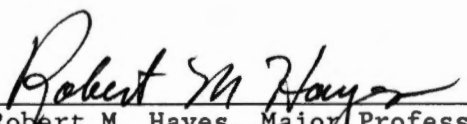
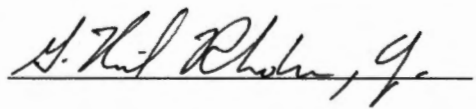
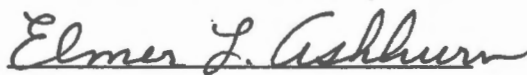


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JOHNSONGRASS INTERFERENCE IN CORN AND CONTROL
WITH SULFONYLUREA HERBICIDES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Blake Alan Brown

December 1989

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DEDICATION

To my parents, Dr. and Mrs. James F. Brown, who instilled in me the desire to further my education, I dedicate this thesis.

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ABSTRACT

Field studies were established at Jackson and Grand Junction, Tennessee in 1988 to investigate the effects of johnsongrass [Sorghum halepense (L.) Pers.] on corn and to determine the optimum time and method of removal of johnsongrass interference in corn.

Experiments were established in areas naturally infested with rhizome johnsongrass. Experimental design was a randomized complete block. Treatments were replicated four times. DPX-V9360 (35 g/ha) and CGA-136872 (30 g/ha) applied postemergence at four weekly intervals beginning at three weeks after planting (WAP) were compared to six dates of mechanical removal at weekly intervals beginning at three WAP. A weedfree check and weedy check were also included.

At Jackson, johnsongrass control for all chemical treatments was lower than that for the weedfree check with the exception of DPX-V9360 applied at five or six WAP. Corn injury was not significant for any treatments except for DPX-V9360 and CGA-136872 applied at six WAP. Yield reductions were observed in the treatments hand hoed at eight WAP, DPX-V9360 applied at three WAP, CGA-136872 applied at three or six WAP, and the weedy check.

At Grand Junction, DPX-V9360 applied at three, four, or five WAP provided good to excellent johnsongrass control and did not differ from the weedfree check. All other chemical treatments provided less johnsongrass control than the weedfree check. Regrowth of johnsongrass was greater with CGA-136872 than with DPX-V9360. Corn stunting was observed in treatments hand hoed at seven or eight WAP, for treatments

with CGA-136872 applied at five or six WAP, for treatments with DPX-V9360 applied at six WAP, and in the weedy check. Stunting was due to the combined effects of chemical injury and johnsongrass interference, but late-season stunting was due predominantly to johnsongrass interference. Corn yields were lower than the weedfree check in all treatments with the exception of those hand hoed at three or four WAP, and DPX-V9360 treatments applied at three, four or five WAP.

The optimum time for mechanical removal of johnsongrass was at three to four WAP, while the optimum time for chemical removal of johnsongrass was at four to five WAP.

Field studies were established at Jackson and Grand Junction, Tennessee in 1988 to determine the effects of various johnsongrass densities on corn yield. The experiments were established in areas naturally infested with rhizome johnsongrass. Johnsongrass was thinned to the desired populations. The experimental design was a randomized complete block. Treatments were replicated four times.

Johnsongrass densities of one plant per 1.5 m of row did not reduce yields, while johnsongrass densities of two or more plants per 1.5 m of row yielded lower than the weedfree check.

Field studies were conducted in 1988 at Jackson and Milan, Tennessee to determine the effects of DPX-V9360 and CGA-136872 on corn growth and yield when applied to weedfree corn at various growth stages under differing environmental conditions. The experimental design was a randomized complete block with a split-split plot factorial arrangement of treatments. Main plots were planting dates; sub-plots were herbicide application dates; and sub-sub-plots were herbicides.

Treatments were replicated three times. Corn was planted at four weekly intervals. For each planting date, each of the two herbicides was applied at five weekly intervals beginning at two weeks and continuing through six weeks after planting.

Corn planted at planting dates two and three was injured more severely than corn planted at planting dates one and four. CGA-136872 injured corn more than did DPX-V9360 across all planting dates and herbicide application dates. Corn injury levels were greatest when the herbicides were applied to two week-old corn. Corn injury levels decreased for herbicide applications made to successively older corn. Barren plant percentage was related to corn injury. Barren plant percentage increased as the level of prior corn injury increased.

At Jackson corn yields increased for corn planted through the third planting date. Yields were reduced for corn planted at the final planting date. Corn yields were reduced when herbicides were applied to two week-old corn. Corn yields for all planting dates were reduced when herbicides were applied on May 26. This application was made during an extended period of cloudy weather, and may have reduced the corn's ability to metabolize the herbicides. Yields were not different at Milan.

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CHAPTER I

INTRODUCTION

Johnsongrass is one of the world's ten worst weeds (24). It is a weed in 30 different crops in 53 countries (24). Johnsongrass is the seventh most commonly occurring weed in Tennessee corn and is the most troublesome weed to control in Tennessee corn (42).

Corn is the third leading cash crop in Tennessee (5). In 1985, corn was produced on 385,000 ha in Tennessee, and total cash receipts from corn were over 125 million dollars. Approximately 85% of Tennessee's corn is harvested for grain with the remainder being used for silage (5).

Approximately 25% of all corn acreage in Tennessee is infested with johnsongrass (43). Johnsongrass control in corn has been limited to the use of preplant and preemergence herbicides, cultivation, and cultural control methods such as crop rotations. Postemergence herbicides have not been available for selective control of johnsongrass in corn. The availability of selective postemergence herbicides for johnsongrass control in corn would provide growers with more flexibility in their johnsongrass management programs. Postemergence herbicides would also be an important tool in no-tillage corn production. No-tillage corn is not presently recommended in fields heavily infested with johnsongrass because cultivation is not an option for johnsongrass control (7). Postemergence herbicides could provide an effective method for controlling johnsongrass in no-tillage

corn. This is an important factor considering the concern being placed on soil conservation. The availability of postemergence johnsongrass control might allow no-till corn to be planted on more highly erodible soils that are infested with johnsongrass.

DPX-V9360 and CGA-136872 are two selective postemergence herbicides being developed for johnsongrass control in corn. Thus the objectives of these studies were to determine: (1) the optimum time of removal of johnsongrass interference from corn with DPX-V9360 and CGA-136872, (2) the effect of various johnsongrass densities on corn yield, and (3) the effects of DPX-V9360 and CGA-136872 on corn growth and yield when applied to corn at various growth stages under differing environmental conditions.

CHAPTER II

LITERATURE REVIEW

A. Characteristics of Johnsongrass

History

Johnsongrass [Sorghum halepense (L.) Pers.], native to the Mediterranean region, is one of the most troublesome plants introduced into the United States. It was introduced intentionally to the United States early in the nineteenth century as a forage crop (36). By the late 1800's, johnsongrass was growing throughout most of the United States. In 1896 United States Department of Agriculture employees reported that johnsongrass was a severe weed and was one of six weeds about which they received the most complaints. This resulted in the first federal appropriation for weed control research in 1900 (35).

Morphology

Johnsongrass is a perennial grass with fleshy rhizomes which grow to 1 cm in diameter and 2 m in length. Roots often arise from the nodes. Culms are erect, unbranched, and grow to 0.5 to 2.5 m tall and 0.5 to 2.0 cm in diameter. Culms often have basal adventitious prop roots. Johnsongrass leaves often have a waxy secretion at the base. Leaf surfaces are glabrous and ribbed with prominent veins. The ligules are membranous with a hairy fringe and 2 to 5 cm long. Leaf blades are flat, bright green or sometimes purplish, and range from 20

to 60 cm in length and 1.0 to 3.3 cm in width. Leaf blades have a conspicuous mid-vein. The inflorescence of johnsongrass is a large, erect panicle up to 50 cm long and 20 cm wide. The panicle is compact at first but later spreads open, branching in numerous slender whorls up to 15 cm long. Spikelets occur in pairs, or in groups of three, at the end of each branch. Spikelet units consist of one sessile spikelet and one or two pedicelled spikelets (56).

Seed Production, Dissemination and Longevity

Johnsongrass is a prolific seed producer. A seed is produced in each sessile spikelet. The number of sessile spikelets per panicle varies from 87 to 352 depending upon ecotype (34). Average seed production of johnsongrass is 28,000 seeds per plant (25).

The dissemination of johnsongrass occurs primarily by seed dispersal. Johnsongrass seeds are transported by wind, water, animals and transport of contaminated crop seed or feed (24). Johnsongrass seeds have a relatively high longevity. Seeds have remained viable for 30 months in soil and after 7 years in dry storage (24).

Johnsongrass Rhizomes

Although johnsongrass is a prolific seed producer, the competitive ability of johnsongrass is due to its extensive rhizome system. Rhizomes store carbohydrates and also serve as reproductive structures that produce shoots from axillary and terminal buds (38). Under unfavorable conditions some johnsongrass rhizomes remain inactive thereby allowing the species to reestablish after a temporary period of

adverse conditions (38).

The rhizome system of johnsongrass consists of primary, secondary and tertiary rhizomes. Primary rhizomes are alive at the beginning of the season and provide buds for renewed growth. Secondary rhizomes arise from extensions from the main rhizomes. Secondary rhizomes emerge and give rise to new plants. Tertiary rhizomes arise from the base of the plant at flowering time. These are large rhizomes which go deep into the soil and usually continue to grow until the occurrence of cold or dry weather. New plants are produced the following season from tertiary rhizomes (24). Stamper reported a maximum rhizome production of 11 tons per acre (50). He also stated that at high temperatures and high soil moisture levels a johnsongrass seed will germinate and produce rhizomes and viable seed in six to nine weeks.

Horowitz found no rhizomes deeper than 45 cm (26). He reported 60% of the total dry weight of subterranean parts was found in the upper 15 cm, 30% was found at 15 to 30 cm, and 10% was found in the 30 to 45 cm layer. He also reported that less than 10% of the dry weight of subterranean parts was composed of roots; therefore the variation in underground weights was mainly due to rhizomes.

Rhizome production in sandy loam soil is twice as great as in clay soil (37). In a Sharkey clay soil, 80% of the rhizomes were produced in the top 7.5 cm, while only 55% of the rhizomes in the sandy loam soil were in the top 7.5 cm. However the rhizomes produced in the top 7.5 cm of the sandy loam soil nearly equaled the total rhizome production in the clay soil. As rhizome length increased, the germination percentage of johnsongrass buds decreased. Plants from

long rhizomes likely have a greater available food reserve to sustain emergence than do plants from short rhizomes. Therefore, plants produced from long rhizomes can emerge from greater soil depths than can plants produced from short rhizomes (37).

Rhizome buds planted 2.5 cm deep in moist soil were killed within one to three days when exposed to temperatures of 50° to 60° C. At 50° C, three days of exposure were required to kill all buds. At 45°C a much longer exposure period was required for control (37). Rhizome buds exposed to 0°C for three or four days withstood appreciable loss in viability. Rhizome buds exposed to -3° or -5°C were killed in two days or less (37).

B. Effects of Johnsongrass on Corn

Johnsongrass Competition in Corn

Weeds decrease corn yield by competing with the crop for essential factors that are required for maximum growth and development. These factors include water, nutrients and light. Competition for water is believed to be the major factor contributing to yield reductions due to competition (2). At critical periods in corn development, such as tasseling or pollinating, severe drought stress for only one or two days may reduce grain yield by more than 20% (47). Weed uptake of nutrients increases the fertilizer requirement and reduces the nutrients available for corn (2). Commercial corn production is dependent upon added fertilizer, and weed competition can cause plant nutrients to be a limiting factor. Competition for light is

significant in areas infested with tall-growing weeds which shade the crop and deprive the corn of adequate light for maximum growth (2).

Competitive effects of several weeds in corn have been reported. These weeds include giant foxtail (Setaria faberi Herrm.) (30), yellow foxtail [Setaria glauca (L.) Beauv.] (28), green foxtail [Setaria viridis (L.) Beauv.] (28, 48), quackgrass [Agropyron repens (L.) Beauv.] (61), smooth pigweed [Amaranthus hybridus (L.)] (39) and common lambsquarters [Chenopodium album (L.)] (48). Although johnsongrass is recognized as the most troublesome weed in corn (2), its competitive effects in corn have not been well documented. Perry reported that season-long johnsongrass competition in corn reduced corn grain yields by 18 to 50% and reduced corn stover yields by 37 to 67% (43). The critical johnsongrass-free requirement of corn was determined to be between two and four weeks after planting. The critical duration of johnsongrass competition in corn was found to be between four and eight weeks after planting depending upon environmental conditions. Johnsongrass competition for six weeks after planting or longer increased corn stalk lodging. Season-long johnsongrass competition resulted in 20% corn stalk lodging. Johnsongrass competition for ten weeks or longer delayed the transition of corn from the vegetative stage to the reproductive stage. Significant reduction in grain yield occurred when a johnsongrass population of 28,600 plants/ha was allowed to interfere with corn throughout the season (43).

