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EFFICACY AND PHYTOTOXICITY OF DPX-79406 ON JOHNSONGRASS AND FIELD CORN

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

W.T. Willian

May 1992

DEDICATION

To my parents, Mr. and Mrs. Kermit Y. Willian, whose love, encouragement and prayers are continually appreciated, I dedicate this thesis.

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to the following persons:

To Dr. William A. Krueger, his major professor, for his support, guidance and assistance in conducting this research, for his advice in preparing this thesis and for his friendship and encouragement throughout the course of this study.

To Dr. G. Neil Rhodes, Jr. for his guidance in planning this research project, for his assistance and advice in preparing this thesis and for serving on my graduate committee.

To Dr. Robert M. Hayes for his assistance and helpful advice in preparing this thesis and for serving on my graduate committee.

To Dr. John Foss and the entire Plant and Soil Science Department, for providing the financial assistance, facilities, and resources for furthering my education and completing this degree.

To Bruce Kirksey, whose help, encouragement and friendship are greatly appreciated.

To the secretaries, Pam, Dawn, Martha, Brenda, Debbie, Jenifer, Misty and Betty, who aided me in countless ways.

To the superintendents and the staff at the Highland Rim, Middle Tennessee, and Knoxville Experiment Stations, whose time and effort are greatly appreciated.

To Blake Brown, Angela Harrison, Matt Thornton, Jeff Herrmann, Terry Kelley, David O'Dell, and the other graduate students, research associates, and professors, who have aided in this thesis and in making my stay an enjoyable one.

To my parents, Mr. and Mrs. Kermit Y. Willian, for their love, support and encouragement.

To my grandparents, Mrs. Mary G. Willian and the late Curtis D. Willian, whose faith in God have always been an inspiration to me.

To Dr. and Mrs. Robert D. Miller and family, whose encouragement throughout the course of this study is greatly appreciated.

To my brothers, Rodney and Tim, for their encouragement.

To Sarah and Justin, for their love and support.

To Jodie, for her love, encouragement, and patience.

ABSTRACT

Field experiments were conducted at Springfield and Spring Hill, Tennessee in 1990 and 1991 to determine when to apply DPX-79406 to achieve maximum johnsongrass control. Experiments were established in areas naturally infested with seedling and rhizome johnsongrass. Treatments were replicated four times in a randomized complete block design. DPX-79406 at 6, 9 and 11 g ha^{-1} was applied postemergence at three stages of johnsongrass growth. Nicosulfuron at 35 g ha^{-1} and primisulfuron at 40 g ha^{-1} were included at each application. A hand-hoed check and weedy check were also included.

Johnsongrass control with DPX-79406 did not differ when applied to 20- or 50-cm johnsongrass. DPX-79406 did not control 75-cm johnsongrass. Nicosulfuron and primisulfuron performed similarly to DPX-79406 at each timing. Corn grain yield did not differ among herbicide treatments applied to 20- or 50-cm johnsongrass. Corn grain yields were always higher than the weedy check when treatments were made to johnsongrass ≤50 cm. Corn grain yields were reduced when DPX-79406 was applied postemergence to 75-cm johnsongrass.

Similarly, no differences in johnsongrass control was observed among herbicides within an application time. DPX-79406 gave excellent control when applied to 20-cm johnsongrass; control decreased by approximately 10% for each successive timing. In general, corn grain yields with the early postemergence treatments did not differ from those of the weedfree check.

Field studies were conducted at Springfield, Spring Hill, and

Knoxville, Tennessee in 1990 and 1991 to compare DPX-79406 to DPX-E9636, primisulfuron and nicosulfuron for johnsongrass control. The experiments were established in areas naturally infested with seedling and rhizome johnsongrass. The experimental design was a randomized complete block with treatments replicated four times. In 1990 DPX-79406 (6, 9 and 11 g ha^{-1}) was compared to DPX-E9636 (9, 13 and 17 g ha^{-1}), nicosulfuron (9, 13, 17 and 35 g ha^{-1}), and primisulfuron (40 g ha^{-1}). In 1991 the following treatments were utilized: DPX-79406 at 6, 9, 11, 18, 27 and 35 g ha^{-1}; nisosulfuron at 6, 9, 11 and 35 g ha^{-1}; and primisulfuron at 40 g ha^{-1}. Treatments were applied both years to 25±5-cm and 70±10-cm johnsongrass. All experiments also included a hand-hoed check and a weedy check.

All treatments controlled 25-cm johnsongrass the first year. Only primisulfuron controlled less johnsongrass than the hand-hoed check. DPX-79406 at 6 and 9 g ha^{-1} failed to control 70-cm johnsongrass. Nicosulfuron and DPX-E9636 at 9 g ha^{-1} failed to control 70-cm johnsongrass. Nicosulfuron at 13 to 35 g ha^{-1} controlled 70-cm johnsongrass ≥87%. DPX-E9636 at 13 to 17 g ha^{-1} gave ≥93% control of 70-cm johnsongrass. Corn grain yields from treatments applied to 25-cm johnsongrass did not differ from the hand-hoed check. Treatments to 70-cm johnsongrass showed considerable variablilty among grain yields. DPX-E9636 applied to 70-cm johnsongrass injured corn and contributed to lower yields. Both herbicides controlled 25-cm johnsongrass at Springfield in 1991. DPX-79406 at 6, 9 and 11 g ha^{-1} controlled johnsongrass better than nicosulfuron at the identical rates. No treatment controlled 70-cm johnsongrass, although yields did not differ

from the hand-hoed check. This was probably due to light johnsongrass pressure at Springfield. Control of 25-cm johnsongrass did not differ among herbicide treatments at Spring Hill in 1990. All treatments applied to 70-cm johnsongrass resulted in control lower than the hand-hoed check. Corn grain yields were not different among treatments to 25-cm johnsongrass, with the exception of primisulfuron at 40 g ha^{-1} and DPX-79406 at 6 g ha^{-1}. Corn yields from plots with 70-cm johnsongrass treated with nicosulfuron and primisulfuron were higher than those with DPX-79406 and DPX-E9636 both years. All treatments to 25-cm johnsongrass with the exception of primisulfuron provided >87% control prior to harvest. No herbicide applied to 70-cm johnsongrass gave control equal to the hand-hoed check. Corn yields were less in plots treated with primisulfuron than in those maintained weedfree by hand-hoeing. DPX-79406 at 35 g ha^{-1} injured 4-leaf corn and contributed to low yields.

At Knoxville in 1990, johnsongrass control did not differ among treatments, regardless of when applied. There were no differences in grain yield among treatments to 25-cm johnsongrass. Corn yields were less than the hand-hoed check when nicosulfuron at 17 g ha^{-1} was applied to 70-cm johnsongrass. In 1991 trials, DPX-79406 controlled 25-cm johnsongrass. No treatment controlled 70-cm johnsongrass. Corn yields from all treatments to 25-cm johnsongrass were greater than the weedy check. Corn yields from plots treated at the 70-cm johnsongrass height were variable.

A field study was conducted at Knoxville in 1991 to assess corn injury from DPX-79406. The experiment was established in a relatively

johnsongrass-free area. Treatments were replicated four times in a randomized complete block design. DPX-79406 at 18, 27, 35 and 54 g ha^{-1} was applied to 4- to 5-leaf corn and to 8- to 9-leaf corn. Nicosulfuron (35 g ha^{-1}) and primisulfuron (40 g ha^{-1}) were also applied at both growth stages. An untreated plot was also included.

DPX-79406 injured 4- to 5-leaf corn at rates of 27 g ha^{-1} or greater. Despite the injury, grain yields were not different from the untreated plot. No treatment caused any injury to 8- to 9-leaf corn.

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CHAPTER I

INTRODUCTION

Johnsongrass [Sorghum halepense (L.) Pers.] is one of the world's worst weeds (81). It is considered one of the ten worst weeds infesting field crops, and ranks as one of the three most serious weeds in corn (Zea mays L.) in the United States (5,81). Johnsongrass is the most troublesome and costly weed in Tennessee corn, infesting approximately 60% of all corn in the state (18,66,67).

Johnsongrass interference can greatly reduce corn yields, therefore control is essential for production. Season-long johnsongrass competition can reduce grain yields by 50% and stover yields by 67% (67). Johnsongrass also reduces soil moisture content and decreases leaf surface area (43). Early methods of johnsongrass control in corn consisted of mechanical cultivation, hand removal and spot treatment with non-selective herbicides (71). The development of soil applied thiocarbamate herbicides offered farmers and researchers a more efficient means of control. However, these herbicides are expensive and must be incorporated, and limit the use of no-till practices.

The need for selective postemergence herbicides for johnsongrass control in corn has been alleviated with the development of nicosulfuron and primisulfuron. These sulfonlyurea herbicides exhibit unprecedented herbicidal activity at low application rates. Applied at 35 g ha^{-1} to 20- to 30-cm johnsongrass, nicosulfuron controls both seedling and rhizome plants. Primisulfuron has performed similarly when applied at a

rate of 40 g ha^{-1} (83,84).

DPX-79406 is a new experimental postemergence corn herbicide. This compound is a 1:1 mixture of two sulfonylureas, nicosulfuron and DPX-E9636. DPX-79406 applied at 15 to 50 g ha^{-1} controls many annual and perennial grasses, as well as some broadleaf species. The low rate needed for control is environmentally desirable and the low residual activity lessens the chances of developing weed resistance (24). Additionally, applications may be made regardless of pH, organic matter content or soil type (40). Little research has been conducted toward assessing activity or optimum application time for johnsongrass control in corn. Furthermore, the corn injury potential with this compound has not been fully clarified. Leek et al.(40) reported that rates of 140 g ha^{-1} did not injure corn. However, several field studies have shown that DPX-79406 can injure corn at rates as low as 18 g ha^{-1}. (51). Thus, the objectives of these studies were to determine: (i) the efficacy of DPX-79406 compared to similar compounds, (ii) the optimum time for application of DPX-79406, and (iii) potential for corn injury with DPX-79406.

