 3.1. Application data for studies conducted at the Winnsboro and St. Joseph locations of the Northeast Research Station in 1995 and 1996.

<table>
<thead>
<tr>
<th>Factor</th>
<th>1995</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Winnsboro</td>
<td>St. Joseph</td>
</tr>
<tr>
<td>Application date</td>
<td>25 August</td>
<td>31 August</td>
</tr>
<tr>
<td>Air temperature (°C)</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>62</td>
<td>86</td>
</tr>
<tr>
<td>Wind speed (km/h)</td>
<td>8 - 13</td>
<td>0 - 3</td>
</tr>
<tr>
<td>Wind direction</td>
<td>North</td>
<td>Northeast</td>
</tr>
<tr>
<td>Sprayer speed (km/h)</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Spray pressure (kPa)</td>
<td>6.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Soybean height (cm)</td>
<td>79</td>
<td>102</td>
</tr>
<tr>
<td>Hemp sesbania density (plants/row m)</td>
<td>3.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Hemp sesbania height (cm)</td>
<td>221</td>
<td>204</td>
</tr>
<tr>
<td>Sicklepod density (plants/row m)</td>
<td>1.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Sicklepod height (cm)</td>
<td>141</td>
<td>109</td>
</tr>
</tbody>
</table>
each experiment. The middle level cards were positioned half way between the
terminal and the soil surface. All bottom cards were placed 10 cm above the soil
surface. Soybean and weed height, measured from the soil surface to the terminal at
application time, and weed densities are shown in Table 3.1. Cards were attached to
a steel rod placed vertically in the soybean row. Ten steel rods were placed
randomly throughout each plot in the center two rows at Winnsboro. Five rods
were placed in each plot at St. Joseph. After application of thiodicarb amended with
Rhodamine WT dye (7 and 10 ml/ha in 1995 and 1996, respectively) to the
appropriate plots, cards were allowed to dry, and placed in waterproof bags for
deposition analysis. Cards were analyzed using a Hewlett Packard ScanJet IIcx
scanner using the Droplet Analyzer Program computer software. This program
analyzed four 6.45-cm² sample areas from each card at a resolution of 400 dots/6.45
cm² to estimate percent deposition.

A feeding bioassay also was conducted at the Winnsboro site. Thirteen (1995)
and ten (1996) randomly selected center soybean leaflets were collected immediately
after thiodicarb application from the top, middle, and bottom third of the crop
canopy from the same position at which cards were placed. Leaflets were placed in

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6WRK Incorporated, Manhattan, KS 66502.

7Hewlett-Packard Company, Boise, ID 83707.

8D. Lambregts and M. Mailander (Unpublished), Department of Environmental
and Agricultural Engineering, Louisiana State University, Baton Rouge, LA 70803.
9-cm petri dishes containing a moistened piece of 9-cm filter paper. Fourth and fifth instar soybean looper larvae from a laboratory strain (USDA-ARS Southern Insect Management Laboratory, Stoneville) reared on pinto bean wheat germ diet (Thomas et al. 1993) were placed in the petri dishes within 1 h after insecticide application and mortality was evaluated 2 DAT. Plots were mechanically harvested using a plot combine to determine yield. Seed yield was adjusted to 13% moisture.

Each experiment was analyzed separately due to variation in weed densities. Data were analyzed using the General Linear Models procedure (SAS Institute 1988). Larval mortality percentage data were transformed by square root or arcsine square root where appropriate for analysis and then retransformed for presentation. If a significant treatment effect was measured at the 0.05 probability level, single degree of freedom contrast analysis (0.05 probability level) was used to make comparisons between selected treatments. Card deposition data were analyzed as a split-plot with weed treatment as the whole-plot and card placement as the sub-plot for individual treatments. The CORR procedure (SAS Institute 1985) was used to make correlations between deposition and thiodicarb effectiveness on soybean looper in the field and in the feeding bioassay.