Maize Dwarf Viruses

Johnsongrass also contributes to the spread of maize viruses.. Maize dwarf mosaic virus (MDMV) and maize chlorotic dwarf virus (MCDV) have caused significant economic losses in the corn growing areas of the United States since the 1960's (8). A survey conducted in the mid-1970's for maize virus and virus-like diseases in the southern and Corn Belt states found that MDMV and MCDV were the most prevalent and damaging viruses affecting corn in the continental United States (17). MDMV overwinters in johnsongrass and is therefore generally limited to areas where johnsongrass occurs frequently. MDMV is transmitted by many aphid species (8). MCDV is not as widely distributed as MDMV, however in states where it is found, it is usually more prevalent and more devastating than MDMV. MCDV also overwinters in johnsongrass, but it is transmitted by a leafhopper (Graminella nigrifrons). MCDV is found only in areas where both its leafhopper vector and johnsongrass are found together (8).

C. Johnsongrass Control in Corn

Various methods of johnsongrass control in corn have been utilized in the past and others are currently being developed. These methods have included cultural, biological and chemical control methods. A johnsongrass control program should have three objectives: (1) to weaken and kill existing plants and their attached rhizomes and prevent formation of new rhizomes; (2) to control seedling plants and deplete the population of seed present in the soil; and (3) to prevent new seed

production (6).

Cultural Control of Johnsongrass

Tillage. Mechanical removal of johnsongrass is the oldest method of johnsongrass control. Before the development of herbicides, johnsongrass was removed by hand pulling, hoeing or cultivation (2). Tillage has been shown to reduce johnsongrass populations significantly. Burt (12) reported that plowing in the summer or fall followed by sufficient tillage to keep johnsongrass regrowth less than 25 cm high reduced the stand of johnsongrass from rhizomes, and resulted in increased corn yields compared to plots not plowed the previous summer or fall. Timing of tillage was also an important factor. Plowing on July 30, followed by a single disking four weeks later resulted in 84% control of rhizome johnsongrass. However, plowing three and seven weeks later resulted in johnsongrass control of 50 and 14%, respectively (12). Rhizome johnsongrass may also be reduced by plowing or chiseling in the fall and exposing the rhizomes to freezing temperatures. Johnsongrass rhizomes lack cold tolerance and can be effectively killed by exposure to temperatures below -4.4° C (6). These results show that tillage can provide effective johnsongrass control. However, this method requires that the area must be fallowed for one season so the soil can be tilled. Therefore, tillage is not a viable option for many producers. Small grain production may work well with these methods. Small grains are sown in the fall after johnsongrass has completed its growing season and are

harvested early in the summer before vigorous growth of johnsongrass has begun. This system would allow the option of summer tillage for johnsongrass control (6).

Crop Rotation. In continuous corn production, the population of several pernicious weeds such as johnsongrass may increase over time. Crop rotations may allow for better management of johnsongrass by the use of alternative herbicides. Johnsongrass can be controlled effectively in cotton or soybeans with sethoxydim or fluazifop (9, 14, 19, 20, 21, 32, 44, 49, 53, 54). Successful johnsongrass control with these herbicides for one or two years would allow corn production the following year with a reduction in johnsongrass interference.

Row Width. Another practice is the reduction of the row width of corn. By reducing the row width, the crop forms a canopy over the row middle and deprives the johnsongrass of light, which reduces the competitiveness of the johnsongrass.

Biological Control of Johnsongrass

Biological weed control involves the use of living natural enemies to control weeds. Little effort has been directed toward integrating biological weed control with more conventional weed control practices (1). However, several biological agents have shown promise as johnsongrass control agents.

Sphacelotheca holci is a pathogen of johnsongrass with epidemiological features that made it potentially conducive for use as

a biological control of this weed (33). S. holci causes loose smut fungus of johnsongrass. Johnsongrass is apparently the only plant affected by this fungus. S. holci infection causes changes in the morphology and growth characteristics of johnsongrass. Infected plants had shorter shoots and rhizomes, fewer rhizomes, and reduced plant weights. Seed production was eliminated also in infected plants. Inoculum levels remained high in infected stands due to production of loose smut spores in infected plants (33). In studies with S. holci, plants were inoculated by cutting the stems and spraying with an aqueous suspension of teliospores. The potential of S. holci as a biological control agent of johnsongrass in corn will depend upon an efficient inoculation technique.

Bipolaris sorghicola is also a pathogen of johnsongrass which causes lesions on the plant. Van Dyke (52) reported that a spore-surfactant-water mixture containing 1.5×10^5 spores/ml sprayed on five day old johnsongrass seedlings killed 60% of the seedlings in six days. The remaining plants were heavily infected with B. sorghicola. A second test using a spray mixture containing 2.0×10^7 spores/ml killed 88% of the seedlings after eight days and by 25 days after inoculation all the seedlings were dead.

The fungus Alternaria alternata produces a cyclic tetrapeptide product known as tentoxin (15). Tentoxin causes extreme chlorosis in a wide range of species. As a result, it can selectively kill weeds in situations where adequate herbicides are not available. Johnsongrass is sensitive to chlorosis caused by tentoxin while corn is insensitive to the toxin, therefore johnsongrass in corn could be selectively

controlled by tentoxin. However, this biological agent has not been commercialized due to difficulties in synthesis and low yields obtained when produced by fermentation.

Chemical Control of Johnsongrass

Dalapon. Chemical control of johnsongrass began in the late 1950's with the introduction of dalapon (46). Dalapon is a non-selective, foliar applied herbicide which translocates through the phloem to kill underground tissue. For effective control, dalapon must be applied to succulent johnsongrass. Early weed control systems involving dalapon began with an early spring application of dalapon to 30 to 45 cm johnsongrass. One week later the johnsongrass infested area was plowed and corn was planted 21 days after the dalapon treatment. EPTC, a herbicide for johnsongrass seedling control, was applied on the day of planting. Usual cultivation practices completed this system. Hicks (23) reported that excellent johnsongrass control could be obtained using this system. However, corn yields were reduced due to delayed planting. It was discovered that fall applications of dalapon could decrease populations of rhizome johnsongrass, and these applications would not interfere with spring planting. Fall applications of dalapon at 4.1 kg/ha reduced rhizome johnsongrass populations the following spring by 90%, but by August johnsongrass populations had increased to 71% of that in the untreated plots (23). This illustrates that although emerged johnsongrass plants can be effectively controlled, seedlings that emerge after layby continue to

be a problem. Dalapon was not used to its full potential because its activity was sometimes erratic due to varying weather conditions, plant size, and soil moisture. Growers perceived the herbicide to be relatively ineffective (46).

Thiocarbamates. The use of the thiocarbamate herbicides began with the introduction of EPTC for use in corn in 1959. Butylate was introduced in the late 1960's (2). These soil incorporated herbicides provide good control of johnsongrass seedlings but only partial control of plants growing from rhizomes. EPTC and butylate were the first selective and effective herbicides for johnsongrass in corn (46).

Early acceptance of thiocarbamates was hindered due to numerous reports of corn injury caused by these herbicides. The occurrence of thiocarbamate injury to corn was reduced but not eliminated by the addition of the protectant, R-25788, to the thiocarbamate herbicides (13). Another problem associated with the thiocarbamates was that of soil conditioning. Soil conditioning occurs when the thiocarbamate herbicides are applied to an area repeatedly (41). This repeated application results in an increase in population of herbicide-degrading microbes. Therefore, microbial degradation of the herbicides is rapidly increased resulting in reduced herbicide efficacy. This problem was temporarily alleviated with the addition of an extender, R-33865, to the herbicides. It was reported that johnsongrass control with either butylate or EPTC was enhanced with the addition of R-33865 (18).

Glyphosate. Glyphosate is a non-selective, foliar applied herbicide that was introduced in the mid-1970's. Glyphosate is translocated through the phloem to rhizomes. Fall applications of glyphosate provide effective control of rhizome johnsongrass (16). Glyphosate acts faster than DSMA and has little soil activity as demonstrated by the fact that grain sorghum planted the day following treatment will germinate and grow normally.

DPX-V9360. DPX-V9360 is an experimental herbicide currently being developed by DuPont. DPX-V9360 is a selective, postemergence herbicide that has shown activity on several weeds in corn including johnsongrass. DPX-V9360 is a member of the sulfonylurea herbicide family, and like other sulfonylureas, the mode of action is the inhibition of acetolactase synthase which blocks branched chain amino acid biosynthesis (4). Symptoms of DPX-V9360 activity include growth inhibition, chlorosis and necrosis followed by death of the plant. Selectivity in corn is achieved by metabolism of the compound to inactive metabolites. Technical information on DPX-V9360 is given in Figure 1.

Field studies have shown that DPX-V9360 controls johnsongrass (11, 22, 27, 31, 40, 45, 55, 59, 60). DPX-V9360 also controls morningglories (Ipomoea spp.)(27, 55, 59, 60), pigweeds (Amaranthus spp.)(27, 55, 59, 60), broadleaf signalgrass [Brachiaria platyphylla (Griseb.) Nash] (27, 45, 55, 59), sicklepod (Cassia obtusifolia L.) (27), spotted spurge (Euphorbia maculata) L.) (55), hemp sesbania [Sesbania exaltata (Raf.)] (55), Texas panicum [Panicum texanum

Code designation	DPX-V9360	CGA-136872
Proposed trade name	Accent	Beacon
Proposed common name		primisulfuron
Formulation	72 DF	75 WG
Vapor pressure	1.2x10 ⁻¹⁸ mm Hg <7.5x10 ⁻¹⁸ Torr.	
	at 25° C	at 20° C
Dissociation constant	pKa = 4.3 at 25 C	
Solubility in water	<u>pH</u>	<u>ppm solubility</u>
	5.6	390
	7.2	18,000
	9.0	250,000
	<u>pH</u>	<u>ppm solubility</u>
	5.0	1
	6.0	9
	7.0	70
	8.0	600
	9.0	4500

Figure 1. Technical information on DPX-V9360 and CGA-136872.

(Buckl.)], red rice (Oryza sativa L.), and goosegrass (Eleusine indica L.) (59).

CGA-136872. CGA-136872 is an experimental herbicide currently being developed by Ciba-Geigy. CGA-136872 is a selective, postemergence herbicide that has herbicidal activity on several weeds in corn including johnsongrass. CGA-136872 is a member of the sulfonylurea herbicide family and its mode of action is the inhibition of acetolactate synthase. Symptoms of activity include inhibition of meristematic tissue growth, yellowing of leaves and death of the growing point followed by death of the entire plant. Selectivity is due to the ability of the corn plant to metabolize CGA-136872 to herbicidally inactive compounds (3). Technical information on CGA-136872 is given in Figure 1.

Field studies have shown CGA-136872 to control johnsongrass (11, 22, 31, 40, 45, 55, 60). CGA-136872 has also given good control of hemp sesbania, redweed [Melochia corchorifolia L.], spotted spurge, prickly sida (Sida spinosa L.), redroot pigweed (Amaranthus retroflexus L.) (55) and tall morningglory (Ipomoea purpurea L.) (60).

CHAPTER III

TIME AND METHOD OF REMOVAL OF JOHNSONGRASS INTERFERENCE

A. Introduction

Chemical control of johnsongrass in corn has previously been limited to preplant burndown applications of dalapon (46), preplant applications of thiocarbamate herbicides (46), or post-harvest applications of dalapon or glyphosate (16). Therefore the constraints of planting or harvesting dictated the timing of herbicide applications. Selective, postemergence herbicides for johnsongrass control in corn have a longer time span in which application is possible. DPX-V9360 and CGA-136872 are two of these selective, postemergence herbicides which are currently being developed. The objective of this experiment was to determine the optimum time of removal of johnsongrass interference from corn by comparing chemical removal with herbicides at four dates with hand removal at six dates.

B. Materials and Methods

Field studies were conducted in 1988 at West Tennessee Experiment Station, Jackson, and at Ames Plantation, Grand Junction. Treatments were replicated four times in a randomized complete block experimental design. The experiments were established in areas naturally infested

with rhizome johnsongrass. With the exception of weed control, University of Tennessee recommended practices for corn production were followed.