CHAPTER II

LITERATURE REVIEW

A. Characteristics of Johnsongrass

History

Johnsongrass [Sorghum halepense (L.) Pers.], a native of the Mediterranean area, has now become established as a troublesome weed in most of the world's agricultural regions. Introduced into the United States in the early 1800's as a forage crop, this species had by the late 19th century been recognized as a troublesome weed throughout most of the country (11). This species was initially known by at least eight Latin names. The first written use of the name johnsongrass was made in 1874 by John Haralson of Selma, Alabama to a U. S. Department of Agriculture employee. This and subsequent letters resulted in the acceptance of johnsongrass as the common name (49,67).

Morphology

Johnsongrass is a member of the Poaceae family of flowering plants, which consists of approximately 600 genera and 7500 species (67). Johnsongrass spreads both by seeds and by scaly, creeping rhizomes. Culms are stout, erect, unbranched and grow to a height of 0.5 to 2.5 m. Culms have diameters of 0.5 to 2 cm and often have basal adventitious prop roots. Leaf sheaths are ribbed and smooth, often with a waxy secretion at the base. Membranous ligules are 2 to 5 mm in

length. Leaf blades are flat, smooth, and many nerved, bright green or sometimes purplish, and are from 20 to 60 cm in length and 0.5 to 5 cm in width. The inflorescence is a large, erect panicle up to 20 cm wide and 50 cm long. At first compact, the panicle later spreads and opens to reveal a purplish, hairy pyramidal form. Spikelets usually occur in pairs although they may occur in threes toward the tip of the inflorescence. When spikelets occur in pairs, the lower one is usually sessile while the upper is pedicelled and stamen-bearing. When occurring in threes, the middle spikelet is sessile while the other two are pedicelled and staminate (29,81).

Seed Production

Johnsongrass is a very prolific seed producer with an average of 28,000 seeds per plant (30). Each sessile spikelet produces a seed. The number of sessile spikelets per panicle ranges from 37 to 352 (53). Seed production is the principal means by which johnsongrass is distributed (67). Johnsongrass seeds are transported by water, wind, animals and in other seed (29,53,75). The seeds exhibit a relatively high longevity, remaining viable for 2.5 yr in soil and up to 7 yr in dry storage (29).

Johnsongrass Rhizomes

Although johnsongrass is a heavy seed producer, its extensive, highly adaptable rhizome system contributes to its proliferation and perniciousness (29). Rhizomes serve both as storage areas for carbohydrates and as reproductive structures, producing shoots from

axillary and terminal buds (53,65). Johnsongrass rhizomes are quite hardy. They are capable of withstanding drought conditions; and if cut into pieces by cultivation, they regenerate quite easily (81). Rhizomes are also capable of overwintering in the field and remain viable and prolific the following year (1,30). The johnsongrass rhizome system consists of primary, secondary and tertiary rhizomes as determined by Holm (29). Only the primary rhizomes are alive at the beginning of the growing season. These primary structures provide buds which become the secondary structures. The secondary rhizomes eventually surface and give rise to new johnsongrass plants. The tertiary rhizomes grow deep into the soil and serve as the primary rhizomes the following year, arising from the base of the plant at flowering time. Horowitz (31) reported that 80% of total rhizome dry weight was present in the upper 20 cm of the soil profile and that no rhizomes penetrated deeper than 40 cm. McWhorter (50) discovered that 80% of rhizomes produced in a clay soil exist in the top 7.5 cm while 80% of the johnsongrass rhizomes in a sandy loam soil occurred in the top 12.5 cm. However, the top 7.5 cm of sandy loam soil produced nearly equal amounts of rhizomes compared to the clay soil (50).

B. Effects of Johnsongrass on Corn

Weeds serve to decrease corn yield by depriving the crop of water, light and nutrients. Water is a critical factor in corn growth and development. Adequate light is deprived from the corn crop when tall-growing weeds provide too much shade for plant development. Weeds also

compete with corn for nutrients and thus increase the fertilizer requirement. Perry (67) reported that season-long johnsongrass competition in corn reduced grain yields by 18 to 50% and stover yields by 37 to 67%. The critical johnsongrass-free requirement of corn was 2 to 4 wk after planting. The critical duration of johnsongrass interference in corn was 4 to 6 wk after planting. Season-long johnsongrass competition caused 20% corn stalk lodging. Periods of johnsongrass competition for 10 wk or more resulted in delay of the transition from vegetative to reproductive stage. Lozanovski et al. (43) reported that strong season-long competition from johnsongrass in corn resulted in reductions of soil moisture content, decreased leaf surface area and reduced corn dry weight by 67%. Johnsongrass also contributes to the spread of maize viruses. Maize dwarf mosaic virus (MDMV) and maize chlorotic dwarf virus (MCDV) are the most damaging viruses to corn in the United States (22). MDMV, transmitted by aphids, and MCDV, transmitted by a leafhopper, both overwinter in johnsongrass and thus are generally found in johnsongrass infested areas. MDMV is the more widely distributed of the two; however, MCDV is usually more injurious to the crop. Disease-tolerant hybrids have aided in alleviating the problem of maize viruses but they do not usually yield as well as susceptible hybrids (5).

C. Johnsongrass Control in Corn

Several methods of johnsongrass control in corn have been utilized in recent years. A johnsongrass control program should consist of crop

rotation, tillage and chemical control methods (13,23,32,34,48,82). Successful management is imperative because its prolific seed production and extensive rhizome system make johnsongrass eradication difficult (67).

Tillage

Prior to the development of herbicides, johnsongrass was removed by mechanical means. Tillage greatly reduces johnsongrass populations. Burt and Willard (13) stated that a fall moldboard plowing followed by disking gave more thorough johnsongrass control than leaving the land unplowed. This same study showed that plowing in the summer or fall followed by sufficient tillage to restrict johnsongrass regrowth to less than 20 to 25 cm high was effective in reducing rhizome-borne johnsongrass populations. McWhorter and Hartwig (48) reported that intensive preplant tillage operations served to diminish rhizome populations by dehydrating them, thus enhancing crop yields. Anderson et al. (1) demonstrated that fall tillage following the mature johnsongrass seed stage to inhibit rhizome growth was an effective means of control.

Crop Rotation

Crop rotation aids in reducing damage by weeds, diseases and insects, which tend to accumulate in continuous cropping systems (67). Summer fallow programs which include tillage and herbicides may be utilized to control rhizome johnsongrass populations (13,48). Effective control of johnsongrass for 1 or 2 yr would allow for corn production

the following year. Sethoxydim, fluazifop-butyl and quizalofop effectively control johnsongrass in soybeans or cotton (9,10,17,27,44,69,74). Retzinger and Rogers (69) showed that sethoxydim and fluazifop-butyl at rates of 0.25 kg ha^{-1} gave > 95% johnsongrass control. Vidrine (77) reported effective seedling johnsongrass control with quizalofop at 0.07 kg ha^{-1}.

Chemical Control of Johnsongrass in Corn

A complete johnsongrass control program should consist of : (1) fall plowing and/or a postemergence herbicide application after crop harvest; (2) either a preplant or preemergence herbicide to provide rhizome and seedling control; (3) cultivation to control surviving johnsongrass plants (67); or postemergence applications of nicosulfuron or primisulfuron.

Glyphosate

Introduced in the mid-1970's, glyphosate is a non-selective, foliar-applied herbicide which is readily absorbed by leaves and translocated throughout the symplastic transport system, and to a lesser degree within the apoplastic system (2,4). Glyphosate is effective on deep-rooted perennials as well as several annual and biennial grasses and broadleaf weeds (67). Jeffery et al. (32) evaluated the effectiveness of preharvest glyphosate in corn. They determined that glyphosate applied when grain moisture was less than 30% provided maximum weed control with minimal crop injury. Glyphosate applied prior to this growth stage caused reduced weight and seedling emergence and

vigor. Rates of 1.1 to 2.2 kg ha^{-1} applied between September 7 and October 7 provided 80% to 90% rhizome johnsongrass control. Sarpe (72) reported that glyphosate provided good control of johnsongrass when applied to corn at the ripening stage when the weeds were still green.

Thiocarbamates

Thiocarbamates are soil-incorporated herbicides which provide good johnsongrass seedling control. However, they exhibit limited control of plants growing from rhizomes. EPTC was the first thiocarbamate herbicide developed. When first used as a preemergence herbicide, EPTC showed highly variable weed control. Soil incorporation to reduce vapor loss improved the consistency of this herbicide (4).

The thiocarbamates were not initially accepted due to several instances of crop injury. Kemp (34) reported EPTC related crop injuries although excellent johnsongrass control was observed. The addition of the protectant dichlormid to the thiocarbamates helped to alleviate the problem of corn injury. Burt and Akinsorotan (14) reported that addition of dichlormid increased by approximately ten times the EPTC required to injure corn. An additional problem with the thiocarbamates was that of soil conditioning. Soils receiving successive annual applications of EPTC exhibit reduced herbicidal efficacy, (57) since EPTC may be degraded within 4 wk after application (23). The addition of the extender diethолate to EPTC helped alleviate this problem. Green et al. (23) reported that additions of diethолate at 6.7 kg ha^{-1} enhanced johnsongrass control. Obrigawitch et al. (58) also reported that diethолate showed effective extension of

thiocarbamate activity in soil.

Sulfonylureas

Discovered in the mid-1970's by DuPont scientist Dr. George Levitt, the sulfonylurea herbicides have become important agents of broad spectrum weed control (6,8). Chemically they are composed of an aryl group, a heterocyclic ring and a sulfonylurea bridge. They have moderate melting points, low vapor pressures, and low to moderate water solubilities. They are weak acids, their acidity being similar to that of acetic acid. Several sulfonylurea herbicides have been developed to control weeds in a variety of crops. These include: chlorimuron and thifensulfuron for selective weed control in soybeans; bensulfuron for selective weed control in rice; chlorsulfuron and metsulfuron for selective weed control in cereal crops and sulfometuron for weed control in noncropland areas (6).