RESULTS AND DISCUSSION

For the control treatment where nozzles were maintained 48 cm above the weed-free soybean canopy, thiodicarb deposition on cards ranged from 3.9 to 11.1%. Deposition for the control treatment was not significantly different from the weed-
free treatment in which nozzles were maintained high enough to cover both weeds and soybean at Winnsboro in 1995 ($P=0.0267$) and St. Joseph in 1996 ($P=0.0095$). The control treatment with nozzles 48 cm above the soybean canopy was not included at St. Joseph in 1995 and insecticide deposition was not detectable on cards at Winnsboro in 1996 due to use of an ineffective dye solution. For thiodicarb efficacy against native field soybean looper, the control treatment resulted in two to 18% larval survival and was not significantly different from the weed-free treatment with the high boom level at Winnsboro in 1995 ($P=0.0267$) and 1996 ($P=0.0038$) and St. Joseph in 1996 ($P=0.0004$). For all parameters measured in the four experiments, results obtained for this control treatment were not significantly different from the weed-free treatment in which nozzles were maintained high enough to provide spray deposition of the weed and soybean canopy, so data for the control treatment was excluded from analysis, and treatment comparisons were made only for nozzles maintained at a single height.

Hemp sesbania and sicklepod influenced insecticide deposition at Winnsboro in 1995 ($P=0.0164$) and at St. Joseph in 1995 ($P=0.0010$) and 1996 ($P=0.0149$). The treatment by card location interaction was significant at St. Joseph in 1995 ($P=0.0214$), but not Winnsboro in 1995 ($P=0.0594$) and St. Joseph in 1996 ($P=0.2117$). In all experiments, differences in droplet deposition between weedy and weed-free plots were observed on cards placed in the top of the canopy, but not in the middle or bottom portions of the canopy (Figure 3.1). There was a strong
Figure 3.1. Influence of hemp sesbania and sicklepod on thiodicarb deposition on dye sensitive cards placed in the bottom, middle, and top of the soybean canopy. The presence of a "*" represents significant difference between the two data points.
tendency for a decrease in deposition between the top and the middle of the canopy for both weedy and weed-free soybean. At Winnsboro in 1995, 17.0 and 12.5\% deposition on cards in the top of the soybean canopy was observed for weed-free and weedy soybean, respectively, with weeds resulting in a 26\% reduction in deposition. Deposition in the middle of the canopy was at least 28\% less than the bottom of the canopy. The senescence of soybean leaves in the lower portion of the canopy where bottom cards were placed could help explain this difference. At St. Joseph in 1995, 11.5 and 6.5\% deposition on cards at the top of the canopy was observed in weed-free and weedy soybean, respectively, a 43\% reduction due to hemp sesbania and sicklepod. Spray deposition was reduced 30\% in the top of the soybean canopy at St. Joseph in 1996 when weeds were present.

Thiodicarb efficacy against native field soybean looper larvae at 3 DAT is expressed as percent larval survival based on the pre-count density in each individual plot. Treatment effects were significant at Winnsboro in 1995 ($P=0.0202$) and 1996 ($P=0.0001$) and at St. Joseph in 1995 ($P=0.0191$) and 1996 ($P=0.0002$). In 1995 at Winnsboro and St. Joseph when no insecticide was applied, soybean looper larval survival was less than 41\% as compared with 54 to 144\% at the same locations in 1996 (Table 3.2). At the time of insecticide application in 1995, larval populations had began to decline through pupation, and there may have been some natural mortality from disease occurring. Contrast analysis revealed no differences in survival from thiodicarb between the weedy and weed-free soybean at the 0.05
Table 3.2. Soybean looper larval survival at Winnsboro and St. Joseph, Louisiana in 1995 and 1996 and bean leaf beetle survival at St. Joseph, LA in 1996, 3 days after treatment in response to weeds and thiodicarb application, and meaningful contrasts between selected treatment effects.