Chemicals were applied with a CO2 backpack sprayer in an aqueous spray volume of 168 L/ha at a speed of 6.0 km/h and a pressure of 220 kPa. All chemical treatments included 0.25% v/v nonionic surfactant.

'Dekalb 689' corn was planted at Jackson on April 14, 1988 at a population of 59,300 plants/ha. At Grand Junction, 'Pioneer 3147' corn was planted on April 21, 1988 at a population of 59,800 plants/ha. The soil at both locations was a Lexington silt loam (Fine-silty, mixed thermic Typic Paleudalf). The soil at Jackson had a pH of 6.5 and an organic matter content of 1.2%. At Grand Junction, the soil had a pH of 6.3 and an organic matter content of 1.0%.

Each plot consisted of four, 9.1 m rows spaced 76 cm apart. Data were collected from the two center rows. Treatments, herbicide rates, and growth stages of corn and johnsongrass at Jackson and Grand Junction are in Tables 1 and 2 respectively. Johnsongrass control and corn injury ratings were recorded at Jackson on June 10, July 8, and July 26, 1988. Ratings were taken at Grand Junction on June 3, 9, and 17, and July 29, 1989. Ratings were recorded on a scale of 0 to 100 with 0 equal to no johnsongrass control or no crop injury and 100 equal to complete control or complete crop kill.

Table 1. Treatments utilized in the experiments to determine optimum time and method for removal of johnsongrass interference in corn at Jackson.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Time After</u> <u>Planting</u> (weeks)	<u>Corn</u> <u>Height</u> (cm)	<u>Corn</u> <u>Leaf</u> <u>Number</u>	<u>Johnsongrass</u> <u>Height</u> (cm)
DPX-V9360	35	3	15	4	30
"	"	4	20	6	36
"	"	5	30	8	46
"	"	6	56	9	71
CGA-136872	30	3	15	4	30
"	"	4	20	6	36
"	"	5	30	8	46
"	"	6	56	9	71
Hand-hoed	--	3	15	4	30
"	--	4	20	6	36
"	--	5	30	8	46
"	--	6	56	9	71
"	--	7	--	-	--
"	--	8	--	-	--
Weedy Check	--	-			
Weedfree Check	--	-			

Table 2. Treatments utilized in the experiments to determine optimum time and method for removal of johnsongrass interference in corn at Grand Junction.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Time After</u> <u>Planting</u> (weeks)	<u>Corn</u>		<u>Johnsongrass</u>	
			<u>Height</u> (cm)	<u>Leaf</u> Number	<u>Height</u> (cm)	<u>Leaf</u> Number
DPX-V9360	35	3	13	3-4	25	2-8
"	"	4	18	5-6	30	4-9
"	"	5	25	8	38	10-12
"	"	6	36	9	46	11-13
CGA-136872	30	3	13	3-4	25	2-8
"	"	4	18	5-6	30	4-9
"	"	5	25	8	38	10-12
"	"	6	36	9	46	11-13
Hand-hoed	--	3	13	3-4	25	2-8
"	--	4	18	5-6	30	4-9
"	--	5	25	8	38	10-12
"	--	6	36	9	46	11-13
"	--	7	--	-	--	--
"	--	8	--	-	--	--
Weedy Check	--	-				
Weedfree Check	--	-				

C. Results and Discussion

Jackson

Johnsongrass control with DPX-V9360 and CGA-136872 ranged from <30% to 93% depending upon the time of application (Table 3). DPX-V9360 applied at three or four weeks after planting (WAP) failed to control johnsongrass. DPX-V9360 applied at five or six WAP gave approximately 80% johnsongrass control initially which increased through the final rating date. CGA-136872 applied at three WAP provided <60% control of johnsongrass, although control was greater than that provided by DPX-V9360 applied on the same date. CGA-136872 applied at four WAP gave 70% control initially, but control decreased to 51% by the final rating. CGA-136872 applied at five or six WAP gave <50% control of johnsongrass. All treatments with the exception of DPX-V9360 applied at five or six WAP had less johnsongrass control than the weedfree check. Johnsongrass control from CGA-136872 decreased as the season progressed with the exception of the five WAP treatment. Johnsongrass control remained relatively constant in the DPX-V9360 treatments. The reason for the reduction in johnsongrass control with CGA-136872 treatments was due to a greater amount of johnsongrass regrowth in treatments with CGA-136872.

Chemical injury to the corn did not differ from the weedfree check in any chemical treatments applied through five WAP (Table 4). However, both DPX-V9360 and CGA-136872 injured corn at six WAP. Corn injury symptoms varied from a slight yellowing in the whorl to severe twisting of the plant. Injury symptoms were not apparent in the DPX-V9360 treatment at the final rating. CGA-136872 initially injured corn more

Table 3. Johnsongrass control as influenced by time and method of removal of johnsongrass at Jackson.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application Date</u> (WAP)	<u>Control on</u> <u>06/10/88</u> (%)	<u>Control on</u> <u>07/08/88</u> (%)	<u>Control on</u> <u>07/26/88</u> (%)
Hand-hoed	--	3	99	99	99
"	--	4	99	99	99
"	--	5	99	99	99
"	--	6	99	99	99
"	--	7	99	99	99
"	--	8	99	99	99
DPX-V9360	35	3	26	31	30
CGA-136872	30	3	58	53	33
DPX-V9360	35	4	58	60	56
CGA-136872	30	4	70	70	51
DPX-V9360	35	5	78	87	86
CGA-136872	30	5	50	46	50
DPX-V9360	35	6	79	93	88
CGA-136872	30	6	54	49	31
Weedy	--	-	0	0	0
Weedfree	--	-	99	99	99
LSD(0.05)			26	25	27

Table 4. Corn injury as influenced by time and method of removal of johnsongrass at Jackson.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	Corn Injury on (06/10/88) (%)	Corn Injury on (07/08/88) (%)	Corn Injury on (07/26/88) (%)
Hand-hoed	--	3	0	0	0
"	--	4	0	0	0
"	--	5	0	0	0
"	--	6	0	0	0
"	--	7	0	0	0
"	--	8	0	0	0
DPX-V9360	35	3	0	0	1
CGA-136872	30	3	3	0	1
DPX-V9360	35	4	0	0	0
CGA-136872	30	4	5	3	1
DPX-V9360	35	5	3	0	0
CGA-136872	30	5	6	1	3
DPX-V9360	35	6	28	10	4
CGA-136872	30	6	50	23	10
Weedy	--	-	0	0	0
Weedfree	--	-	0	0	0
LSD(0.05)			11	4	4

severely than DPX-V9360, and the injury was still visible at the final rating. The greater injury from herbicides applied at six WAP may be attributed to five days of rainfall and cloudy conditions prior to application which could have reduced corn's ability to metabolize the herbicides. Selectivity has been shown to be related to differential metabolism (3, 4).

Corn stunt ratings were taken to evaluate the combined effects of chemical injury and johnsongrass interference (Table 5). At the initial rating, elevated corn stunting was observed only in the chemical treatments applied at six WAP. This was due primarily to excessive chemical injury observed in the treatments. As the season progressed, corn stunting was observed in more treatments due to interference resulting from poor johnsongrass control. By the final rating, corn stunting was observed in all treatments except hand hoeing through seven WAP, CGA-136872 applied at four WAP, and DPX-V9360 applied at six WAP.

A count of barren plants was taken to determine if DPX-V9360 or CGA-136872 affected corn ear production (Table 6). The percentage of barren plants was greater in treatments of DPX-V9360 applied at three WAP, and CGA-136872 applied at three and six WAP, than in the weedfree check. The weedy check also had an increase in barren plants, although this difference was not significant. The treatments with the highest percentage of barren plants were also the treatments with the poorest johnsongrass control, therefore barren plant percentage appears to be due to johnsongrass interference rather than herbicide injury. Corn yields decreased in hand hoed treatments from three through eight WAP, although hand hoeing at eight WAP was the only treatment that yielded

Table 5. Corn stunt as influenced by time and method of removal of johnsongrass at Jackson.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	<u>Corn</u> <u>Stunt on</u> <u>(06/10/88)</u> (%)	<u>Corn</u> <u>Stunt on</u> <u>(07/08/88)</u> (%)	<u>Corn</u> <u>Stunt on</u> <u>(07/26/88)</u> (%)
Hand-hoed	--	3	3	3	0
"	--	4	14	4	1
"	--	5	20	5	9
"	--	6	19	4	8
"	--	7	15	9	10
"	--	8	15	29	20
DPX-V9360	35	3	20	28	25
CGA-136872	30	3	13	18	23
DPX-V9360	35	4	15	18	19
CGA-136872	30	4	9	9	10
DPX-V9360	35	5	21	16	14
CGA-136872	35	5	16	14	19
DPX-V9360	35	6	28	9	6
CGA-136872	30	6	55	23	28
Weedy	--	-	19	35	28
Weedfree	--	-	5	1	0
LSD(0.05)			16	13	13

Table 6. Influence of time and method of removal of johnsongrass on barren plant percentage at Jackson.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	<u>Barren</u> <u>Plants</u> (%)
Hand-hoed	--	3	3
"	--	4	2
"	--	5	1
"	--	6	1
"	--	7	1
"	--	8	3
DPX-V9360	35	3	19
CGA-136872	30	3	18
DPX-V9360	35	4	7
CGA-136872	30	4	2
DPX-V9360	35	5	4
CGA-136872	30	5	3
DPX-V9360	35	6	4
CGA-136872	30	6	13
Weedy	--	-	11
Weedfree	--	-	3
LSD(0.05)			8

lower than the weedfree check (Table 7). DPX-V9360 applied at three WAP and CGA-136872 applied at three or six WAP yielded less than the weedfree check. Yields for the remaining chemical treatments were not different from the weedfree check. At application dates of four through six WAP, increased johnsongrass control resulted in improved corn yields. There were no differences between treatments in corn grain moisture or test weight (Table 7).

Grand Junction

Johnsongrass control with DPX-V9360 and CGA-136872 ranged from <25% to >90% depending upon the time of application and rating date (Table 8). DPX-V9360 applied at three WAP maintained 70 to 86% johnsongrass control. Johnsongrass control of >90% was obtained with DPX-V9360 applied at four through six WAP. Johnsongrass control for all DPX-V9360 treatments was equal to the weedfree check at the final rating date. CGA-136872 applied at three WAP gave <65% johnsongrass control. CGA-136872 applied at four WAP initially gave approximately 80% johnsongrass control, but because of regrowth, control dropped to 50% by the final rating. CGA-136872 applied at five WAP peaked at 71% control, but by the final rating, control had dropped to 35%. CGA-136872 applied at six WAP never provided over 55% johnsongrass control.

Although chemical injury at this location was minimal, a rating of corn stunting was taken to measure the combined effects of chemical injury and johnsongrass interference on corn vigor (Table 9). Corn stunting was attributed to johnsongrass interference rather than to chemical injury because the greatest amount of corn stunting was

Table 7. Corn yield, moisture percentage and test weight as influenced by time and method of removal of johnsongrass at Jackson.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	<u>Yield</u> (kg/ha)	<u>Grain</u> <u>Moisture</u> (%)	<u>Test</u> <u>Weight</u> (kg/m ³)
Hand-hoed	--	3	7812	19.2	701
"	--	4	7312	19.6	698
"	--	5	7750	19.6	691
"	--	6	7562	19.3	696
"	--	7	6812	19.8	695
"	--	8	5312	19.3	687
DPX-V9360	35	3	4312	19.5	689
CGA-136872	30	3	4062	19.9	695
DPX-V9360	35	4	6125	19.7	690
CGA-136872	30	4	6750	19.8	690
DPX-V9360	35	5	6812	20.4	690
CGA-136872	30	5	6125	19.7	699
DPX-V9360	35	6	6625	19.7	690
CGA-136872	30	6	4375	19.8	692
Weedy	--	-	4312	19.4	692
Weedfree	--	-	7437	19.8	694
LSD(0.05)			1812	0.9	NS

Table 8. Johnsongrass control as influenced by time and method of removal of johnsongrass at Grand Junction.