Sulfonylurea herbicides exhibit unprecedented herbicidal activity at low rates (19). They are commonly used at 4 to 20 g ai ha^{-1} (39,79). They are easily absorbed by foliage and roots and translocated throughout the plant via the xylem and phloem. Sulfonylureas are effective because they inhibit cell growth and division. Specifically, they inhibit acetolactate synthase (ALS), also known as acetohydroxyacid synthase (AHAS), an enzyme active in the synthesis pathway of the amino acids valine, leucine and isoleucine (6,8,16,39,45,68,73). Inhibition of ALS prevents (i) the condensation of two pyruvate molecules which results in the formation of CO_2 and α-acetolactate, leading to the synthesis of valine; and (ii) the joining of pyruvate with α-

ketobutyrate to form α-aceto-α-hydroxybutyrate, which are intermediates in leucine and isoleucine formation (6). Sulfonylureas exhibit low toxicities to fish and mammals (6,39,73). Animals lack the ability to synthesize the branched-chain amino acids, and thus lack the enzymes inhibited by sulfonylurea herbicides (45).

Since many crop plants are able to metabolize them, sulfonylureas exhibit selective toxicity to weeds and crops. Selectivity occurs when the crop species is able to metabolically inactivate the herbicide while the weed species cannot (6,45). Temperature seems to affect the relative toxicity of sulfonlyureas to certain species. Blair and Martin (8) reported that increased temperature enhances metsulfuron-methyl and chlorsulfuron activity against sensitive species while having the opposite effect on tolerant species. Degradation in soils occurs at rates similar to many other conventional herbicides, with the exception of chlorsulfuron, which may persist in soils for more than one growing season (6,19,39). This is important because replanting highly sensitive crops into sulfonylurea treated soil can be detrimental (6). These herbicides are degraded by means of soil microorganisms and chemical hydrolysis. Since hydrolysis of these compounds is fastest at low pH, they are only weakly adsorbed by soils and thus persist longer at higher pH (6,8). At pH 7.0 or greater, microbial degradation is inhibited (79). Walker et al. (79) reported that adsorption of both chlorsulfuron and metsulfuron-methyl was negatively correlated with soil pH. Degradation rates of both herbicides were negatively correlated with soil pH. Walker and Welch (80) reported similar results in an experiment dealing with degradation rates of chlorsulfuron, metsulfuron-

methyl and triasulfuron. They reported that triasulfuron was less mobile in the soil than the other two compounds. Walker et al. (79) reported that the degradation occurred in a two-step process, which consisted of an initial rapid loss followed by a gradual dwindling of soil residue.

Nicosulfuron

Nicosulfuron is a selective postemergence sulfonylurea herbicide recently developed by DuPont. Nicosulfuron controls weeds by inhibiting acetolactate synthase, thus blocking branched chain amino acid synthesis (8,16). Recent field tests have shown that nicosulfuron provides 79% to 95% control of johnsongrass with little or no crop injury (42,56,78,84). Williams and Gillham (83) reported that rates of 35 g ha^{-1} or greater applied to 8- to 10-leaf johnsongrass provided excellent control. Nicosulfuron may injure corn when applied at high rates. Morton and Harvey (54) reported slight corn injury when nicosulfuron was applied at 72 g ha^{-1}. Mueller et al. (56) observed corn stunting when the herbicide was used at 140 g ha^{-1}. Obrigawitch et al. (59) observed better control when nicosulfuron was applied to johnsongrass at the 4- to 6- or 7- to 8-leaf stage than when applied at the 2- to 4-leaf stage. He concluded that better control was achieved at the later leaf stages because tillering and plant emergence from rhizomes was more nearly complete.

Nicosulfuron has been shown to control several other weed species. Williams and Gillham (83) reported that nicosulfuron at rates of 18 to 70 g ha^{-1} controlled morninglories (Ipomoea spp.), pigweed (Amaranthus

spp.), red rice (Oryza sativa L.), goosegrass (Eleusine indica L.), Texas panicum [Panicum texanum (Buckl.)], and broadleaf signalgrass [Brachiaria platyphylla (Griseb.) Nash]. Nicosulfuron also controlled quackgrass [Elytrigia repens (L.) Nevski] (7), sicklepod (Cassia obtusifolia L.) (33), and spotted spurge (Euphorbia maculata L.) (78).

Primisulfuron

Primisulfuron is a selective postemergence herbicide recently developed by Ciba-Geigy. Like other sulfonylureas, primisulfuron controls weeds by inhibiting acetolactate synthase. Primisulfuron's selectivity is due to corn's ability to metabolize the compound into inactive metabolites. Primisulfuron provides good control of johnsongrass (12,28,42,56,70,78,84). Worsham and Saunders (84) reported 90% to 100% control when primisulfuron was applied to johnsongrass at the 4- to 6-leaf stage. When applied to the 6- to 8-leaf stage, primisulfuron provided only 70% control. The critical timing of application has not been determined though since Thompson et al. (76) showed that primisulfuron applied at the 6-leaf stage provided maximum control. Mueller et al. (56) reported >70% control at rates of 20, 30, and 40 g ai ha^{-1}. Brown et al. (12) determined that primisulfuron-treated corn exhibited late season stunting due to regrowth of the johnsongrass. Mueller et al. (56) observed 13% to 16% stunting and up to 8% chlorosis in treated corn.

Other weeds controlled by primisulfuron include hemp sesbania, spotted spurge, redroot pigweed (Amaranthus retroflexus L.), prickly sida (Sida spinosa L.), redweed (Melochia corchorifolia L.) (78), tall

morningglory (Ipomoea purpurea L.) (84), and quackgrass (7).

DPX-E9636

DPX-E9636 is a new sulfonylurea herbicide for use in field corn and potatoes. Postemergence applications at 17 to 35 g ha^{-1} controlled many annual and perennial grasses and many broadleaf weeds. DPX-E9636 degrades rapidly in the soil, and should therefore integrate easily into a crop rotation program (41). DPX-E9636 provides good to excellent johnsongrass control (60), but may cause significant early season corn injury (61).

DPX-79406

DPX-79406 is a new postemergence herbicide for corn. This compound, a 1:1 mixture of nicosulfuron and DPX-E9636, provides a wider spectrum of control and allows for greater flexibility of rotational crops than does nicosulfuron alone (24). Rates of 15 to 50 g ha^{-1} are used to control many annual and perennial grasses as well as some broadleaf species. DPX-79406 controls foxtails (Setaria spp.) (52,55), velvetleaf (Abutilon theophrasti Medik.) (55), barnyardgrass [Echinochloa crus-galli (L.) Beauv.], panicums (Panicum spp.), wooly cupgrass [Eriochloa villosa (Thunb.) Kunth], wild-proso millet (Panicum miliaceum L.) (35), shattercane [Sorghum bicolor (L.) Moench], quackgrass, redroot pigweed and johnsongrass (40).

CHAPTER III

OPTIMUM TIME TO APPLY DPX-79406 FOR JOHNSONGRASS CONTROL

A. Introduction

DPX-79406 is an experimental postemergence corn herbicide which has shown good to excellent activity on many troublesome grass species. When applied at 18 to 35 g ha^{-1} to 2- to 5-leaf grass, DPX-79406 controls foxtails (52,55), panicums, wooly cupgrass, wild-proso millet (35), quackgrass and shattercane (40). Corn is subject to injury and reduced grain yield when DPX-79406 is applied at rates >18 g ha^{-1} (25,46,47). Reduced rates of DPX-79406 may prove less injurious while still maintaining good weed control.

Johnsongrass is the most troublesome weed in Tennessee corn, infesting approximately 60% of all corn acreage in the state. Worthington (85) reported >83% control of 23- to 33-cm johnsongrass with DPX-79406 when applied at 17.5 g ha^{-1} or greater. Krueger et al. (38) reported >92% control of 18-cm johnsongrass with DPX-79406 when applied at 18 to 35 g ha^{-1}. The objective of this experiment was to evaluate the effects of DPX-79406 rate and time of application on johnsongrass control and corn injury.

B. Materials and Methods

Field studies were conducted in 1990 and 1991 at Highland Rim

Experiment Station, Springfield, and at Middle Tennessee Experiment Station, Spring Hill. A randomized complete block design was utilized, with treatments replicated four times. The experiments were established in areas naturally infested with seedling and rhizome johnsongrass.

DeKalb 'DK 689' corn was planted at Springfield on April 20, 1990 and May 2, 1991 at a population of 54,340 plants ha^{-1}. At Spring Hill, DeKalb 'DK 689' was planted on April 27, 1990 and April 26, 1991 at a population of 54,340 plants ha^{-1}. Atrazine was applied preemergence at each location at 2.2 kg ha^{-1} for broadleaf weed control. The soil at Springfield was of the Dickson series (fine-silty, siliceous, thermic Glossic Fragiudults) with a pH of 5.5 and an organic carbon content of 0.6%. At Spring Hill the soil was of the Maury series (fine, mixed, mesic Typic Paleudalfs) with 1% organic carbon and a pH of 6.2.

Postemergence herbicide treatments included DPX-79406 at 6, 9 and 11 g ha^{-1}; nicosulfuron at 35 g ha^{-1}; primisulfuron at 40 g ha^{-1}; a weedy check; and a hand-hoed check which was hoed at 2 wk intervals during the growing season. Herbicides were applied to 20±5-cm, 50±5-cm, and 75±10-cm johnsongrass. Herbicides were applied with a CO_2- backpack sprayer delivering 160 L ha^{-1} at a speed of 4.8 km h^{-1} and a pressure of 240 kPa. All postemergence treatments included 0.25% v/v nonionic surfactant.

Plots at Springfield were four 9.1 m rows spaced 76 cm apart in 1990 but the plot length was reduced to 7.6 m in 1991. Individual plots at Spring Hill consisted of four, 6.1 m rows spaced 91 cm apart. Johnsongrass control and corn injury were recorded 3 wk after each treatment. 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. Corn was harvested on September 18, 1990 and September 25, 1991 at Springfield, while harvest dates at Spring Hill were October 12, 1990 and September 16, 1991. Grain yield is reported at 15.5% moisture. Weed control, crop injury and yield was obtained from the two center rows of each four-row plot. Data were subjected to analysis of variance and means were separated with an LSD at the 5% level.