<table>
<thead>
<tr>
<th>Treatment/Contrasts</th>
<th>Soybean looper larval survival(^a)</th>
<th>Bean leaf beetle survival(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecticide Weed(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No insecticide Weed-free</td>
<td>40.8</td>
<td>9.0</td>
</tr>
<tr>
<td>No insecticide Weedy</td>
<td>25.7</td>
<td>13.3</td>
</tr>
<tr>
<td>Thiodicarb Weed-free</td>
<td>4.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Thiodicarb Weedy</td>
<td>21.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contrasts(^c)</th>
<th>(F)</th>
<th>(P)</th>
<th>(F)</th>
<th>(P)</th>
<th>(F)</th>
<th>(P)</th>
<th>(F)</th>
<th>(P)</th>
<th>(F)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No insecticide/weed-free vs thiodicarb/weed-free</td>
<td>17.40</td>
<td>0.0042</td>
<td>3.22</td>
<td>0.0980</td>
<td>10.45</td>
<td>0.0103</td>
<td>19.48</td>
<td>0.0008</td>
<td>12.45</td>
<td>0.0042</td>
</tr>
<tr>
<td>No insecticide/weedy vs thiodicarb/weedy</td>
<td>0.17</td>
<td>0.6889</td>
<td>13.85</td>
<td>0.0029</td>
<td>9.90</td>
<td>0.0188</td>
<td>5.35</td>
<td>0.0393</td>
<td>22.85</td>
<td>0.0004</td>
</tr>
<tr>
<td>Thiodicarb/weed-free vs thiodicarb/weedy</td>
<td>5.58</td>
<td>0.0501</td>
<td>0.26</td>
<td>0.6216</td>
<td>0.01</td>
<td>0.9230</td>
<td>0.07</td>
<td>0.7919</td>
<td>0.01</td>
<td>0.9291</td>
</tr>
</tbody>
</table>

\(^a\)Survival is based on pre-count measurements in each plot.
\(^b\)Mean density of hemp sesbania and sicklepod was 3.4 and 1.0 (Winnsboro 1995), 4.5 and 2.5 (St. Joseph 1995), 0.5 and 3.4 (Winnsboro 1996), 7.4 and 2.1/row m (St. Joseph 1996), respectively.
\(^c\)Single degree of freedom contrasts.
probability level. In three of the four experiments, larval survival was less when thiodicarb was applied than not applied.

Correlations between mean deposition of the three card locations together for each insecticide treatment and soybean looper larval survival were not significant (Winnsboro 1995, r=0.4592, prob > |R| =0.1332; St. Joseph 1995, r=0.4661, prob > |R| =0.0836; St. Joseph 1996, r=0.1421, prob > |R| =0.6133). Soybean looper larvae habitually feed in the lower half to two-thirds of the soybean plant (Herzog 1980), whereas the differences in insecticide deposition in the present study were at the top of the soybean canopy. Furthermore, thiodicarb requires ingestion by soybean looper to be effective (Thomson 1982). Significant treatment effects (P<0.0006) were also observed for bean leaf beetle survival at St. Joseph in 1996 (Table 3.2). Thiodicarb reduced bean leaf beetle populations and control was equivalent regardless of weed presence.

In the feeding bioassays at Winnsboro, the treatment effect was not significant at the canopy bottom in 1995 (P=0.1991), but was significant at the bottom in 1996 (0.0182), middle in 1995 (0.0164) and 1996 (0.0008), and top of the soybean canopy in 1995 (0.0484) and 1996 (0.0014). Mortality of soybean looper larvae on leaflets from weedy and weed-free soybean treated with thiodicarb was similar when collected from the middle or top of the soybean canopy both years, and at the bottom in 1995 (Table 3.3). At the bottom of the canopy in 1996, greater mortality was observed in weedy soybean than weed-free soybean. There was no significant
Table 3.3. Influence of weeds and thiodicarb at Winnsboro, Louisiana in 1995 and 1996 on soybean looper larval mortality 2 days after treatment in the feeding bioassays, and meaningful contrasts between selected treatment effects.

<table>
<thead>
<tr>
<th>Treatment/Contrasts</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottom*</td>
</tr>
<tr>
<td>Insecticide</td>
<td>Weed*</td>
</tr>
<tr>
<td>No insecticide</td>
<td></td>
</tr>
<tr>
<td>Weed-free</td>
<td>9.5</td>
</tr>
<tr>
<td>Thiodicarb</td>
<td></td>
</tr>
<tr>
<td>Weed-free</td>
<td>28.8</td>
</tr>
<tr>
<td>Weedy</td>
<td>32.5</td>
</tr>
<tr>
<td>Contrasts*</td>
<td></td>
</tr>
<tr>
<td>No insecticide/weed-free vs thiodicarb/weed-free</td>
<td>-</td>
</tr>
<tr>
<td>Thiodicarb/weed-free vs thiodicarb/weedy</td>
<td>-</td>
</tr>
</tbody>
</table>