Treatment	Rate (g ai/ha)	Application	Johnsongrass Control			
		Date (WAP)	(6/03/88) (%)	(6/09/88) (%)	(6/17/88) (%)	(7/29/88) (%)
Hand-hoed	--	3	99	99	99	98
"	--	4	99	99	99	98
"	--	5	99	99	99	84
"	--	6	99	99	99	74
"	--	7	0	99	99	54
"	--	8	0	0	99	38
DPX-V9360	35	3	83	70	86	79
CGA-136872	30	3	60	45	65	48
DPX-V9360	35	4	85	83	92	84
CGA-136872	30	4	80	78	80	50
DPX-V9360	35	5	44	83	93	91
CGA-136872	30	5	25	48	71	35
DPX-V9360	35	6	0	23	80	94
CGA-136872	30	6	0	21	55	50
Weedy	--	-	0	0	8	11
Weedfree	--	-	99	99	99	98
LSD(0.05)			9	17	16	25

Table 9. Corn stunting as influenced by time and method of removal of johnsongrass at Grand Junction.

Treatment	Rate (g ai/ha)	Application	Corn Injury			
		Date (WAP)	(6/03/88) (%)	(6/09/88) (%)	(6/17/88) (%)	(7/29/88) (%)
Hand-hoed	--	3	3	4	6	0
"	--	4	4	8	15	1
"	--	5	6	13	23	15
"	--	6	5	14	25	20
"	--	7	5	13	34	26
"	--	8	3	10	28	34
DPX-V9360	35	3	4	4	1	8
CGA-136872	30	3	3	4	14	19
DPX-V9360	35	4	3	3	9	9
CGA-136872	30	4	6	4	18	23
DPX-V9360	35	5	3	5	6	11
CGA-136872	30	5	9	6	24	38
DPX-V9360	35	6	1	4	13	25
CGA-136872	30	6	0	8	16	29
Weedy	--	-	4	24	21	53
Weedfree	--	-	0	4	6	0
LSD(0.05)			7	8	21	21

observed in treatments with the least johnsongrass control or in treatments that consisted of a control practice applied at five WAP or later. Corn stunting was not significant where johnsongrass was effectively controlled by five WAP. Stem diameters of corn plants were measured on June 17, 1988 (Table 10). Hand-hoed treatments at six through eight WAP had smaller stem diameters than the weedfree check. There were no differences between the remaining treatments and the weedfree check, however for each application date through five WAP there was a trend for corn in the DPX-V9360 treatments to have greater stem diameters than in CGA-136872 treatments. Stem diameters also tended to decrease for each successive application date. This response was expected due to a longer period of johnsongrass interference with each successive application date.

The weedy check was the only treatment with more barren plants than the weedfree check (Table 11). Results were similar to those from Jackson in that treatments with the highest percentage of barren plants were those with the least johnsongrass control.

Corn yields reflected those treatments in which johnsongrass interference was effectively removed (Table 12). Treatments hand-hoed at three or four WAP, and DPX-V9360 applied at three through five WAP effectively removed johnsongrass interference and produced grain yields indistinguishable from the weedfree check. Yields were lower than the weedfree check in all other treatments. In the hand-hoed treatments, corn yield decreased as the number of weeks after planting to hoeing increased. Corn yields were higher with DPX-V9360 than CGA-136872 at each application date. There were no differences in corn grain

Table 10. Corn stem diameters as influenced by time and method of removal of johnsongrass at Grand Junction.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	<u>Stem</u> <u>Diameter</u> <u>on 06/17/88</u> (%)
Hand-hoed	--	3	2.60
"	--	4	2.57
"	--	5	2.42
"	--	6	2.11
"	--	7	2.05
"	--	8	2.09
DPX-V9360	35	3	2.59
CGA-136872	30	3	2.41
DPX-V9360	35	4	2.55
CGA-136872	30	4	2.36
DPX-V9360	35	5	2.79
CGA-136872	30	5	2.22
DPX-V9360	35	6	2.21
CGA-136872	30	6	2.25
Weedy	--	-	2.17
Weedfree	--	-	2.65
LSD(0.05)			0.52

Table 11. Influence of time and method of removal of johnsongrass on barren plant percentage at Grand Junction.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	<u>Barren</u> <u>Plants</u> (%)
Hand-hoed	--	3	4.5
"	--	4	6.7
"	--	5	4.1
"	--	6	7.2
"	--	7	18.0
"	--	8	17.2
DPX-V9360	35	3	5.7
CGA-136872	30	3	9.7
DPX-V9360	35	4	6.5
CGA-136872	30	4	9.8
DPX-V9360	35	5	5.7
CGA-136872	30	5	18.4
DPX-V9360	35	6	9.3
CGA-136872	30	6	10.2
Weedy	--	-	19.7
Weedfree	--	-	5.7
LSD(0.05)			13.8

Table 12. Corn yield, moisture percentage and test weight as influenced by time and method of removal of johnsongrass at Grand Junction.

<u>Treatment</u>	<u>Rate</u> (g ai/ha)	<u>Application</u> <u>Date</u> (WAP)	<u>Yield</u> (kg/ha)	<u>Grain</u> <u>Moisture</u> (%)	<u>Test</u> <u>Weight</u> (kg/m ³)
Hand-hoed	--	3	7625	21.9	616
"	--	4	6750	22.9	615
"	--	5	5625	22.6	618
"	--	6	4688	22.2	601
"	--	7	3688	22.4	600
"	--	8	3875	22.0	619
DPX-V9360	35	3	6750	20.1	634
CGA-136872	30	3	4875	21.7	597
DPX-V9360	35	4	6125	21.2	611
CGA-136872	30	4	4688	20.9	598
DPX-V9360	35	5	6688	22.1	616
CGA-136872	30	5	3938	22.4	606
DPX-V9360	35	6	5000	23.1	628
CGA-136872	30	6	4000	22.4	600
Weedy	--	-	2750	19.7	616
Weedfree	--	-	8250	23.6	612
LSD(0.05)			2188	2.9	NS

moisture between herbicides or between hand-hoed treatments and the weedfree check (Table 12). However, there was a slight trend toward higher corn grain moistures with later applications of herbicides. No differences in test weight (Table 12) were noted between the weedfree check and other treatments, although at each application date there was a trend for treatments with DPX-V9360 to have a higher test weight percentage than treatments with CGA-136872. This difference was probably due to increased johnsongrass interference in the CGA-136872 treatments that resulted in incomplete filling of grain.

CHAPTER IV

THRESHOLD DENSITY OF JOHNSONGRASS

IN CORN

A. Introduction

The development of selective, postemergence herbicides for johnsongrass control in corn will provide growers with an effective tool for johnsongrass management. However with rising production costs, farmers need an accurate model to determine the economic threshold, i.e. the johnsongrass population at which treatment becomes profitable. The effect of various weed densities in corn has been studied for several weeds including smooth pigweed (39), green foxtail and lambsquarters (47), and giant foxtail (30). The effect of various johnsongrass densities has been reported for cotton (10) and soybeans (57, 58). However the effect of various johnsongrass densities in corn is not well documented. Perry reported that significant corn yield losses occurred when a johnsongrass population of 28,576 plants/ha was allowed to compete with corn the entire growing season (43). The purpose of these experiments was to determine the effect of various johnsongrass densities on corn yield.

B. Materials and Methods

Field studies were conducted in 1988 at West Tennessee Experiment Station at Jackson, and at Ames Plantation near Grand Junction, TN. Each density was replicated four times in a randomized complete block experimental design. The experiments were established in areas naturally infested with rhizome johnsongrass and were thinned to the desired populations. With the exception of weed control, University of Tennessee recommended practices for corn production were followed.

'Pioneer 3389' corn was planted at Jackson on April 14, 1988 at a population of 59,300 plants/ha. At Grand Junction, 'Pioneer 3147' corn was planted on April 21, 1988 at a population of 59,800 plants/ha. The soil at both locations was a Lexington silt loam (Fine-silty, mixed thermic Typic Paleudalf). The soil at Jackson had a pH of 6.6 and an organic matter content of 1.2%. At Grand Junction, the soil had a pH of 6.0 and an organic matter content of 1.0%.

Each plot consisted of four, 9.1 m rows spaced 76 cm apart. Johnsongrass populations were established in the two center rows of each plot. Johnsongrass was established in 6.1 m of each row leaving 1.5 m at each end johnsongrass-free. Johnsongrass densities at Jackson and Grand Junction are in Tables 13 and 14, respectively. After removal of 1.5 m from the end of each row, the remaining corn from the two center rows of each plot was harvested. Corn was harvested on September 12, 1988 at Jackson and on August 31, 1988 at Grand Junction, and yields were recorded.

Table 13. Treatments utilized for johnsongrass threshold study at Jackson.

Number	Johnsongrass Density (No./6.1 m)
1	1
2	2
3	4
4	8
5	16
6	weedy check *
7	weedfree check

* Weedy check consisted of planting eight rhizomes per row plus eight rhizomes between the two rows plus overseeding of the entire plot at the time of corn planting.

Table 14. Treatments utilized for johnsongrass threshold study at Grand Junction.

Number	Johnsongrass Density (No./6.1 m)
1	1
2	2
3	4
4	8
5	12
6	16
7	weedy check
8	weedfree check

C. Results and Discussion

Jackson

Corn yields decreased with increasing johnsongrass densities up to 16 plants per 6.1 m of row (Table 15). Johnsongrass densities up to four plants per 6.1 m of row did not yield differently from the weedfree check. All other treatments yielded less than the weedfree check. The weedy check reduced corn yields by 50%. Corn yield reductions corresponded well with increasing johnsongrass densities in all treatments.

There were no differences in test weight among johnsongrass densities (Table 15). However with increasing johnsongrass densities, there was a trend toward decreasing test weights.

Treatments with two or four johnsongrass plants per 6.1 m of row had a lower corn grain moisture percentage than the weedfree check (Table 15). Corn grain moistures from the other treatments were not different from the weedfree check.

Grand Junction

Corn grain yields were not reduced at johnsongrass densities up to four plants per 6.1 m of row (Table 16). All other johnsongrass densities yielded lower than the weedfree check. The weedy check reduced corn yield by 78%. Increasing johnsongrass densities resulted in correspondingly lower corn grain yields for all treatments. This relationship was expected due to the competitiveness of johnsongrass.

Table 15. Influence of johnsongrass density on corn grain yield, test weight, and moisture content at Jackson.

<u>Johnsongrass Density</u> (no./6.1 m)	<u>Yield</u> (kg/ha)	<u>Test Weight</u> (kg/m ³)	<u>Grain Moisture</u> (%)
1	6813	703	19.4
2	6250	713	18.5
4	5750	712	18.5
8	5563	709	19.2
16	3625	685	20.1
weedy	3563	682	19.7
weedfree	7063	705	19.7
LSD(0.05)	1313	NS	0.9

Table 16. Influence of johnsongrass density on corn grain yield, test weight, and moisture content at Grand Junction.

<u>Johnsongrass Density</u> (No./6.1 m)	<u>Yield</u> (kg/ha)	<u>Test Weight</u> (kg/m ³)	<u>Grain Moisture</u> (%)
1	5812	560	24.8
2	5438	565	26.8
4	5438	583	25.1
8	4375	569	23.7
12	4313	575	22.0
16	3750	575	23.2
weedy	1375	550	23.1
weedfree	6188	568	25.3
LSD(0.05)	875	NS	3.0

Test weight was measured at harvest and there were no differences among treatments (Table 16). Corn grain moisture percentage was also measured at harvest and the johnsongrass density of 12 plants per 6.1 m of row had a lower moisture percentage than the weedfree check (Table 16). There were no differences in moisture percentage between the remaining treatments and the weedfree check. No consistent patterns were observed between johnsongrass densities and test weight or corn grain moisture percentage.

These data suggest that corn can tolerate johnsongrass up to a density of one plant per 1.5 m of row without sustaining yield losses. However, yields may be reduced due to reduced harvesting efficiency.

CHAPTER V

EFFECTS OF DPX-V9360 AND CGA-136872 ON CORN GROWTH AND YIELD UNDER VARIOUS ENVIRONMENTAL CONDITIONS

A. Introduction

DPX-V9360 and CGA-136872 are selective, postemergence herbicides that give good to excellent control of johnsongrass in corn. Studies are currently being conducted to evaluate the efficacy of these herbicides at different rates and growth stages of johnsongrass. Equally important, however is the effect of these herbicides at different growth stages of corn. The objectives of these experiments were to determine the effects of DPX-V9360 and CGA-136872 on corn growth and yield when applied to corn at various growth stages under differing environmental conditions.