C. Results and Discussion

Springfield

Johnsongrass control with DPX-79406 in first-year trials ranged from 50% to 98% depending on application time (Table 1). Similar control was obtained with DPX-79406 on 20-cm and 50-cm johnsongrass. Control of 75-cm johnsongrass with DPX-79406 was only 50 to 60%. Nicosulfuron controlled 97% of the johnsongrass ≤50 cm while controlling only 68% of the 76-cm johnsongrass. Primisulfuron applied to 20-, 50- and 75-cm johnsongrass gave 93%, 94% and 47% control, respectively.

DPX-79406 injured corn at rates greater than 6 g ha^{-1} when applied at the 4- and 7-leaf stage and at all rates at the 9-leaf stage (Figure 1). Nicosulfuron injury was visible when applied at the 7- and 9-leaf growth stage. Primisulfuron was more injurious to corn than nicosulfuron regardless of growth stage. This agrees with previous research by Brown (11). Corn injury symptoms ranged from a slight chlorosis to twisting in the whorl. Injury from any treatment was not

Table 1. Johnsongrass control and corn grain yield in 1990 as influenced by time of removal of johnsongrass with postemergence herbicides at Springfield.

Treatment	Rate	Johnsongrass Height	Time of Treatment	Johnsongrass Control 15 DAT[a]	Grain Yield
	g ai ha^{-1}	cm	WAP[b]	%	kg ha^{-1}
DPX-79406	6	20	5	96	3907
DPX-79406	9	"	"	96	3907
DPX-79406	11	"	"	96	3772
Nicosulfuron	35	"	"	97	3637
Primisulfuron	40	"	"	93	2627
DPX-79406	6	50	7	92	3233
DPX-79406	9	"	"	96	2829
DPX-79406	11	"	"	98	3301
Nicosulfuron	35	"	"	97	3368
Primisulfuron	40	"	"	94	2896
DPX-79406	6	75	9	50	2021
DPX-79406	9	"	"	60	3503
DPX-79406	11	"	"	60	2425
Nicosulfuron	35	"	"	68	3435
Primisulfuron	40	"	"	47	2425
Weedy Check	---	---	---	0	1819
Hand-hoed	---	---	---	99	3705
LSD (0.05)				18	1420

[a]DAT = days after treatment
[b]WAP = weeks after planting

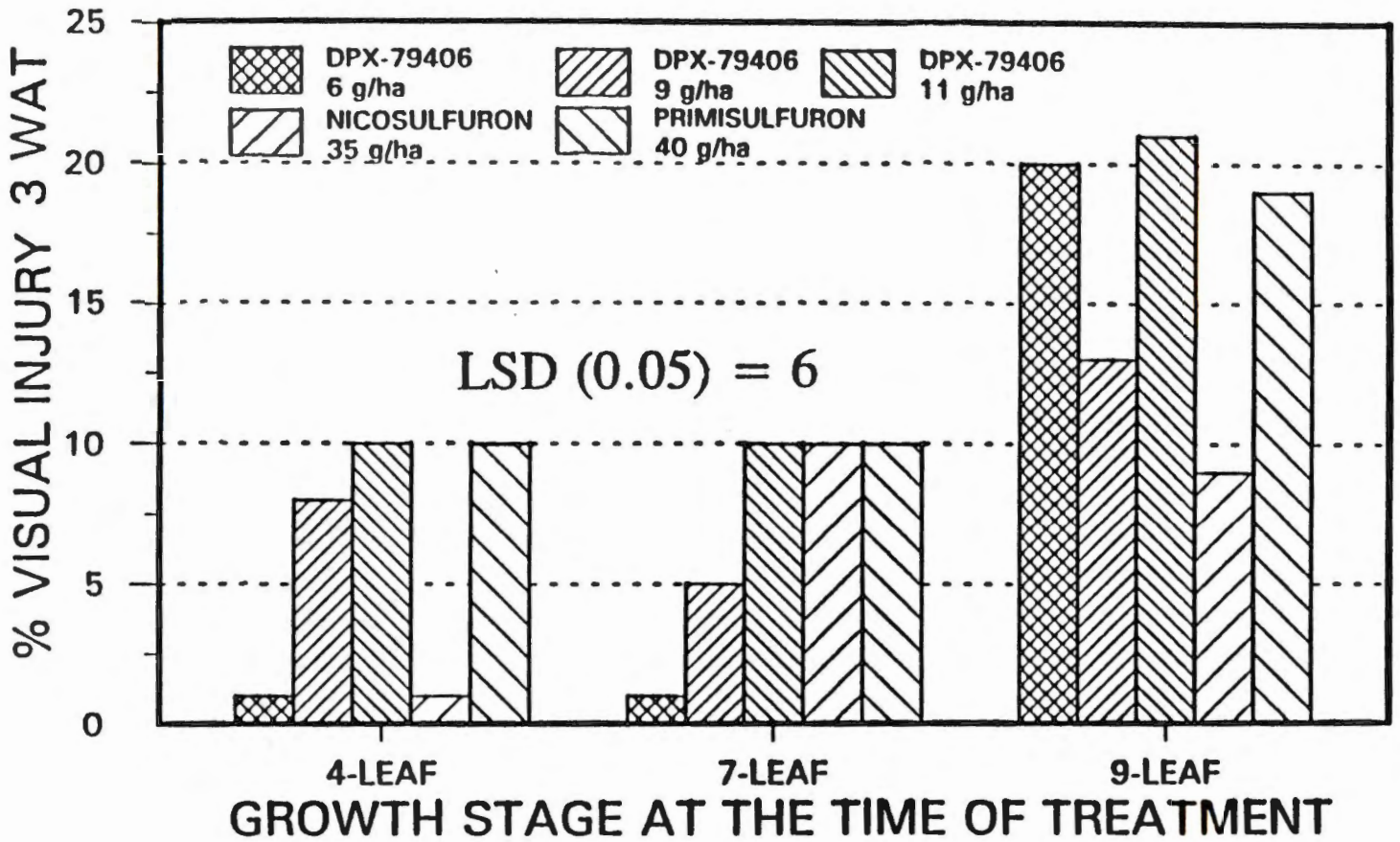

Figure 1. Corn visual injury in 1990 as influenced by time of removal of johnsongrass with postemergence herbicides at Springfield.

evident just prior to harvest.

Corn yields with DPX-79406 applied at the 4-leaf stage were comparable to the weedfree check (Table 1). No differences in yield were observed between applications to 4- and 7-leaf corn with respect to treatment. DPX-79406 applied at 6 g ha^{-1} to 9-leaf corn produced less grain than the weedfree check and DPX-79406 at 9 g ha^{-1}. Nicosulfuron treated plots tended to yield more than the primisulfuron treatments regardless of application timing, though the differences were not significant. This is probably due to a significant amount of late season johnsongrass regrowth in the primisulfuron plots. Nicosulfuron has been shown to be more readily absorbed by rhizome johnsongrass than primisulfuron, often providing more complete late season control (15).

Trials at Springfield in 1991 demonstrated differences in johnsongrass control between times of application (Table 2). Johnsongrass control of 91% was obtained with DPX-79406 applied to 20-cm johnsongrass, while nicosulfuron and primisulfuron provided 97 and 93% control, respectively. No herbicide controlled 50- or 75-cm johnsongrass. No herbicide treatment injured corn during the 1991 growing season. Corn yields were poor for all treatments due to drought during tasseling (Table 2). All treatments to 20- and 50-cm johnsongrass yielded significantly higher than the weedy check. DPX-79406 at 9 and 11 g ha^{-1} were the only treatments applied to 75-cm johnsongrass that improved yields over the weedy check.

Table 2. Johnsongrass control and corn grain yield in 1991 as influenced by time of removal of johnsongrass with postemergence herbicides at Springfield.

Treatment	Rate	Johnsongrass Height	Time of Treatment	Johnsongrass Control 15 DAT[a]	Grain Yield
	g ai ha^{-1}	cm	WAP[b]	%	kg ha^{-1}
DPX-79406	6	20	3	91	2896
DPX-79406	9	"	"	91	3840
DPX-79406	11	"	"	94	3840
Nicosulfuron	35	"	"	97	3435
Primisulfuron	40	"	"	93	2896
DPX-79406	6	50	6	10	3233
DPX-79406	9	"	"	15	3166
DPX-79406	11	"	"	35	3907
Nicosulfuron	35	"	"	28	4378
Primisulfuron	40	"	"	13	3705
DPX-79406	6	75	7	10	2425
DPX-79406	9	"	"	8	3166
DPX-79406	11	"	"	14	2829
Nicosulfuron	35	"	"	18	2021
Primisulfuron	40	"	"	10	1617
Weedy Check	___	___	___	0	1280
Hand-hoed	___	___	___	99	3099
LSD (0.05)				13	1510

[a]DAT = days after treatment
[b]WAP = weeks after planting

Spring Hill

Johnsongrass control with DPX-79406 compared favorably to nicosulfuron and primisulfuron at all applications (Table 3). No differences were observed among treatments within an application time. Treatments to 20-cm johnsongrass gave control equal to the hand-hoed plots. Control of 50-cm johnsongrass ranged from 77 to 85%, while herbicides applied to 75-cm johnsongrass provided 59 to 75% control. All treatments with the exception of DPX-79406 at 6 g ha^{-1} injured corn at the 4-leaf stage, although injury symptoms were not apparent at 4 WAT. No injury was observed as a result of the later herbicide applications. With the exception of DPX-79406 at 9 g ha^{-1}, corn yields from herbicides applied to the 20- to 50-cm johnsongrass were equal to the hand-hoed controls (Table 3). No differences in yields within timing were noted for johnsongrass treated at the 20- or 50-cm growth stage. Corn yields from plots treated when johnsongrass was 75-cm were higher when 35 g ha^{-1} was used compared to DPX-79406 at 11 g ha^{-1}. At Spring Hill in 1991 johnsongrass control differed among the different times of application. Again, juvenile johnsongrasss (20 cm) was controlled by all treatments, although DPX-79406 and nicosulfuron were more effective at this stage than primisulfuron (Table 4). No treatment controlled 50- or 75-cm johnsongrass. DPX-79406 at 6 g ha^{-1} failed to control 75-cm johnsongrass while the remaining treatments provided only minimal control. Corn was not injured by any herbicide regardless of rate or when applied. With the exception of primisulfuron, all herbicide treatments to 20-cm johnsongrass produced corn yields comparable to the hand-hoed plots (Table 4). Grain yields were variable

Table 3. Johnsongrass control and corn grain yield in 1990 as influenced by time of removal of johnsongrass with postemergence herbicides at Spring Hill.