*Bottom, middle, and top represent the bottom, middle, and top-thirds of the soybean canopy where leaflets were removed.

b Mean density of hemp sesbania and sicklepod was 3.4 and 1.0 (1995) and 0.5 and 3.4/row m (1996), respectively.

c Single degree of freedom contrasts.
correlation \( r=0.2544, \text{ prob} > |R| =0.1343 \) between thiodicarb deposition and mortality in the feeding bioassay at Winnsboro in 1995. Because the only difference in insecticide spray deposition between weedy and weed-free soybean was at the top of the canopy (Figure 3.1), lower insecticide efficacy from the presence of weeds would not be expected in the bottom and middle portions of the canopy. Even though thiodicarb deposition in weedy soybean at the top of the canopy was lower than in weed-free soybean, the amount deposited was probably sufficient to control soybean loopers.

No differences in light penetration into the soybean canopy were observed between the weedy and weed-free soybean at Winnsboro in 1995 \( P=0.1994 \) (Table 3.4). At St. Joseph in 1995 \( P=0.0146 \) and 1996 \( P=0.0485 \) where thiodicarb was to be applied, PAR was reduced more in weedy soybean than in weed-free soybean, indicating that less light penetrated the weed infested canopy. These findings support the differences observed within the top of the soybean canopy in respect to insecticide deposition (Figure 3.1).

Weed interference and insecticide treatment significantly affected soybean yield at St. Joseph in 1995 \( P=0.0002 \) and Winnsboro in 1996 \( P=0.0276 \), but not St. Joseph in 1996 \( P=0.1154 \). Soybean yields at Winnsboro in 1995 were extremely low \((<134 \text{ kg/ha})\) due to environmental conditions, and since few conclusions can be drawn, data are not presented. At St. Joseph in 1995 where thiodicarb was applied, hemp sesbania and sicklepod reduced yields 69\% in relation to weed-free
Table 3.4. Photosynthetically active radiation (PAR) reduction into the soybean canopy as influenced by weeds at Winnsboro and St. Joseph, Louisiana in 1995 and 1996, and meaningful contrast between a selected treatment effect.

<table>
<thead>
<tr>
<th>Treatment/Contrast</th>
<th>PAR reduction*</th>
<th>1995</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>μm/m²/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No insecticide</td>
<td>Weed-free</td>
<td>233</td>
<td>179</td>
</tr>
<tr>
<td>No insecticide</td>
<td>Weedy</td>
<td>806</td>
<td>781</td>
</tr>
<tr>
<td>Thiodicarb</td>
<td>Weed-free</td>
<td>467</td>
<td>504</td>
</tr>
<tr>
<td>Thiodicarb</td>
<td>Weedy</td>
<td>684</td>
<td>1157</td>
</tr>
<tr>
<td>Contrast*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiodicarb/weed-free vs thiodicarb/weedy</td>
<td>-</td>
<td>-</td>
<td>6.58</td>
</tr>
</tbody>
</table>

*Value expressed as a difference between PAR above the canopy and PAR within the canopy.

*a Mean density of hemp sesbania and sicklepod was 3.4 and 1.0 (Winnsboro 1995), 4.5 and 2.5 (St. Joseph 1995), 7.4 and 2.1/row m (St. Joseph 1996), respectively.

*Single degree of freedom contrast.
soybean (Table 3.5). Insecticide application, however, did not result in a yield increase for weedy or weed-free plots, possibly because soybean looper populations had already began to decline at time of application. At Winnsboro in 1996 where thiodicarb was applied, soybean yield was not reduced by weeds in relation to weed-free soybean. Thiodicarb application also did not result in a yield increase.

This research suggests that weeds capable of producing biomass above the soybean canopy such as hemp sesbania and sicklepod can influence thiodicarb deposition into the soybean canopy. A difference in thiodicarb deposition occurred only in the terminal area of the soybean canopy, and deposition was much lower in the middle and lower levels of the crop canopy, regardless of weed presence. Differences in insecticide deposition within the crop canopy, however, were not reflected in differences in soybean looper larval mortality. Thiodicarb has excellent activity on soybean looper (Leonard et al. 1990). It is possible that different results may have been obtained with use of a less efficacious insecticide or with an insecticide tolerant soybean looper strain.