B. Materials and Methods

Field studies were conducted in 1988 at the West Tennessee Experiment Station, Jackson and at the Milan Experiment Station, Milan. The experimental design was a randomized complete block with a split-split plot factorial arrangement of treatments. Main plots were planting dates; sub-plots were herbicide application dates; and sub-sub-plots were herbicides. Treatments were replicated three times. At Jackson, terbufos was applied in-furrow at planting at the rate of 1.35

kg/ha for insect control. At Milan, carbofuran was applied in-furrow at planting at the rate of 1.12 kg/ha for insect control. Cultural practices were followed according to University of Tennessee recommendations.

Herbicides were applied with a CO₂ backpack sprayer in an aqueous spray volume of 137 L/ha at a speed of 6.0 km/h and a pressure of 220 kPa. All chemical treatments included 0.25% v/v nonionic surfactant.

'DeKalb 689' corn was planted at Jackson and 'Pioneer 3389' corn was planted at Milan. Corn was planted at four weekly intervals. For each planting date, each of the two herbicides was applied at five weekly intervals beginning at two weeks and continuing through six weeks after planting. Plots consisted of four, 9.1 m rows spaced 76 cm apart. Data were collected from the two center rows of each plot. Treatments, herbicide rates, and corn stage of growth at treatment are given for Jackson and Milan in Tables 17 and 18, respectively. Corn injury was evaluated one week after each herbicide application and a final rating was taken on July 8, 1988 at Jackson and on June 29, 1988 at Milan. Corn injury ratings were made to determine how quickly corn injury symptoms became evident and how long the injury persisted. A variable, hereafter referred to as post-time, was used to describe these results. Post-time is defined as the period of time from the treatment date to a specific rating date. For example, a post-time of three would describe a rating made three weeks after treatment. Ratings were recorded on a scale of 0 to 100 with 0 equal to no injury and 100 equal to complete crop kill. A count of barren plants was made on August 16, 1988 at Jackson and on August 15, 1988 at Milan, and the

Table 17. Treatments utilized to study the effect of DPX-V9360 and CGA-136872 on corn growth and yield under various environmental conditions at Jackson.

Planting Date	Treatment Date	Treatment	Rate (g ai/ha)	Corn Leaf Number
April 14	April 29	DPX-V9360	35	3
"	April 29	CGA-136872	20	3
"	May 5	DPX-V9360	35	4
"	May 5	CGA-136872	20	4
"	May 12	DPX-V9360	35	5
"	May 12	CGA-136872	20	5
"	May 19	DPX-V9360	35	8
"	May 19	CGA-136872	20	8
"	May 26	DPX-V9360	35	9
"	May 26	CGA-136872	20	9
"	Check	-----	--	--
"	Check	-----	--	--
April 21	May 5	DPX-V9360	35	3
"	May 5	CGA-136872	20	3
"	May 12	DPX-V9360	35	4
"	May 12	CGA-136872	20	4
"	May 19	DPX-V9360	35	6-7
"	May 19	CGA-136872	20	6-7
"	May 26	DPX-V9360	35	8
"	May 26	CGA-136872	20	8
"	June 3	DPX-V9360	35	10
"	June 3	CGA-136872	20	10
"	Check	-----	--	--
"	Check	-----	--	--
April 28	May 12	DPX-V9360	35	3
"	May 12	CGA-136872	20	3
"	May 19	DPX-V9360	35	6
"	May 19	CGA-136872	20	6
"	May 26	DPX-V9360	35	8
"	May 26	CGA-136872	20	8
"	June 3	DPX-V9360	35	8
"	June 3	CGA-136872	20	8
"	June 9	DPX-V9360	35	10
"	June 9	CGA-136872	20	10
"	Check	-----	--	--
"	Check	-----	--	--
May 5	May 19	DPX-V9360	35	4
"	May 19	CGA-136872	20	4
"	May 26	DPX-V9360	35	5
"	May 26	CGA-136872	20	5
"	June 3	DPX-V9360	35	7
"	June 3	CGA-136872	20	7
"	June 9	DPX-V9360	35	9
"	June 9	CGA-136872	20	9
"	June 16	DPX-V9360	35	--
"	June 16	CGA-136872	20	--
"	Check	-----	--	--
"	Check	-----	--	--

Table 18. Treatments utilized to study the effect of DPX-V9360 and CGA-136872 on corn growth and yield under various environmental conditions at Milan.

Planting Date	Treatment Date	Treatment	Rate (g ai/ha)	Corn Leaf Number
April 11	April 25	DPX-V9360	35	2
"	April 25	CGA-136872	20	2
"	May 2	DPX-V9360	35	4-5
"	May 2	CGA-136872	20	4-5
"	May 10	DPX-V9360	35	7
"	May 10	CGA-136872	20	7
"	May 16	DPX-V9360	35	9
"	May 16	CGA-136872	20	9
"	May 25	DPX-V9360	35	11
"	May 25	CGA-136872	20	11
"	Check	-----	--	--
"	Check	-----	--	--
April 19	May 2	DPX-V9360	35	3
"	May 2	CGA-136872	20	3
"	May 10	DPX-V9360	35	6
"	May 10	CGA-136872	20	6
"	May 16	DPX-V9360	35	8
"	May 16	CGA-136872	20	8
"	May 25	DPX-V9360	35	9
"	May 25	CGA-136872	20	9
"	May 30	DPX-V9360	35	11-12
"	May 30	CGA-136872	20	11-12
"	Check	-----	--	--
"	Check	-----	--	--
April 25	May 10	DPX-V9360	35	2-4
"	May 10	CGA-136872	20	2-4
"	May 16	DPX-V9360	35	4-6
"	May 16	CGA-136872	20	4-6
"	May 25	DPX-V9360	35	6-8
"	May 25	CGA-136872	20	6-8
"	May 30	DPX-V9360	35	9-10
"	May 30	CGA-136872	20	9-10
"	June 6	DPX-V9360	35	12
"	June 6	CGA-136872	20	12
"	Check	-----	--	--
"	Check	-----	--	--
May 2	May 16	DPX-V9360	35	4
"	May 16	CGA-136872	20	4
"	May 25	DPX-V9360	35	6
"	May 25	CGA-136872	20	6
"	May 30	DPX-V9360	35	7-8
"	May 30	CGA-136872	20	7-8
"	June 6	DPX-V9360	35	10
"	June 6	CGA-136872	20	10
"	June 13	DPX-V9360	35	--
"	June 13	CGA-136872	20	--
"	Check	-----	--	--
"	Check	-----	--	--

percentage of barren plants was calculated.

C. Results and Discussion

Jackson

Corn injury was affected by planting date, age of the corn at treatment and herbicide (Table 19). Corn injury levels were generally higher at Jackson than at Milan, and this may partly be attributed to interaction with terbufos at Jackson. An interaction between terbufos and the sulfonylurea herbicides has been noted which results in increased levels of phytotoxicity in corn (29,51). At Milan, where carbofuran was used as a soil-applied insecticide, lower injury levels were observed. This insecticide has not been shown to interact with the sulfonylurea herbicides.

The effects of planting date were due to different environmental conditions present at planting and continuing throughout the season. Effects of planting date on corn injury are shown in Figure 2. Corn injury increased from the first through the third planting dates; however corn injury decreased for the final planting date. Planting date effect was not related to temperature or rainfall (Table A-1). However, corn injury did follow the same trend as for solar radiation (Table 20). Corn injury increased with greater levels of solar radiation through the third planting date. For the fourth planting date, corn injury decreased with decreasing levels of solar radiation. There appears to be some relationship between corn injury and solar radiation levels. These results, however contradict earlier findings

Table 19. Analysis of variance for injury to corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson.

Source	DF	SS	MS	F	Pr > F
Planting Date (PD)	3	3514	1171	14.1	0.0001
Replication (R)	2	669	334	4.0	0.0187
Age (A)	4	10077	2519	30.3	0.0001
PD * A * R	50	31466	629	7.6	0.0001
Herbicide	1	1851	1851	22.3	0.0001
Post-time	9	23789	2643	31.8	0.0001

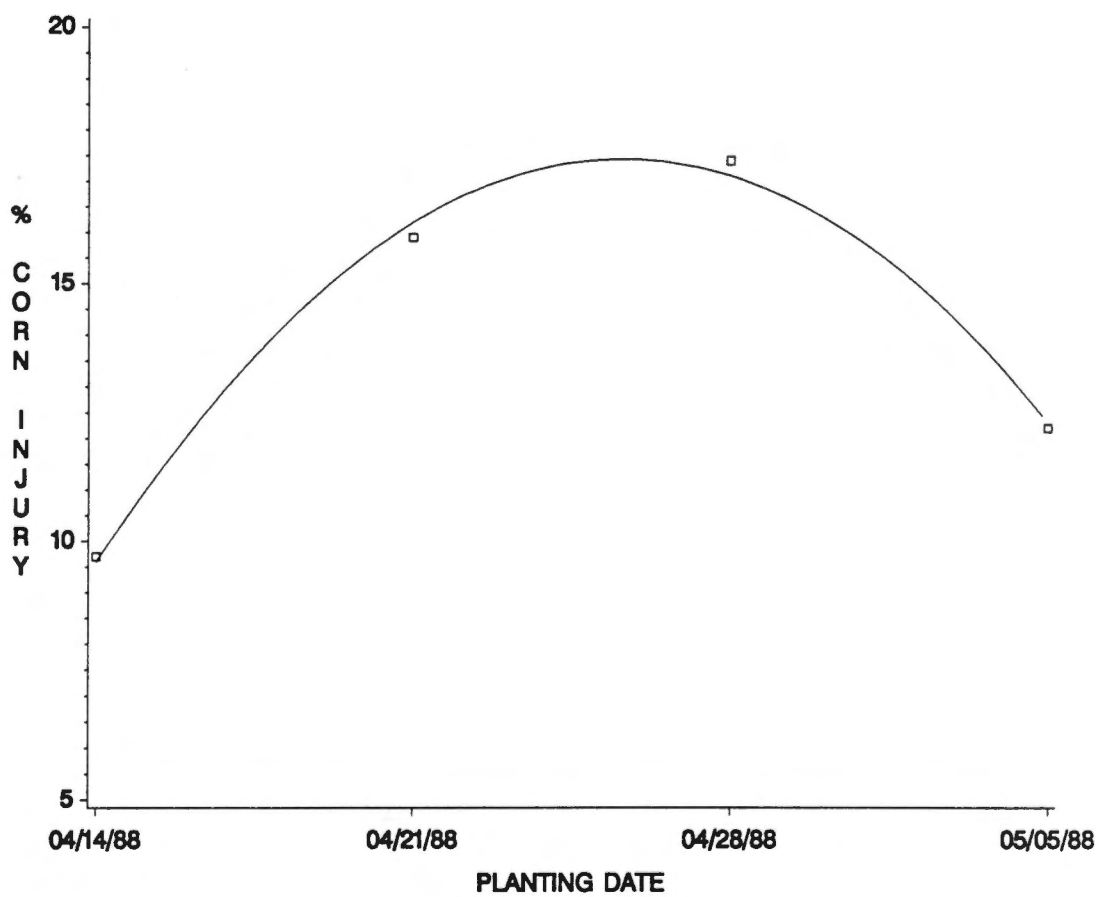


Figure 2. Corn injury as affected by planting date for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson.

Table 20. Solar radiation for planting date periods at Jackson.

Planting Date	Dates	Total Solar Radiation (watt-hours m ² day ⁻¹)
April 14	April 14 - June 9	340,669
April 21	April 21 - June 16	351,716
April 28	April 28 - June 23	377,385
May 5	May 5 - June 30	360,164

where corn injury levels were increased under cloudy conditions (Chapter III). Further research is needed to elucidate the effect of environmental factors on corn injury.

The effects of DPX-V9360 and CGA-136872 on corn injury are shown in Figure 3. CGA-136872 caused higher levels of corn injury than did DPX-V9360 across all planting dates and treatment dates. These results are similar to those observed in a previous study (Chapter III).

Corn injury as affected by age of the corn at treatment is illustrated in Figure 4. Results indicate that corn injury decreases with increasing age of the corn at the time of treatment. Corn treated at the age of two weeks had more injury due to the inability of the plant to metabolize the herbicides to inactive metabolites. As the age of the corn increased, photosynthesis rate of the corn probably increased thereby providing greater amounts of available energy for metabolism of the herbicides. Thus injury levels decreased when herbicide applications were made to older corn.

Figure 5 shows the levels of corn injury at various post-times. Results from Figure 5 indicate that corn injury was evident at post-time one. Corn injury reached a maximum at post-time two or approximately two weeks after treatment. Corn injury decreased with time after two weeks following treatment. These results were as expected in that corn injury may not be manifested completely until approximately two weeks after treatment. Injury levels decrease as corn begins to recover. These results suggest that ratings be made at two weeks following treatment in order to observe maximum corn injury from DPX-V9360 and CGA-136872.