Treatment	Rate	Johnsongrass Height	Time of Treatment	Johnsongrass Control 15 DAT[a]	Grain Yield
	g ai ha^{-1}	cm	WAP[b]	%	kg ha^{-1}
DPX-79406	6	20	4	94	7275
DPX-79406	9	"	"	99	6197
DPX-79406	11	"	"	96	6938
Nicosulfuron	35	"	"	99	7005
Primisulfuron	40	"	"	91	7140
DPX-79406	6	50	7	85	5793
DPX-79406	9	"	"	80	6062
DPX-79406	11	"	"	81	5726
Nicosulfuron	35	"	"	77	6601
Primisulfuron	40	"	"	83	5995
DPX-79406	6	75	8	64	6803
DPX-79406	9	"	"	59	6669
DPX-79406	11	"	"	72	5456
Nicosulfuron	35	"	"	75	7073
Primisulfuron	40	"	"	70	6601
Weedy Check	—	—	—	0	6130
Hand-hoed	—	—	—	99	7881
LSD (0.05)				15	1600

[a]DAT = days after treatment
[b]WAP = weeks after planting

Table 4. Johnsongrass control and corn grain yield in 1991 as influenced by time of removal of johnsongrass with postemergence herbicides at Spring Hill.

Treatment	Rate	Johnsongrass Height	Time of Treatment	Johnsongrass Control 15 DAT[a]	Grain Yield
	g ai ha^{-1}	cm	WAP[b]	%	kg ha^{-1}
DPX-79406	6	20	3	91	7342
DPX-79406	9	"	"	96	7814
DPX-79406	11	"	"	95	7746
Nicosulfuron	35	"	"	93	7948
Primisulfuron	40	"	"	81	6197
DPX-79406	6	50	6	23	7410
DPX-79406	9	"	"	48	6534
DPX-79406	11	"	"	33	6601
Nicosulfuron	35	"	"	51	5860
Primisulfuron	40	"	"	36	6534
DPX-79406	6	75	7	0	6601
DPX-79406	9	"	"	10	7140
DPX-79406	11	"	"	15	6264
Nicosulfuron	35	"	"	35	6938
Primisulfuron	40	"	"	25	5726
Weedy Check	—	—	—	0	6803
Hand-hoed	—	—	—	99	7746
LSD (0.05)				28	1340

[a]DAT = days after treatment
[b]WAP = weeks after planting

among DPX-79406 treatments to 50- and 75-cm johnsongrass. Weedy and hand-hoed plots were not different in respect to yield, due to a light johnsongrass infestation.

DPX-79406 controlled >90% of the 20-cm johnsongrass and ≥80% of the 50-cm johnsongrass. Nicosulfuron and primisulfuron performed similarly to DPX-79406 on 20- to 50-cm johnsongrass. DPX-79406 controlled <60% of the 50-cm johnsongrass and <20% of the 75-cm johnsongrass. Nicosulfuron controlled <55% of the 50-cm johnsongrass and <40% of the 75-cm johnsongrass while primisulfuron controlled <40% of the 50-cm johnsongrass and <30% of the 75-cm johnsongrass. Treatments applied to 20-cm johnsongrass produced grain yields equal to the hand-hoed plot, regardless of herbicide or rate. Corn yields from treatments to 50- to 75-cm johnsongrass were variable, depending on johnsongrass pressure. Areas of light to moderate johnsongrass pressure (Springfield) showed no trend of yield reduction in response to 50- to 75-cm applications. Johnsongrass infestation was heavier at Spring Hill, and corn yields were lower in plots receiving treatments at the 50- to 75-cm johnsongrass stage. DPX-79406 injured corn in 1990 at each application time. However, injury was not evident at 4 WAT and yield was not reduced. No injury was observed at either location during the 1991 growing season. These results indicate that growers will have a 2 week period in which to apply DPX-79406 to obtain maximum johnsongrass control and corn yield. In areas of heavy johnsongrass infestation, growers would benefit from an application to 20-cm johnsongrass to minimize yield losses resulting from johnsongrass competition.

CHAPTER IV

COMPARISON OF SEVERAL POSTEMERGENCE HERBICIDES FOR JOHNSONGRASS CONTROL IN CORN

A. Introduction

Nicosulfuron and primisulfuron are promising new postemergence corn herbicides which control many annual and perennial grasses, and some broadleaf weeds (7,20,21,33,83). Both nicosulfuron and primisulfuron control >80% of the emerged johnsongrass when applied 4 to 6 WAP (11,83,84). DPX-E9636 and DPX-79406 are new low-dose experimental sulfonylurea herbicides for use in field corn. DPX-E9636 at rates of 17 to 35 g ha^{-1} controls johnsongrass (60) but may cause early season corn injury (61). DPX-79406, a 1:1 mixture of nicosulfuron and DPX-E9636, controls a broader weed spectrum and provides greater rotational crop flexibility than nicosulfuron (24). DPX-79406 at 17 g ha^{-1} or greater control johnsongrass (38,85) but may cause corn stunting and chlorosis. The objective of this experiment was to evaluate johnsongrass control with DPX-E9636 and DPX-79406 compared to nicosulfuron and primisulfuron.

B. Materials and Methods

Field experiments were conducted in 1990 and 1991 at Highland Rim Experiment Station, Springfield, TN, on a soil of the Dickson series (fine-silty, siliceous, thermic Glossic Fragiudults) with a pH of 5.5

and 0.6% organic carbon; at Middle Tennessee Experiment Station, Spring Hill, TN, on a soil of the Maury series (fine, mixed, mesic Typic Paleudults) with a pH of 6.2 and 1% organic carbon; and the Knoxville Experiment Station Holston Branch, Knoxville, TN, on a soil of the Staser series (fine-loamy, mixed, thermic Cumulic Hapludolls) with a pH of 6.2 and 1% organic carbon. The studies were established in areas naturally infested with seedling and rhizome johnsongrass. Treatments were replicated four times in a randomized complete block design.

The herbicide treatments were applied to 25±5 cm and 70±10 cm johnsongrass. The herbicide rates used in the 1990 experiments were : DPX-79406 at 6, 9 and 11 g ha^{-1}; DPX-E9636 at 9, 13 and 17 g ha^{-1}; nicosulfuron at 9, 13, 17 and 35 g ha^{-1}; and primisulfuron at 40 g ha^{-1}. Herbicide rates utilized in 1991 were: DPX-79406 at 6, 9, 11, 18, 27 and 35 g ha^{-1}; nicosulfuron at 6, 9, 11, and 35 g ha^{-1}; and primisulfuron at 40 g ha^{-1}. A weedy check as well as a hand-hoed check were also included. The hand-hoed check was hoed at 2 wk intervals throughout the growing season.

At Springfield, DeKalb 'DK 689' corn was planted into conventionally tilled beds on April 20, 1990 and May 2, 1991 at a population of 51,870 plants ha^{-1}. Postemergence applications were made to 25-cm johnsongrass when corn was at the 4- to 5-leaf stage and to 70 cm johnsongrass when corn was at the 8- to 9-leaf stage of growth.

At Spring Hill, DeKalb 'DK 689' was planted April 27, 1990 and April 26, 1991 at a population of 54,530 plants ha^{-1}. Applications were made to 25-cm johnsongrass (4- to 5-leaf corn) and to 70-cm weeds when corn was at the 7- to 8-leaf stage.

At Knoxville, corn was planted on May 14, 1990 and May 15, 1991 at a population of 49,400 plants ha^{-1}. Postemergence treatments were applied to 25-cm johnsongrass when corn was at the 5-leaf stage and to 70-cm johnsongrass when corn was at the 9- to 10-leaf growth stage. Atrazine was applied preemergence at each location at 2.2 kg ha^{-1} for broadleaf weed control. All postemergence herbicides were applied in a volume of 160 L ha^{-1} with a CO_2-pressurized backpack sprayer at a speed of 4.8 km h^{-1} and a pressure of 240 kPa. All postemergence treatments included 0.25% v/v nonionic surfactant.

Plots at Springfield were four rows spaced 76 cm apart; 9.1 m in length in 1990 and 7.6 m in 1991. Individual plots at Spring Hill consisted of four, 6.1 m rows spaced 91 cm apart. Plot dimensions at Knoxville were four, 6.1 m rows spaced 91 cm apart in 1990 and 9.1 m spaced 91 cm apart in 1991. Johnsongrass control and corn injury ratings were taken 2 wk after each respective treatment and an end of season johnsongrass control rating was taken in 1991. 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. Corn was harvested on September 18, 1990 and September 25, 1991 at Springfield; October 12, 1990 and September 16, 1991 at Spring Hill; and October 26, 1990 and September 23, 1991 at Knoxville with grain yields reported at 15.5% moisture. Weed control, crop injury and yield data were obtained from the two center rows of each four row plot. All data were subjected to analysis of variance, and means were separated with an LSD at the 5% level.

C. Results and Discussion

Springfield

All treatments controlled 25-cm johnsongrass (Table 5). No differences in control were noted among DPX-79406, DPX-E9636 and nicosulfuron, regardless of application rate. All herbicides except primisulfuron provided johnsongrass control equal to that of the hand-hoed check. DPX-79406 at 6 and 11 g ha^{-1} failed to control 70-cm johnsongrass. Johnsongrass control with nicosulfuron was equal to the hand-hoed check except at the 9 g ha^{-1} rate. DPX-E9636 at 9 g ha^{-1} failed to control 70-cm johnsongrass; however, the 13 and 17 g ha^{-1} rates provided control equal to the hand-hoed plots.