Weed management strategies should consider yield losses associated with weed competition. Maximum yield observed in this study was 1490 kg/ha with yield loss due to weeds in only one of three experiments. From an economical perspective, it would probably not be advisable to apply any pesticide in this situation. Although further research should consider other insecticide use strategies and weed species, soybean looper management practices may not need to be altered when weeds are present, assuming that an economic return can be expected.
Table 3.5. Soybean yield response to weeds and thiodicarb application at St. Joseph, Louisiana in 1995 and 1996 and Winnsboro, Louisiana in 1996, and meaningful contrasts between selected treatment effects.

<table>
<thead>
<tr>
<th>Treatment/Contrasts</th>
<th>Yield</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>St. Joseph</td>
<td>Winnsboro</td>
</tr>
<tr>
<td>Weed*</td>
<td></td>
<td>kg/ha</td>
<td>kg/ha</td>
</tr>
<tr>
<td>Insecticide</td>
<td></td>
<td>1995</td>
<td>1996</td>
</tr>
<tr>
<td>No insecticide</td>
<td>Weed-free</td>
<td>1150</td>
<td>1010</td>
</tr>
<tr>
<td>No insecticide</td>
<td>Weedy</td>
<td>690</td>
<td>700</td>
</tr>
<tr>
<td>Thiodicarb</td>
<td>Weed-free</td>
<td>1370</td>
<td>1430</td>
</tr>
<tr>
<td>Thiodicarb</td>
<td>Weedy</td>
<td>420</td>
<td>1010</td>
</tr>
</tbody>
</table>

Contrasts*1

<table>
<thead>
<tr>
<th>Contrasts*1</th>
<th>F</th>
<th>P</th>
<th>F</th>
<th>P</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No insecticide/weed-free vs thiodicarb/weed-free</td>
<td>3.17</td>
<td>0.1055</td>
<td>4.80</td>
<td>0.0561</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No insecticide/weedy vs thiodicarb/weedy</td>
<td>2.31</td>
<td>0.1595</td>
<td>2.61</td>
<td>0.1404</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thiodicarb/weed-free vs thiodicarb/weedy</td>
<td>37.44</td>
<td>0.0001</td>
<td>4.80</td>
<td>0.0561</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Mean density of hemp sesbania and sicklepod was 4.5 and 2.5 (St. Joseph 1995), 0.5 and 3.4 (Winnsboro 1996), 7.4 and 2.1/row m (St. Joseph 1996), respectively.

*Single degree of freedom contrasts.
LITERATURE CITED


Wier, A. T. and D. J. Boethel. 1996. Symbiotic nitrogen fixation and yield of soybean following defoliation by soybean looper (Lepidoptera: Noctuidae) during pod or seed development. J. Econ. Entomol. 89:525-535.
CHAPTER IV

SUMMARY

Field studies were conducted to evaluate the influence of simulated insect defoliation in combination with season-long competition from weeds on weed and soybean growth and soybean yield. Weeds consisted of johnsongrass [Sorghum halepense (L.) Pers.] at 15 plants/6 m, common cocklebur (Xanthium strumarium L.) at 3 plants/6 m, and hemp sesbania [Sesbania exaltata (Raf.) Rydb. ex A.W. Hill] at 12 plants/6 m of row. Defoliation levels were imposed by removing 0, 1, and 2 leaflets per soybean trifoliate to approximate 0, 33, and 66% defoliation, respectively. Simulated defoliations were performed when soybean was at R2 (full bloom) and R5 (beginning seed development).

Johnsongrass, common cocklebur, and hemp sesbania height and dry weight were not affected by defoliation level or defoliation stage. Soybean yield response to weed interference and defoliation was additive both years. In 1994, averaged across defoliation levels and stages, johnsongrass, common cocklebur, and hemp sesbania reduced soybean yield 30, 15, and 14%, respectively, in comparison to weed-free soybean. Johnsongrass reduced yield 35% in 1995, whereas for common cocklebur yield was equivalent for weedy and weed-free soybean. A linear relationship between soybean yield and defoliation level was observed both years. Defoliation levels of 33 and 66% reduced yield 6 and 20%, respectively, in 1994 and 12 and 23%, respectively, in 1995. Defoliation at R5 resulted in 10% lower...
yield than defoliation at R2 in only one year. Soybean 100-seed weight was not influenced by weed interference either year. As with yield, a linear decrease in seed weight was observed as defoliation level increased. Seed weight in 1995 was 3.3% lower in soybean defoliated at R5 compared with defoliation at R2.