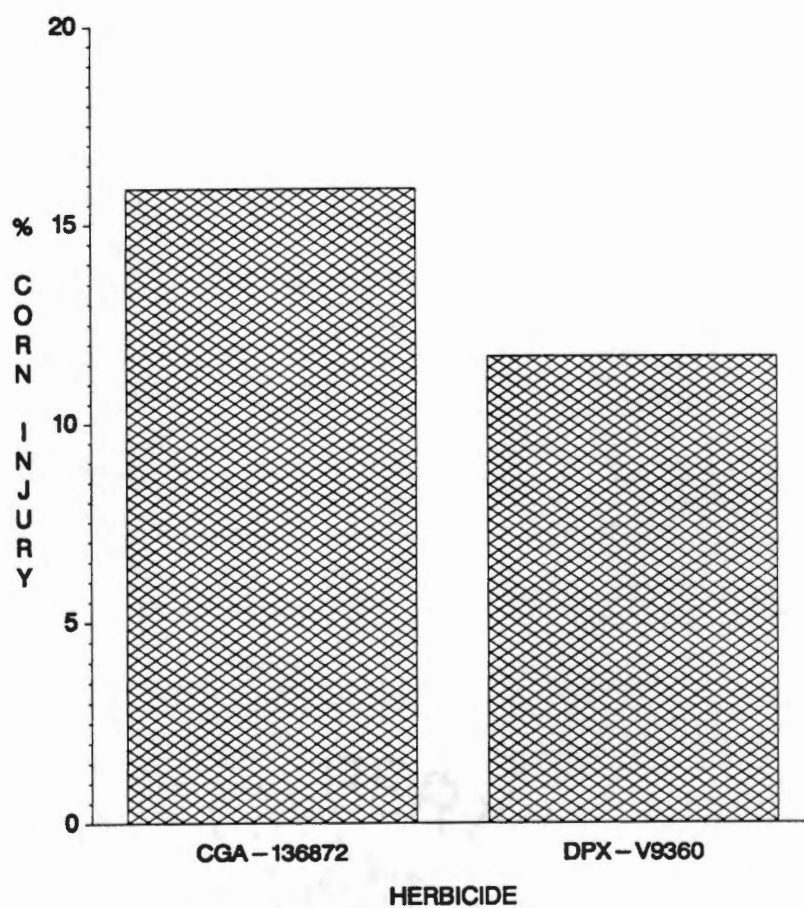


Figure 3. Corn injury as affected by herbicide for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson. Corn injury with CGA-136872 was significantly greater than with DPX-V9360 according to the F-test at the 5% level of probability.

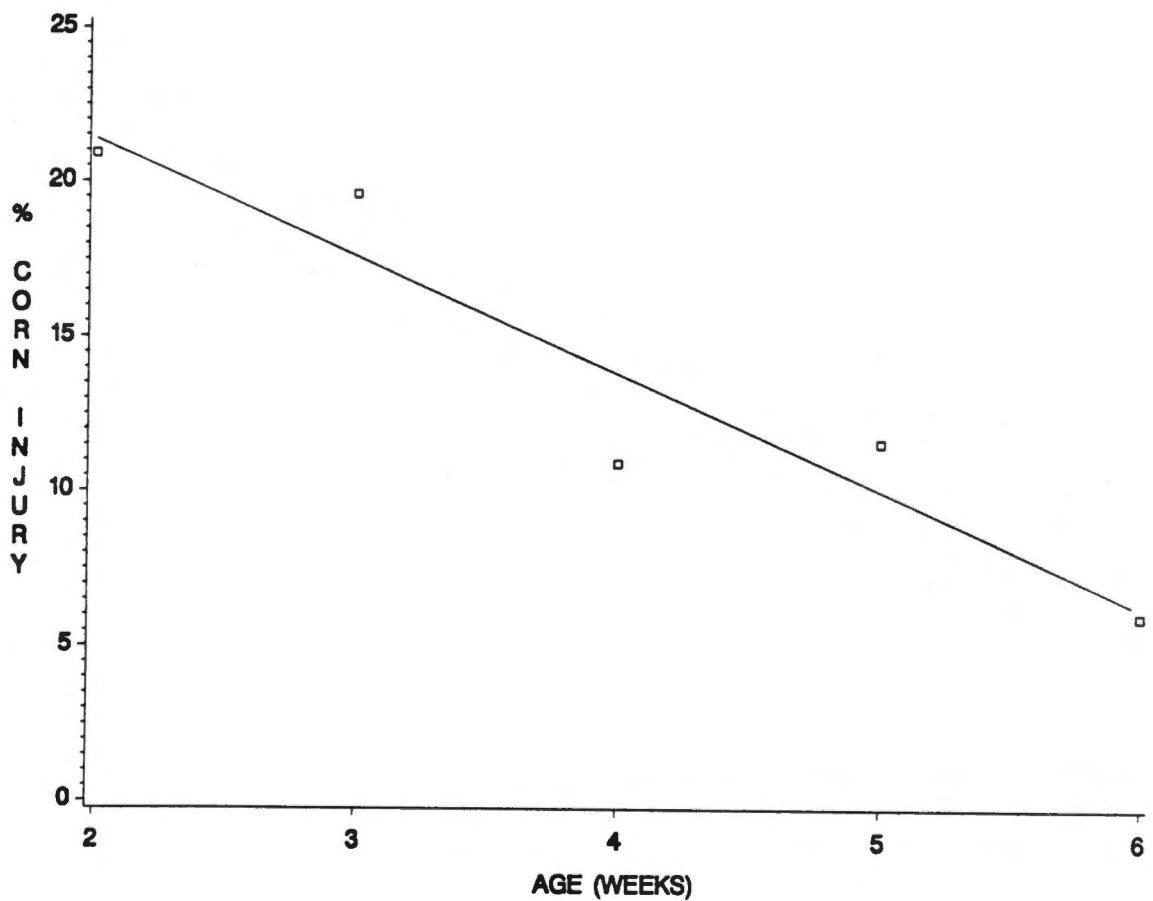


Figure 4. Corn injury as affected by age of corn at time of treatment for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson.

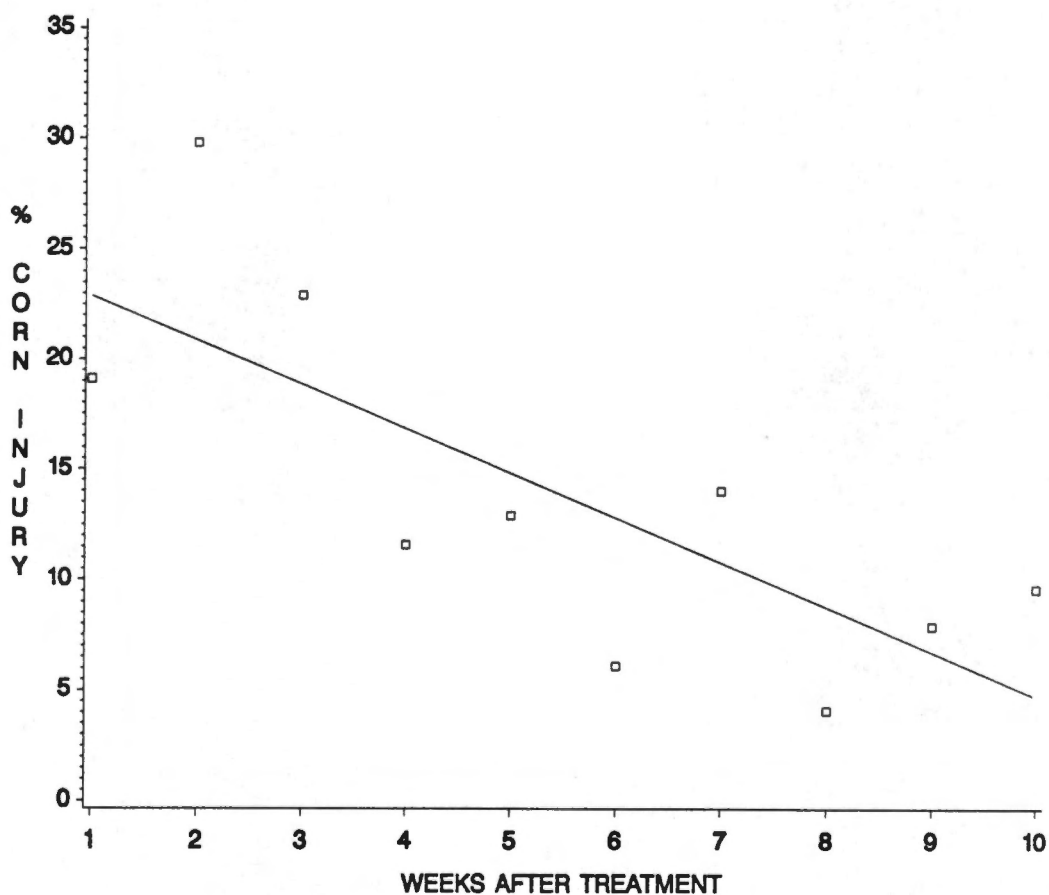


Figure 5. Corn injury as a function of time following treatment with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson.

Treatment date, herbicide, and age of the corn at the time of treatment affected ear production (Tables 21 and 22). Herbicide treatments applied at weekly intervals to corn planted on April 14 did not affect the barren plant percentage compared to the check. For corn planted on April 21, the first two treatment dates had a greater percentage of barren plants than did the check. These first two treatments were made to corn at two and three weeks of age, respectively. This difference is due likely to the elevated injury levels caused by herbicides when applied at these stages. Ear production was not affected by herbicides applied to four to six week-old corn. Corn planted on April 28 and treated when two or four weeks old had a greater percentage of barren plants than the check. The increase in barren plant percentage at the first treatment date was probably due to greater injury to young corn. The increased barren plant percentage in corn treated at the third date was also probably linked to elevated injury levels observed at this date due to a period of cloudy, rainy weather which reduced the ability of the corn to metabolize the herbicides. At the final planting date of May 5, increased barren plant percentages occurred from treatments applied on May 26. This was probably due to the conditions present on May 26 as described previously.

Barren plants appear to be linked somewhat to prior corn injury levels. The highest barren plant percentages were observed in corn treated at the earliest stages. These stage were also those that sustained the highest injury levels. Increased barren plant percentages were also observed at the May 26 treatment date for corn planted at the

Table 21. Analysis of variance for barren plant percentage for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson.

Source	DF	Type III SS	MS	F	Pr > F
Plt Date	3	0.072	0.024	2.54	0.060
Rep	2	0.031	0.015	1.62	0.201
Plt Date *					
Rep	6	0.069	0.011	1.21	0.305
Tmt Date	7	0.280	0.040	4.20	0.001
Herbicide	1	0.039	0.039	4.15	0.044
Age	4	0.179	0.044	4.69	0.001
Herbicide *					
Age	5	0.081	0.016	1.70	0.140

Table 22. Barren plant percentage as affected by DPX-V9360 and CGA-136872 applied to corn under various environmental conditions at Jackson.^a

Treatment Dates	Planting Dates			
	04/14/88	04/21/88	04/28/88	05/05/88
04/29/88	3.56 ^A			
05/05/88	2.77 ^{AB}	14.23 ^A		
05/12/88	0.29 ^B	6.46 ^B	14.25 ^A	
05/19/88	1.54 ^{AB}	1.40 ^{CD}	5.96 ^{BC}	8.06 ^{AB}
05/26/88	2.39 ^{AB}	4.46 ^{BC}	9.18 ^B	9.67 ^A
06/02/88		0.82 ^D	1.95 ^{DE}	4.84 ^{ABC}
06/09/88			1.08 ^E	0.49 ^C
06/16/88				1.06 ^C
Check	1.34 ^{AB}	1.83 ^{CD}	3.24 ^{CD}	1.49 ^{BC}

^aMeans within a column relative to the same planting date followed by the same letter are not significantly different at the 5% level using Waller-Duncan's multiple range test.

last two planting dates where corn was younger.

Corn yields were affected by dates of planting (Table 23). Among the checks, corn planted on April 14 yielded lower than corn planted at the other dates. Early planted corn usually yields higher than corn planted later, however in 1988, yields of early planted corn were lower due to dry conditions during pollination. Corn planted on April 21 and April 28 pollinated under conditions of greater soil moisture and produced greater yields. Corn planted at the final date of May 5 had reduced yields due to the delayed planting.