Corn was injured when DPX-E9636 was applied to 70-cm johnsongrass (Figure 2). Corn injury ranged from 20% at 9 g ha^{-1} to 30% at 17 g ha^{-1}. These treatments to 9-leaf corn resulted in injury from each herbicide, although corn sprayed with DPX-79406, nicosulfuron and primisulfuron did not exhibit injury at harvest. Injury symptoms from DPX-E9636 persisted longest. Injury to 5-leaf corn was minimal with all herbicides.

Corn grain yields were comparable to the hand-hoed check with all treatments applied to 25-cm johnsongrass (Table 5). Yields from DPX-79406 treated plots compared favorably with nicosulfuron treatments. The 6 and 9 g ha^{-1} rates of DPX-79406 and the 9 g ha^{-1} rate of nicosulfuron failed to produce yields equal to the remaining treatments due to significant amounts of late-season johnsongrass regrowth in these plots. Differences in yield were observed among treatments to 70-cm johnsongrass. DPX-79406 at 6 g ha^{-1} and nicosulfuron at 13 and

Table 5. Comparison of postemergence herbicides for johnsongrass control at Springfield in 1990.

Treatment	Rate	Johnsongrass Height	Johnsongrass Control 3 WAT[a]	Grain Yield
	g ai ha^{-1}	cm	%	kg ha^{-1}
DPX-79406	6	25	96	3705
DPX-79406	9	"	98	3840
DPX-79406	11	"	97	4378
Nicosulfuron	9	"	96	3840
Nicosulfuron	13	"	96	4244
Nicosulfuron	17	"	97	4648
Nicosulfuron	35	"	99	4109
DPX-E9636	9	"	97	4378
DPX-E9636	13	"	98	4311
DPX-E9636	17	"	95	4715
Primisulfuron	40	"	85	4446
DPX-79406	6	70	79	3435
DPX-79406	9	"	96	2829
DPX-79406	11	"	82	3166
Nicosulfuron	9	"	82	2694
Nicosulfuron	13	"	93	3503
Nicosulfuron	17	"	87	3435
Nicosulfuron	35	"	87	2896
DPX-E9636	9	"	77	2829
DPX-E9636	13	"	93	2694
DPX-E9636	17	"	98	2762
Primisulfuron	40	"	73	2560
Weedy Check	___	___	0	1347
Hand-hoed	___	___	99	4244
LSD (0.05)			13	1010

[a]WAT = weeks after treatment

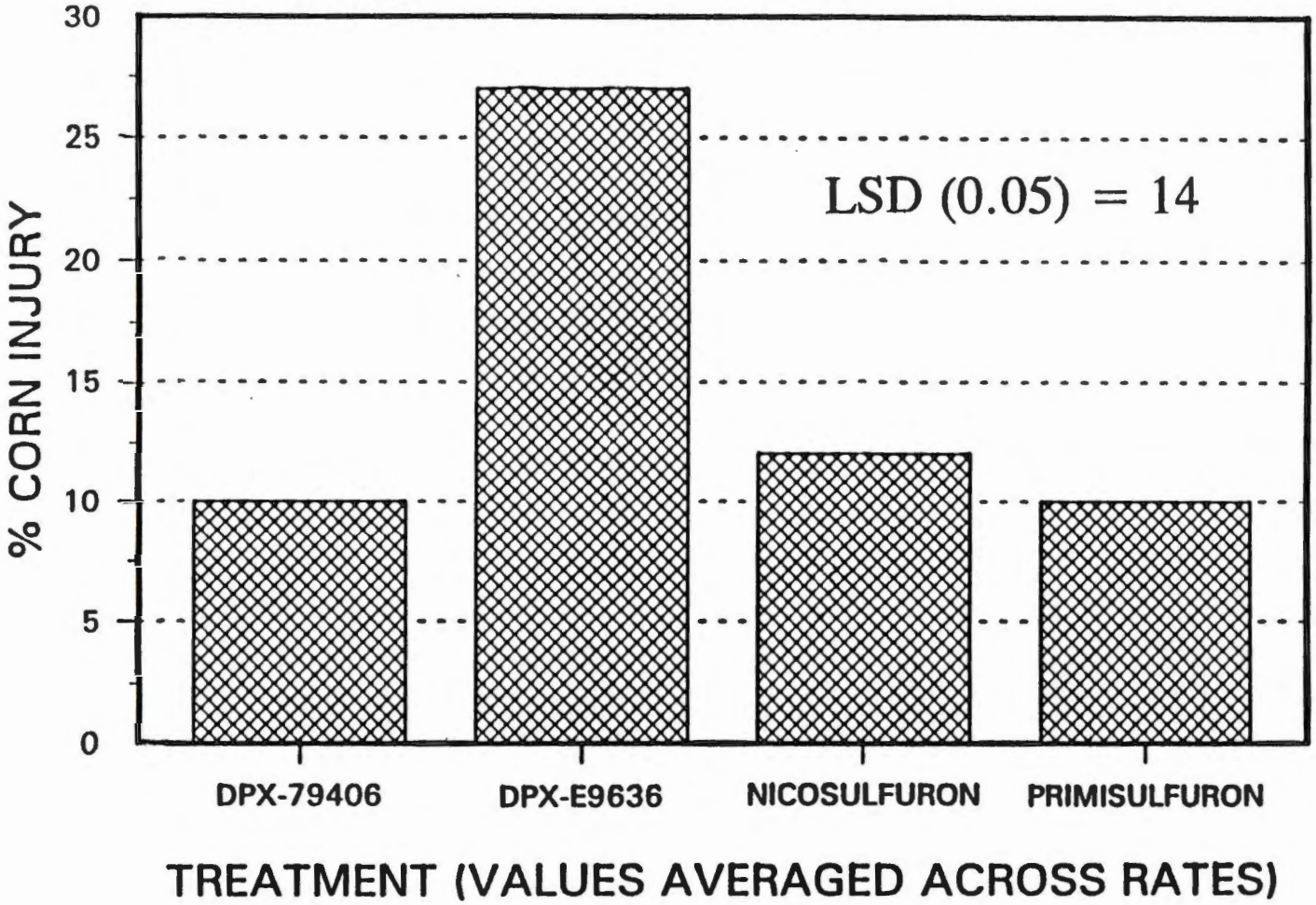

Figure 2. Injury at Springfield in 1990 for postemergence applications of DPX-79406, DPX-E9636, nicosulfuron and primisulfuron to 9-leaf corn.

17 g ha^{-1} were the only treatments which produced yields comparable to the hand-hoed check plots. Corn injury probably contributed to the low yields observed with the DPX-E9636 treated plots.

All herbicide treatments controlled 25-cm johnsongrass at Springfield in 1991 (Table 6). DPX-79406 at 6 g ha^{-1} gave >84% johnsongrass control while rates of 11 to 35 g ha^{-1} provided >95% control. DPX-79406 at 6, 9 and 11 g ha^{-1} was more effective than nicosulfuron at identical rates. Nicosulfuron at 6 to 11 g ha^{-1} were the only treatments with less johnsongrass control than the hand-hoed plots. Nicosulfuron at 35 g ha^{-1} and primisulfuron at 40 g ha^{-1} controlled 25-cm johnsongrass. No treatment controlled 70-cm johnsongrass. However, DPX-79406, in general, provided more control than did nicosulfuron or primisulfuron.

Drought conditions during the 1991 growing season contributed to poor corn yields from all herbicide treatments (Table 7). No rainfall occured from July 15 to August 18, which was detrimental during the transition from the vegetative to reproductive stage of corn (Appendix A). Corn yields did not differ between any treatment and the hand-hoed check. DPX-79406 at 27 and 35 g ha^{-1} applied to 25-cm johnsongrass and nicosulfuron at 35 g ha^{-1} on 70-cm johnsongrass produced the greatest yields within their respective timings.

Spring Hill

Control did not differ among treatments applied to 25-cm johnsongrass (Table 8). Johnsongrass control with DPX-79406 ranged from 93 to 98% while nicosulfuron provided 89 to 96% johnsongrass control.

Table 6. Comparison of postemergence herbicides for johnsongrass control at Springfield in 1991.

Treatment	Rate	Johnsongrass Height	Johnsongrass Control 2 WAT[a]	Johnsongrass Control 15 WAT
	g ai ha^{-1}	cm	---------%-------	
DPX-79406	6	25	84	75
DPX-79406	9	"	85	74
DPX-79406	11	"	95	76
DPX-79406	18	"	96	76
DPX-79406	27	"	96	80
DPX-79406	35	"	99	88
Nicosulfuron	6	"	77	76
Nicosulfuron	9	"	80	81
Nicosulfuron	11	"	79	76
Nicosulfuron	35	"	94	89
Primisulfuron	40	"	97	85
DPX-79406	6	70	30	34
DPX-79406	9	"	24	25
DPX-79406	11	"	29	34
DPX-79406	18	"	41	39
DPX-79406	27	"	26	49
DPX-79406	35	"	31	50
Nicosulfuron	6	"	18	18
Nicosulfuron	9	"	34	38
Nicosulfuron	11	"	20	28
Nicosulfuron	35	"	18	13
Primisulfuron	40	"	23	33
Weedy Check	___	___	0	0
Hand-hoed	___	___	99	95
LSD (0.05)			16	23

[a]WAT = weeks after treatment

Table 7. Corn grain yield in 1991 as influenced by time of application of postemergence herbicides at Springfield.

Treatment	Rate	Johnsongrass Height	Grain Yield
	g ai ha^{-1}	cm	kg ha^{-1}
DPX-79406	6	25	1549
DPX-79406	9	"	1145
DPX-79406	11	"	1078
DPX-79406	18	"	1684
DPX-79406	27	"	2021
DPX-79406	35	"	2021
Nicosulfuron	6	"	1617
Nicosulfuron	9	"	1819
Nicosulfuron	11	"	1078
Nicosulfuron	35	"	2021
Primisulfuron	40	"	1482
DPX-79406	6	70	1617
DPX-79406	9	"	1010
DPX-79406	11	"	1617
DPX-79406	18	"	2088
DPX-79406	27	"	2290
DPX-79406	35	"	1617
Nicosulfuron	6	"	1549
Nicosulfuron	9	"	1010
Nicosulfuron	11	"	1213
Nicosulfuron	35	"	2560
Primisulfuron	40	"	1819
Weedy Check	—	—	1549
Hand-hoed	—	—	1415
LSD (0.05)			1280

Table 8. Comparison of postemergence herbicides for johnsongrass control at Spring Hill in 1990.