Soybean yield response to weed interference and simulated insect defoliation was additive in this study, which is in agreement with other research. This is especially noteworthy because of the variation in soybean varieties, growth habit, and environmental conditions. Findings clearly show the importance of avoiding stress to soybean from weed interference and defoliation. Controlling both weeds and insects would be necessary for maximizing productivity.

Field experiments also evaluated the influence of hemp sesbania and sicklepod [Senna obtusifolia (L.) Irwin and Barneby] on thiodicarb insecticide deposition within the soybean canopy and on soybean looper [Pseudoplusia includens (Walker)] control. Insecticide deposition was highest on dye-sensitive cards placed in the top of the soybean canopy and hemp sesbania and sicklepod reduced insecticide spray deposition 26, 43, and 30% in comparison with weed-free soybean. Weeds did not reduce deposition in the middle or bottom levels of the canopy. Additionally, weeds did not negatively affect thiodicarb efficacy against soybean looper in the field or in a feeding bioassay. Even though thiodicarb deposition was lower in weedy soybean at the top of the canopy than in weed-free soybean, the amount deposited was sufficient for soybean looper control. It is possible that different results may have
been obtained with use of insecticides less efficacious than thiodicarb or with a soybean looper strain more tolerant to thiodicarb.

Overall results of these studies show the importance of controlling both weeds and insects in a soybean production system. Pest management strategies should consider yield losses associated with both weed competition and insects, as well as the indirect effect weeds may have on insecticide deposition and insect mortality. Soybean looper management may need to be altered when weeds are present. Lack of adequate weed control early season, however, may reduce the economic incentive to control insects later in the season. These studies clearly show the importance of implementing integrated pest management strategies for control of weeds and insects in a soybean production system.
VITA

Charles Frost Grymes, known to his friends as Charlie, was born in Houston, Texas on July 22, 1968 to Gordon and Billie Grymes. He grew up on rice farms near Cypress, Texas and LaWard, Texas. His father also raised soybean, corn, and grain sorghum. Charlie grew to appreciate agricultural life as he worked many long days with his family on the farm. He attended Industrial High School where he played football and golf and graduated as salutatorian. He was also actively involved with the band, 4-H, and FFA. Charlie obtained his Bachelor of Science degree from Texas A&M University in Agronomy in 1990. While completing his degree, he worked for Dr. Paul Nester with American Cyanamid Company in the area of herbicide research. During this endeavor, Charlie became interested in the weed science field. He completed his Master of Science degree in Agronomy from Texas A&M University under the direction of Dr. J. M. Chandler with emphasis on weed science. After graduation, he interned with Mr. James Whitehead, an entomologist with American Cyanamid at Cheneyville, Louisiana. While working for James, Charlie learned a great deal about cotton insect pests and their management. His colleagues at this time suggested he pursue a Doctor of Philosophy in weed science working on an interdisciplinary weed science and entomology project. He moved to Baton Rouge, Louisiana in January 1994, three days after marrying his wife Lorissa, to pursue a Ph. D. at Louisiana State University under the direction of Dr. James L. Griffin. During his first year at
L. S. U., Charlie decided to minor in entomology working on an interdisciplinary project. During his graduate program at Louisiana State University, Charlie held membership in the Weed Science Society of America, the Southern Weed Science Society, and the Louisiana Plant Protection Association. He was a member of the third place team at the Southern Weed Science Society Weed Contest in 1994. Charlie also was awarded first place in the oral paper competition at the 1996 meeting of the Southern Weed Science Society and second place at the 1996 Louisiana Plant Protection Association Meeting. He was also awarded the Louisiana Consultants Association Scholarship in 1995.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Charles F. Grymes

Major Field: Plant Health

Title of Dissertation: Interactive Effects of Weeds and Defoliating Insects in Soybean (Glycine Max)

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

[Signatures]

[Signatures]

Date of Examination:

January 24, 1997