Yields also were affected by timing of herbicide application. Yields were reduced when herbicides were applied at date one within each planting date. For each planting date the first herbicide application was made at two weeks after planting (WAP) to three-to four-leaf corn. Various environmental conditions were encountered for each planting date, therefore the yield reductions can be attributed to the growth stage of corn. Apparently corn treated with DPX-V9360 and CGA-136872 at two WAP could not adequately metabolize these compounds, thus significant levels of injury were sustained resulting in reduced yields. DPX-V9360 and CGA-136872 applied on May 12 reduced corn yields for corn planted on April 21 and April 28. Yields were not reduced for corn planted on April 14. Again, reduced yields resulted when DPX-V9360 and CGA-136872 were applied to younger corn.

DPX-V9360 and CGA-136872 applied on May 26 reduced yields for corn at all planting dates. Corn stage of growth ranged from five to nine leaves. Reduced yields resulted from corn treated at all stages of growth, indicating that these yield reductions were due to environmental

Table 23. Corn yield averaged across herbicides when treated with DPX-V9360 and CGA-136872 under various environmental conditions at Jackson.

Application Dates	Planting Dates			
	04/14/88	04/21/88	04/28/88	05/05/88
	(kg/ha)			
04/29/88	6630*			
05/05/88	7440	6310*		
05/12/88	7701	6881*	5598*	
05/19/88	7970	7967	7744	6392*
05/26/88	6815*	6561*	6047*	5761*
06/02/88		7785	7606	7606
06/09/88			7986	7132
06/16/88				7471
Check	7738	8102	8425	7979
LSD (0.05) for checks		537		

* Significant application date effect according to Dunnett's T test at the 5% level of probability.

factors. Prior to the herbicide application, 5.3 cm of rain were received over a period of four days. Cloudy conditions coupled with cooler temperatures reduced the ability of corn to metabolize the herbicides, resulting in greater injury and reduced yields.

Milan

Corn injury was affected by planting date, herbicide, and age (Table 24). Planting date effects are shown in Figure 6. The results were similar to those obtained at Jackson in that corn injury increased through the third planting date and then decreased for corn planted at the fourth planting date.

Herbicide effects on corn injury are shown in Figure 7. CGA-136872 injured corn more severely than did DPX-V9360 across all planting dates and treatment dates. These results were similar to those from Jackson.

Figure 8 illustrates the effects of the age of corn at treatment on observed injury levels. Results were similar to those at Jackson in that elevated corn injury levels were observed for corn treated at two weeks of age. Corn injury levels decreased as the age of the corn at treatment increased. This appeared to be related to the enhanced ability to detoxify the herbicides with increasing age. Figure 9 shows corn injury as a function of time after treatment. At this location the maximum injury level was observed at one week after treatment. There was a general decrease in injury levels with time. These results are similar to those observed at Jackson.

No differences were observed in barren plant percentage which is probably related to the lower levels of injury incurred at this

Table 24. Analysis of variance for injury to corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Milan.

Source	DF	SS	MS	F	Pr > F
Planting Date (PD)	3	507	169	3.0	0.032
Replication (R)	2	221	110	1.9	0.146
Age (A)	4	241	60	1.1	0.376
PD * A * R	50	2873	57	1.0	0.460
Herbicide	1	525	525	9.2	0.003
Post-time	8	1067	133	2.4	0.019

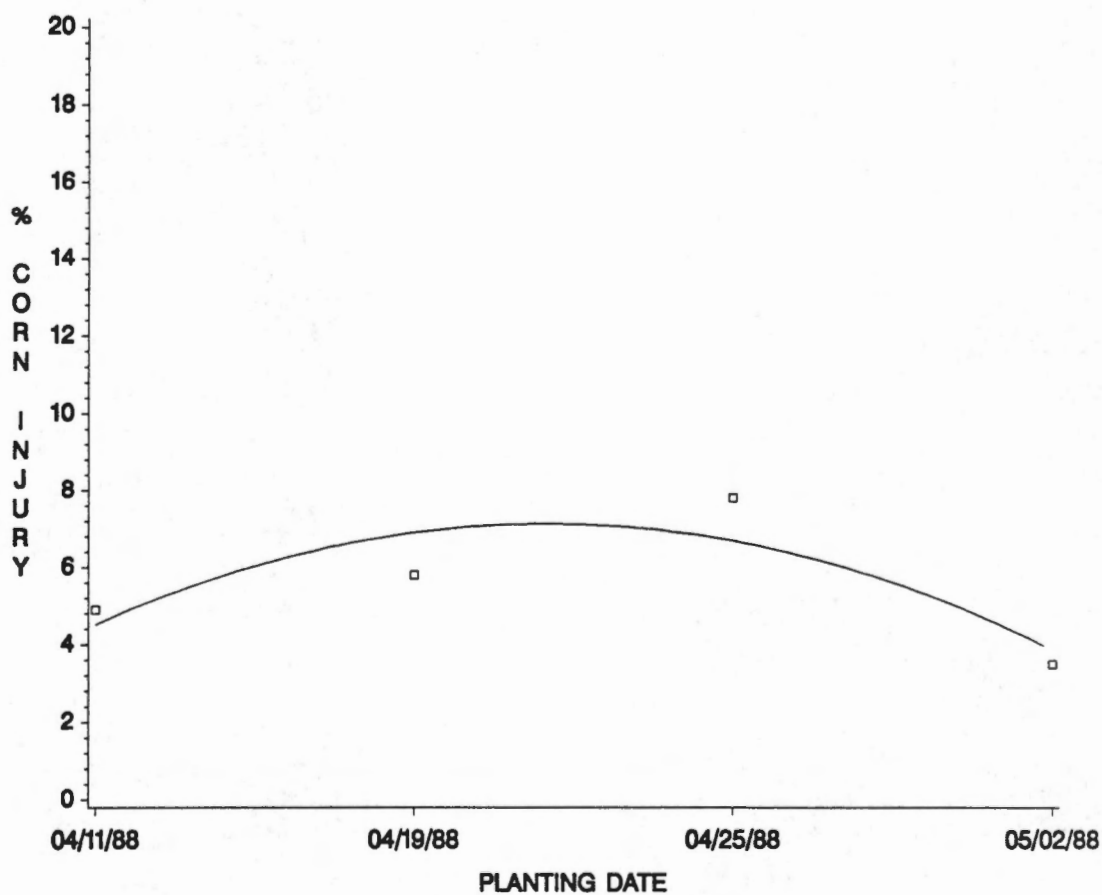


Figure 6. Corn injury as influenced by planting date for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Milan.

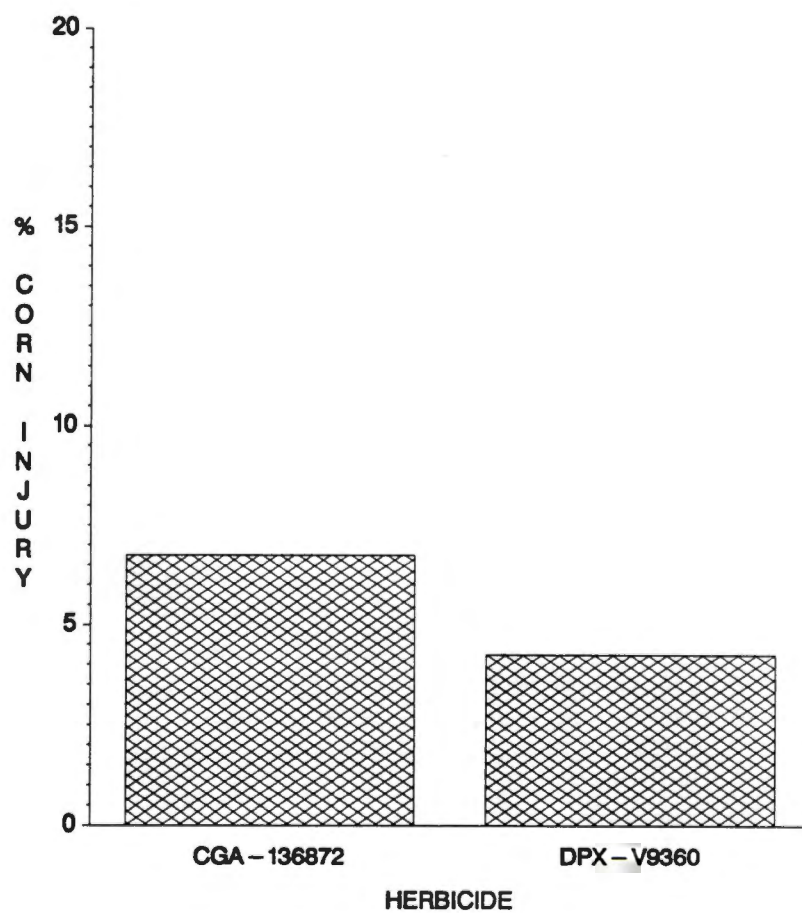


Figure 7. Corn injury as affected by herbicide for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Milan.

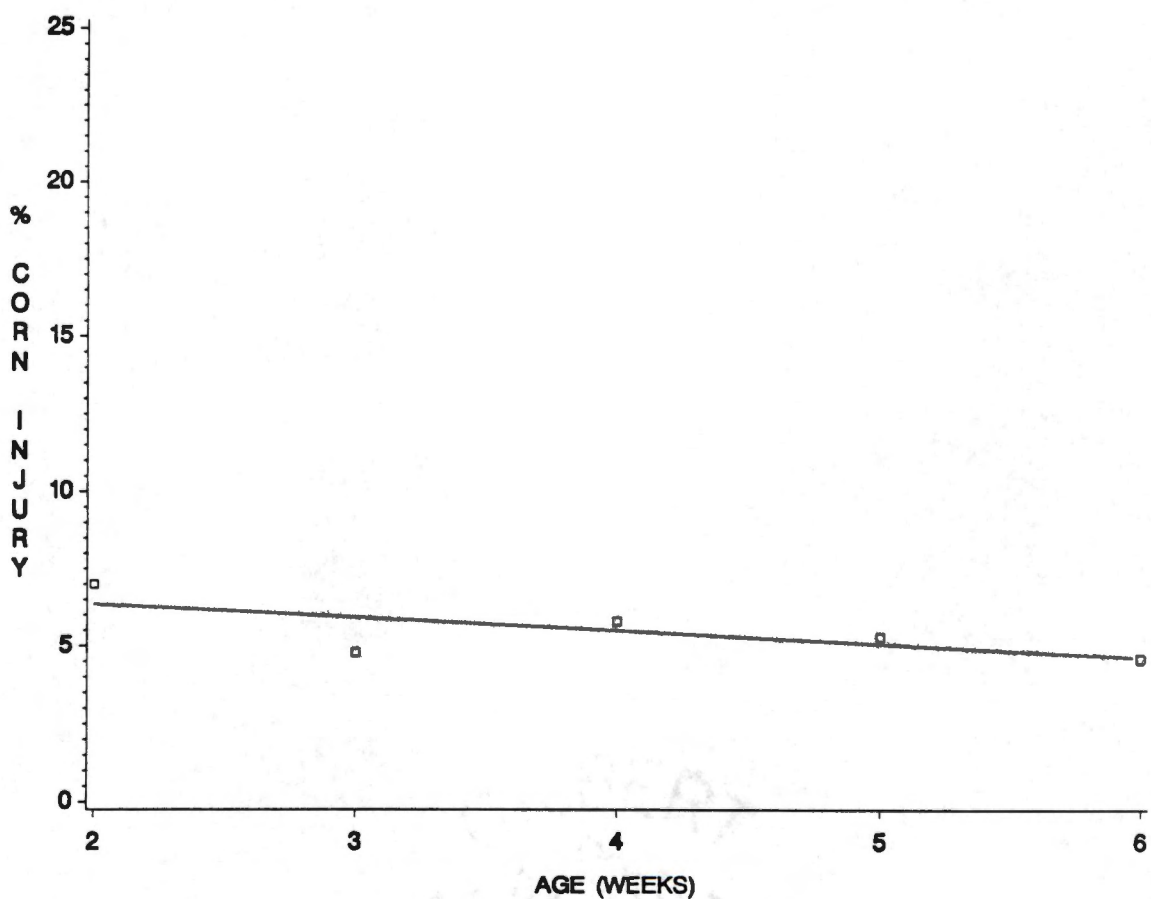


Figure 8. Corn injury as affected by age of corn at time of treatment for corn treated with DPX-V9360 and CGA-136872 under various environmental conditions at Milan.