Treatment	Rate	Johnsongrass Height	Johnsongrass Control 3 WAT[a]	Grain Yield
	g ai ha^{-1}	cm	%	kg ha^{-1}
DPX-79406	6	25	93	7140
DPX-79406	9	"	96	8218
DPX-79406	11	"	98	8555
Nicosulfuron	9	"	89	7949
Nicosulfuron	13	"	94	8151
Nicosulfuron	17	"	94	8218
Nicosulfuron	35	"	96	7612
DPX-E9636	9	"	96	8151
DPX-E9636	13	"	95	7544
DPX-E9636	17	"	95	8016
Primisulfuron	40	"	98	7073
DPX-79406	6	70	64	7342
DPX-79406	9	"	73	7275
DPX-79406	11	"	71	7005
Nicosulfuron	9	"	56	8016
Nicosulfuron	13	"	73	8016
Nicosulfuron	17	"	75	8016
Nicosulfuron	35	"	68	7208
DPX-E9636	9	"	75	7140
DPX-E9636	13	"	74	6534
DPX-E9636	17	"	73	7612
Primisulfuron	40	"	79	8083
Weedy Check	___	___	0	7275
Hand-hoed	___	___	99	8959
LSD (0.05)			12	1620

[a]WAT = weeks after treatment

DPX-E9636 and primisulfuron averaged 96% and 98% control, respectively. All treatments applied to 70-cm johnsongrass had less johnsongrass control than the hand-hoed check. Control did not differ between DPX-79406 and DPX-E9636 rates. Johnsongrass control with nicosulfuron at 9 g ha^{-1} was less than the three higher rates. Johnsongrass control did not differ between DPX-79406 or DPX-E9636 and nicosulfuron with the exception of the 9 g ha^{-1} rate. Primisulfuron provided the highest control of 70-cm johnsongrass. No herbicide treatment caused injury, regardless of application time.

Corn grain yield did not differ among treatments to 25-cm johnsongrass with the exception of primisulfuron and the lowest rate of DPX-79406. Although these treatments controlled johnsongrass at 2 WAT, late season regrowth may have contributed to reduced yields. Grain yields from treatments to 70-cm johnsongrass were higher with nicosulfuron and primisulfuron than either DPX-79406 or DPX-E9636.

Johnsongrass was controlled in 1991 with all herbicides when applied at the 25-cm height (Table 9). DPX-79406 controlled 92 to 99% of the johnsongrass depending on rate. All treatments except primisulfuron provided ≥87% control of 25-cm johnsongrass at 15 WAT. DPX-79406 applied to 70-cm johnsongrass provided ≥58% control. Efficacy of DPX-79406 at 9 g ha^{-1} differed from that of nicosulfuron at 6 g ha^{-1}. Treatments to 70-cm johnsongrass provided control less than that of the hand-hoed plots. DPX-79406 at 27 and 35 g ha^{-1} were the only treatments which maintained control of 70-cm johnsongrass throughout the growing season.

Table 9. Comparison of postemergence herbicides for johnsongrass control at Spring Hill in 1991.

Treatment	Rate	Johnsongrass Height	Johnsongrass Control 2 WAT[a]	Johnsongrass Control 15 WAT
	g ai ha^{-1}	cm	--------%-------	
DPX-79406	6	25	92	87
DPX-79406	9	"	94	90
DPX-79406	11	"	95	92
DPX-79406	18	"	98	96
DPX-79406	27	"	99	92
DPX-79406	35	"	99	95
Nicosulfuron	6	"	88	87
Nicosulfuron	9	"	86	95
Nicosulfuron	11	"	92	94
Nicosulfuron	35	"	90	92
Primisulfuron	40	"	94	68
DPX-79406	6	70	71	51
DPX-79406	9	"	76	48
DPX-79406	11	"	63	46
DPX-79406	18	"	58	49
DPX-79406	27	"	69	67
DPX-79406	35	"	58	72
Nicosulfuron	6	"	51	33
Nicosulfuron	9	"	69	50
Nicosulfuron	11	"	55	36
Nicosulfuron	35	"	66	64
Primisulfuron	40	"	65	35
Weedy Check	___	___	0	0
Hand-hoed	___	___	99	98
LSD (0.05)			22	22

[a]WAT = weeks after treatment

DPX-79406 injured corn at all rates when applied at the 5-leaf stage. Injury was not apparent 4 WAT except from the 35 g ha^{-1} rate, which initially caused 45% corn injury. DPX-79406 at 27 g ha^{-1} and primisulfuron at 40 g ha^{-1} injured corn 18 and 15%, respectively.

Corn yields were comparable to the hand-hoed check with treatments applied to 25-cm johnsongrass with the exception of DPX-79406 at 35 g ha^{-1} and primisulfuron (Table 10). Corn injury at 2 WAT and stunting from this rate of DPX-79406 probably contributed to the yield reduction. Johnsongrass regrowth in the primisulfuron plots may have contributed to poor yields. Corn yields from the postemergence treatments to 70-cm johnsongrass were similar to those to 25-cm johnsongrass despite <76% johnsongrass control. Primisulfuron was the only treatment applied to 70-cm johnsongrass with corn yields less than the hand-hoed check.

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Treatments did not differ with respect to johnsongrass control, regardless of application time (Table 11). DPX-79406 provided control of 25-cm johnsongrass equal to nicosulfuron. DPX-79406 at 6 g ha^{-1} did not control 70-cm johnsongrass. DPX-79406 at 11 g ha^{-1} provided 89% johnsongrass control. Nicosulfuron averaged 78% control when applied at this stage. The most acceptable control was achieved with the 13 and 17 g ha^{-1} rates of DPX-E9636 which provided 95% control. No crop injury was observed at Knoxville in 1990.

Grain yields did not differ among treatment when applied to 25-cm johnsongrass. Corn with 25-cm johnsongrass treated with nicosulfuron at 17 g ha^{-1} yielded lower than the hand-hoed check. Corn yields did not

Table 10. Corn grain yield in 1991 as influenced by time of application of postemergence herbicides at Spring Hill.

Treatment	Rate	Johnsongrass Height	Grain Yield
	g ai ha^{-1}	cm	kg ha^{-1}
DPX-79406	6	25	6803
DPX-79406	9	"	7679
DPX-79406	11	"	7342
DPX-79406	18	"	6938
DPX-79406	27	"	7275
DPX-79406	35	"	5928
Nicosulfuron	6	"	6871
Nicosulfuron	9	"	7949
Nicosulfuron	11	"	7612
Nicosulfuron	35	"	7005
Primisulfuron	40	"	5995
DPX-79406	6	70	7679
DPX-79406	9	"	7208
DPX-79406	11	"	7275
DPX-79406	18	"	6467
DPX-79406	27	"	7746
DPX-79406	35	"	7073
Nicosulfuron	6	"	7342
Nicosulfuron	9	"	7342
Nicosulfuron	11	"	6938
Nicosulfuron	35	"	7410
Primisulfuron	40	"	6197
Weedy Check	—	—	7140
Hand-hoed	—	—	7746
LSD (0.05)			1550

Table 11. Comparison of postemergence herbicides for johnsongrass control at Knoxville in 1990.

Treatment	Rate	Johnsongrass Height	Johnsongrass Control 3 WAT[a]	Grain Yield
	g ai ha^{-1}	cm	%	kg ha^{-1}
DPX-79406	6	25	86	4917
DPX-79406	9	"	74	5591
DPX-79406	11	"	90	6130
Nicosulfuron	9	"	80	5456
Nicosulfuron	13	"	89	6332
Nicosulfuron	17	"	79	4917
Nicosulfuron	35	"	84	6736
DPX-E9636	9	"	86	4715
DPX-E9636	13	"	87	5254
DPX-E9636	17	"	91	5524
Primisulfuron	40	"	74	5389
DPX-79406	6	70	69	6534
DPX-79406	9	"	90	5052
DPX-79406	11	"	88	4648
Nicosulfuron	9	"	78	5254
Nicosulfuron	13	"	77	4715
Nicosulfuron	17	"	77	4244
Nicosulfuron	35	"	78	5119
DPX-E9636	9	"	74	5928
DPX-E9636	13	"	94	5052
DPX-E9636	17	"	96	5052
Primisulfuron	40	"	84	5052
Weedy Check	___	___	0	5052
Hand-hoed	___	___	99	6264
LSD (0.05)			35	1950

[a]WAT = weeks after treatment

differ between the weedy control plot and the hand-hoed plot. This was probably due to a light infestation of rhizome johnsongrass.

In 1991 trials, DPX-79406 at 6 to 35 g ha^{-1} provided 91 to 98% control of 25-cm johnsongrass (Table 12). Nicosulfuron at 35 g ha^{-1} and primisulfuron at 40 g ha^{-1} controlled 90% and 89% of the johnsongrass at 2 WAT. Nicosulfuron at 6 to 11 g ha^{-1} provided 78 to 84% control, less than the hand-hoed check. DPX-79406 at 27 and 35 g ha^{-1} gave better control than nicosulfuron at 6, 9 or 11 g ha^{-1}. DPX-79406 at 9 and 11 g ha^{-1} provided better control than nicosulfuron at 6 g ha^{-1}. Johnsongrass control with DPX-79406 ranged from 92 to 99% prior to harvest. All treatments to 25-cm johnsongrass maintained excellent control throughout the growing season. No herbicide controlled 70-cm johnsongrass. Corn yields from all treatments to 25-cm johnsongrass were higher than the weedy check plots (Table 13). Nicosulfuron at 11 and 35 g ha^{-1} and DPX-79406 at 27 g ha^{-1} were the only treatments applied to 70-cm johnsongrass that had higher yields than the weedy check.