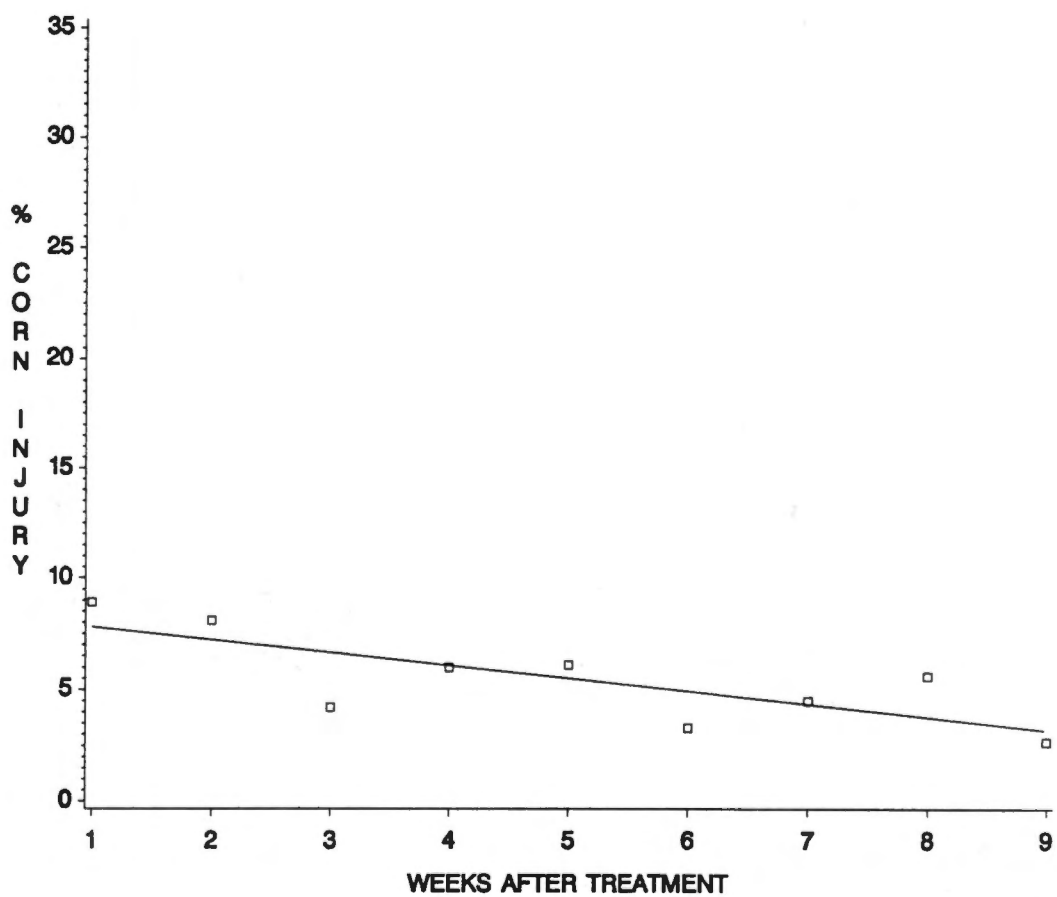


Figure 9. Corn injury as a function of time following treatment with DPX-V9360 and CGA-136872 under various environmental conditions at Milan.

location.

Corn yields were affected by planting dates (Table 25). Corn yields were similar to those at Jackson in that corn yields increased through the third planting date and then decreased for the final planting date. Corn treated at the first application date within the April 25 planting date yielded lower than the other treatments within that planting date. No other differences were noted for yield at this location. This was due in part to reduced injury levels observed at this location.

Table 25. Corn yield averaged across herbicides when treated with DPX-V9360 and CGA-136872 under various environmental conditions at Milan.

Application Dates	Planting Dates			
	04/11/88	04/19/88	04/25/88	05/02/88
	(kg/ha)			
04/25/88	8039			
05/02/88	7700	8318		
05/09/88	7330	8805	7889*	
05/16/88	8874	9482	8685	8337
05/23/88	8140	8893	8645	8861
05/30/88		8269	8469	7964
06/06/88			8457	8136
06/13/88				7951
Check	8294	9294	9464	8171
LSD (0.05) for checks			113	

*- Significant application date effect according to Dunnett's T test at the 5% level of probability.

CHAPTER VI

GENERAL SUMMARY

The objectives of this research were to determine: (1) the optimum time of removal of johnsongrass interference from corn with DPX-V9360 and CGA-136872, (2) the effect of various johnsongrass densities on corn yield and (3) the effects of DPX-V9360 and CGA-136872 on corn growth and yield when applied to corn at various growth stages under differing environmental conditions.

Johnsongrass interference can significantly reduce corn yield. The development of selective, postemergence herbicides for johnsongrass control in corn will provide growers with an additional tool for johnsongrass management in corn.

Results from field studies indicate that application timing of postemergence johnsongrass herbicides is critical in reducing johnsongrass interference and reducing corn yield losses. In field studies with DPX-V9360 and CGA-136872, the optimum time for application of the herbicides appeared to be at four or five weeks after planting (WAP). Herbicide applications before four WAP provided good control of johnsongrass initially, however johnsongrass control decreased throughout the remainder of the season due to regrowth of johnsongrass and emergence of johnsongrass after the herbicide application date. Herbicide applications after five WAP gave good johnsongrass control, however the effects of the prolonged period of johnsongrass interference were evident in that corn yields were reduced. These results indicate

that growers will have a period of approximately two weeks in which to treat johnsongrass in order to attain optimum johnsongrass control and maximum yield.

Field studies have shown that corn yield is inversely proportional to johnsongrass density, due to the increase in johnsongrass interference with increasing johnsongrass densities. Johnsongrass densities up to four plants per 6.1 m of row did not reduce corn yield. This density corresponds to a johnsongrass population of 8611 plants/ha. Johnsongrass densities of 8 plants per 6.1 m of row or greater caused a significant reduction in corn yield. This density corresponds to a johnsongrass population of 17,222 plants/ha or one plant per 1.5 m of row. These results could be used to determine the johnsongrass density at which treatment with postemergence herbicides would be profitable based upon the projected corn price at harvest, treatment costs and potential yield increases.

Field studies with DPX-V9360 and CGA-136872 revealed that corn is affected by these herbicides depending upon the stage of corn at application and environmental conditions present at the time of application. Corn injury levels were highest for corn planted from April 19 to 21 or from April 25 to 28. Lower injury levels were observed in corn planted from April 11 to 14 or from May 2 to 5. Injury levels increased with increasing amounts of solar radiation; however, these results are contradictory to other studies which show corn injury levels to be greater when the herbicides were applied under cloudy conditions. Future research should address this inconsistency in order to determine the environmental conditions under which unacceptable

injury levels might occur.

Corn treated with CGA-136872 sustained more injury than did corn treated with DPX-V9360 across all planting dates and herbicide application dates. This effect was magnified when terbufos was used as a soil-applied insecticide.

DPX-V9360 and CGA-136872 caused the most injury when applied to two week-old corn. Injury levels decreased as the age of the corn at the time of treatment increased. Corn injury was evident by one week after treatment; however, the maximum injury levels were observed at two weeks after treatment. Corn injury decreased with time thereafter.

The percentage of barren plants increased as the level of prior corn injury increased. Treatments which sustained little or no injury had few barren plants.

Corn yields at Jackson increased for each planting date through April 28. Corn yields were reduced for corn planted on May 5. Yields normally would have been greatest for the earliest planted corn (April 14), however in 1988 early planted corn was severely affected by dry weather. Corn planted after April 14 received rainfall prior to pollination which resulted in greater yields. Corn yields were also reduced by herbicide applications made to young corn. The first treatment within each planting date was made to two week-old corn. Corn treated at this stage had reduced yields regardless of the planting date. This yield reduction was probably due in part to increased injury levels observed in corn treated at this stage. Corn yields were also reduced in all corn treated on May 26. Again, this reduction was probably due to high injury levels observed for corn treated on this

date.

At Milan corn yields increased through the third planting date (April 25). Corn yields were lower for the first herbicide application date within the April 25 planting date. No other differences in corn yield were observed at Milan.

In conclusion, DPX-V9360 and CGA-136872 provide good to excellent control of johnsongrass. The optimum time to apply these herbicides appears to be at four to five weeks after planting in order to get maximum season-long johnsongrass control, minimum corn injury, and maximum yields. Future research should examine the possibilities of sequential applications of these herbicides, the interaction with organophosphate insecticides, and the environmental factors which may cause unacceptable levels of injury.

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APPENDICES

APPENDIX A
ENVIRONMENTAL DATA

GILBERT
11/22/89
LANCASTER BOND
100% COTTON FIBRE

APPENDIX A

Table A-1. Environmental conditions at Jackson.

Day	April			May			June		
	Temp. (°C)		Rain (cm)	Temp. (°C)		Rain (cm)	Temp. (°C)		Rain (cm)
	Max.	Min.		Max.	Min.		Max.	Min.	
1	23	16	0.76	26	7		32	17	
2	23	18	0.03	27	11		31	18	
3	26	9		26	11	0.76	28	13	
4	28	13		19	6	T	25	10	
5	31	9	0.31	24	9		28	12	
6	18	3		26	9		31	13	
7	19	6		28	16		33	14	
8	22	5		28	12	0.97	34	19	0.13
9	23	7		28	10		22	10	
10	20	9	T	27	9		24	8	
11	13	8	1.27	26	12		27	11	
12	19	6		28	13		31	15	
13	22	7		30	14		32	16	
14	25	8	T	31	17		33	16	
15	14	1	0.33	32	18	T	34	17	
16	18	4		31	12	T	33	19	
17	26	11	2.36	25	10		32	15	
18	24	2	0.25	27	10		33	19	
19	16	3		28	13		33	18	
20	23	7		30	15		35	19	
21	29	16		31	18	1.07	36	20	
22	24	17		26	15	2.08	37	21	
23	29	7		23	16	1.30	37	22	
24	18	9		22	11	0.81	37	23	
25	19	5		22	9		37	22	
26	24	8		25	9		38	22	
27	18	3		28	12		31	13	
28	20	3		29	13		34	17	
29	23	8		30	15		37	22	0.41
30	23	5		32	16		26	19	0.61
31				33	17				

APPENDIX A

Table A-2. Environmental conditions at Milan.

Day	April			May			June		
	Temp. (°C)		Rain (cm)	Temp. (°C)		Rain (cm)	Temp. (°C)		Rain (cm)
	Max.	Min.		Max.	Min.		Max.	Min.	
1	20	14	2.51	26	6		35	16	
2	23	17	0.36	28	7		32	16	
3	25	9		26	13	1.93	32	12	
4	28	9	0.51	16	13	0.38	26	10	
5	31	11		24	8		29	12	
6	19	9		26	9		32	12	
7	21	6		29	9		34	13	
8	21	6		28	16	0.81	36	14	
9	23	6		28	10		23	9	
10	20	8		28	9		25	7	
11	17	8	0.18	27	9		28	7	
12	21	9		29	12		33	10	
13	24	7		31	13		34	13	
14	25	7		31	15		35	14	
15	14	-1	0.18	33	15		35	16	
16	19	-1		32	13		33	16	
17	26	5	1.32	26	10		32	14	
18	22	4		28	10		33	14	
19	17	2		29	10		36	17	
20	23	2		32	12		36	17	
21	29	11		33	14	1.22	38	18	
22	26	18		26	15	1.93	38	19	
23	30	4		24	15	1.12	39	21	
24	19	6		24	10	0.13	39	21	
25	21	4		22	7		38	22	
26	26	4		25	7		39	18	
27	19	3		28	9		32	13	
28	21	3	0.74	31	10		36	13	
29	24	3		32	13		38	13	
30	24	4		33	14		27	19	
31				33	16				

VITA

Blake Alan Brown was born in Knoxville, Tennessee on December 29, 1963. He graduated from North Side High School in Jackson, Tennessee in May 1982. He entered the University of Tennessee at Knoxville in September 1982 and completed a Bachelor of Science degree in Plant and Soil Science in June 1987. In June 1987, he entered the University of Tennessee, Knoxville, as a Graduate Research Assistant in the Department of Plant and Soil Science. He received his Master of Science degree in December 1989.

The author is a member of the Weed Science Society of America and Tennessee Agricultural Chemicals Association. Following graduation, he will enter Mississippi State University as a Graduate Research Assistant in the Department of Plant Pathology and Weed Science, and pursue a Ph.D in weed science with research emphasis in turf weed control.