DPX-79406 controlled 25-cm johnsongrass; control was generally >90%. There was no trend toward increased control with increasing DPX-79406 rate, rates of 6 to 11 g ha^{-1} performed similarly to the 18 to 35 g ha^{-1} rates. DPX-E9636 provided the most complete control of 25-cm johnsongrass but caused the most corn injury. Primisulfuron provided 74 to 98% control of 25-cm johnsongrass at 3 WAT. Nicosulfuron provided >75% control of 25-cm johnsongrass at 3 WAT and maintained better control throughout the growing season than either DPX-79406 or primisulfuron. DPX-E9636 at 13 and 17 g ha^{-1} provided 73 to 98% control

Table 12. Comparison of postemergence herbicides for johnsongrass control at Knoxville in 1991.

Treatment	Rate	Johnsongrass Height	Johnsongrass Control 2 WAT[a]	Johnsongrass Control 15 WAT
	g ai ha^{-1}	cm	--------%------	
DPX-79406	6	25	91	92
DPX-79406	9	"	95	98
DPX-79406	11	"	95	98
DPX-79406	18	"	91	94
DPX-79406	27	"	98	99
DPX-79406	35	"	98	99
Nicosulfuron	6	"	78	76
Nicosulfuron	9	"	82	82
Nicosulfuron	11	"	84	95
Nicosulfuron	35	"	90	97
Primisulfuron	40	"	89	89
DPX-79406	6	70	20	25
DPX-79406	9	"	18	13
DPX-79406	11	"	8	13
DPX-79406	18	"	20	28
DPX-79406	27	"	35	28
DPX-79406	35	"	29	29
Nicosulfuron	6	"	29	21
Nicosulfuron	9	"	8	20
Nicosulfuron	11	"	28	33
Nicosulfuron	35	"	25	23
Primisulfuron	40	"	23	21
Weedy Check	___	___	0	0
Hand-hoed	___	___	99	98
LSD (0.05)			14	17

[a]WAT = weeks after treatment

Table 13. Corn grain yield in 1991 as influenced by time of application of postemergence herbicides at Knoxville.

Treatment	Rate	Johnsongrass Height	Grain Yield
	g ai ha^{-1}	cm	kg ha^{-1}
DPX-79406	6	25	10239
DPX-79406	9	"	9161
DPX-79406	11	"	9633
DPX-79406	18	"	10171
DPX-79406	27	"	9700
DPX-79406	35	"	9767
Nicosulfuron	6	"	10373
Nicosulfuron	9	"	9565
Nicosulfuron	11	"	10373
Nicosulfuron	35	"	9767
Primisulfuron	40	"	10239
DPX-79406	6	70	9026
DPX-79406	9	"	8083
DPX-79406	11	"	8420
DPX-79406	18	"	6332
DPX-79406	27	"	9296
DPX-79406	35	"	7679
Nicosulfuron	6	"	6938
Nicosulfuron	9	"	8151
Nicosulfuron	11	"	9430
Nicosulfuron	35	"	8555
Primisulfuron	40	"	8420
Weedy Check	___	___	6669
Hand-hoed	___	___	11114
LSD (0.05)			2690

of 70-cm johnsongrass at 3 WAT, but caused 30% corn injury. Neither DPX-79406 at 6 to 35 g ha^{-1} nor nicosulfuron at 6 to 35 g ha^{-1} controlled 70-cm johnsongrass. Primisulfuron provided 58% control of 70-cm johnsongrass when averaged across years. Corn grain yields were comparable to the hand-hoed check with all treatments applied to 25-cm johnsongrass. Corn yields were lower when johnsongrass was treated at 70-cm. These studies indicate that DPX-79406 at rates of 6 to 11 g ha^{-1} controls 25-cm johnsongrass, comparing favorably to nicosulfuron at 35 g ha^{-1} and primisulfuron at 40 g ha^{-1}. DPX-79406 controls johnsongrass at half the rate of nicosulfuron or primisulfuron, and provides a broader spectrum of weed control than either. DPX-79406 should integrate easily into a johnsongrass management program.

CHAPTER V

CORN INJURY AS INFLUENCED BY RATE AND TIMING OF DPX-79406 APPLICATIONS

A. Introduction

DPX-79406 is a new experimental sulfonylurea herbicide for postemergence use in field corn. This 1:1 mixture of DPX-E9636 and nicosulfuron controls many annual and perennial grasses, as well as some broadleaf weeds, when applied at 15 to 50 g ha^{-1}. DPX-79406 can cause significant injury when applied to 4- to 5-leaf corn. McMullan and Czerkawski (46) reported corn injury and a decrease in grain yield when DPX-79406 was applied to 5-leaf corn. Owen et al. (64) reported up to 15% injury when DPX-79406 was applied at 35 g ha^{-1} to 4- to 5-leaf corn. Several other studies have reported crop injury from this herbicide when applied early postemergence (36,37,47). DPX-79406 may cause injury when applied at later growth stages. Owen (62) reported 22 to 27% corn injury from DPX-79406 when applied at 35 to 70 g ha^{-1} to 7- to 8-leaf corn. The potential for crop injury has not been fully clarified though since several reports indicate little to no corn injury from rates of 70 g ha^{-1} or greater (3,20,26,40,63). The objective of this experiment was to evaluate the crop injury associated with DPX-79406 when applied to 4- to 5-leaf and 8- to 9-leaf corn.

B. Materials and Methods

A field experiment was conducted in 1991 at the Knoxville Plant Science Field Laboratory, Knoxville, TN, on a soil of the Sequatchie series (fine-loamy, siliceous, thermic Humic Hapludults) with a pH of 6.5 and 0.7% organic carbon. The study was established on a relatively johnsongrass-free site with treatments replicated four times in a randomized complete block design. Individual plots consisted of four 7.6 m rows spaced 76 cm apart. DeKalb 'DK 689' corn was planted on April 25, 1991 at a population of 49,400 plants ha^{-1}. Atrazine at 2.2 kg ha^{-1} and alachlor at 2.2 kg ha^{-1} were applied preemergence to provide broad-spectrum weed control.

The herbicide rates used were: DPX-79406 at 18, 27, 35 and 54 g ha^{-1}; nicosulfuron at 35 g ha^{-1}; primisulfuron at 40 g ha^{-1}; and an untreated check. Each postemergence treatment was applied to corn at the 4- to 5-leaf stage and at the 8- to 9-leaf stage. All postemergence herbicides were applied with a CO_2-pressurized backpack sprayer delivering 160 L ha^{-1} at a speed of 4.8 km h^{-1} and a pressure of 240 kPa and included 0.25% v/v nonionic surfactant.

Injury ratings were taken 2 and 5 wk after each respective treatment. Injury ratings were recorded on a scale of 0 to 100 with 0 equal to no corn injury and 100 equal to complete corn kill. Corn was harvested on September 18, 1991 and grain yields are reported at 15.5% moisture. Corn injury and yield data were obtained from the two center rows of each four row plot. Data were subjected to analysis of variance and means were separated with an LSD at the 5% significance level.

C. Results and Discussion

DPX-79406 injured 4- to 5-leaf corn when applied at rates of 27 g ha^{-1} or greater (Table 14). Rates of 35 and 54 g ha^{-1} caused 23 and 43% injury at 2 WAT. Injury from these two treatments decreased to 13 and 23% by 5 WAT. Corn injury from primisulfuron was 5% at 2 WAT and had not decreased by 5 WAT. DPX-79406 at 18 g ha^{-1} and nicosulfuron did not injure corn at the 4- to 5-leaf stage. No injury was observed from any treatment applied at the 8- to 9-leaf stage. DPX-79406 at 35 and 54 g ha^{-1} applied to 4- to 5-leaf corn had the lowest grain yields. However, no treatment yield differed from the untreated check yield, regardless of corn growth stage.

Table 14. Corn injury and grain yield as influenced by postemergence herbicide, rate and corn growth stage at Knoxville.

Treatment	Rate	Corn Stage	Visual Injury 2 WAT[a]	Visual Injury 5 WAT	Grain Yield
	g ai ha^{-1}	Leaf No.	-------%------		kg ha^{-1}
DPX-79406	18	4-5	0	0	9498
DPX-79406	27	"	6	8	10104
DPX-79406	35	"	23	13	9026
DPX-79406	54	"	43	23	9430
Nicosulfuron	35	"	0	0	11182
Primisulfuron	40	"	5	5	10171
DPX-79406	18	8-9	0	0	10710
DPX-79406	27	"	0	0	9969
DPX-79406	35	"	3	0	9700
DPX-79406	54	"	5	3	10306
Nicosulfuron	35	"	3	0	10239
Primisulfuron	40	"	0	0	10037
Untreated	---	---	0	0	11114
LSD (0.05)			7	4	2900

[a]WAT = weeks after treatment

CHAPTER VI

GENERAL SUMMARY

The objectives of this research were: (i) to determine the optimum timing of DPX-79406 to maximize johnsongrass control, (ii) to compare the efficacy of DPX-79406 with similar compounds and (iii) to assess the corn injury potential from DPX-79406.

The development of nicosulfuron and primisulfuron has provided growers with a postemergence option for grass control in corn. DPX-79406 offers control of a broader spectrum of weeds and greater rotational crop flexibility than either nicosulfuron or primisulfuron.

Field studies with DPX-79406 indicate that johnsongrass control is better when applied to 25-cm johnsongrass than to 70-cm johnsongrass. Corn yields were often decreased with the later application.

DPX-79406 and DPX-E9636 control many annual and perennial grasses when applied at 18 g ha^{-1}. Little is known about johnsongrass control with DPX-79406 and DPX-E9636. DPX-79406 and DPX-E9636 compared favorably with nicosulfuron and primisulfuron in controlling johnsongrass. These compounds exhibit greater herbicidal activity than nicosulfuron and primisulfuron; thus, good control was achieved with rates as low as 6 g ha^{-1} when applied to 25-cm johnsongrass. DPX-E9636 at 13 and 17 g ha^{-1} provided the best control of 70-cm johnsongrass. However, corn injury often occurred, thus reducing grain yield. Control of 25-cm johhsongrass was not different among DPX-79406 rates. These data indicate that DPX-79406 at 6 to 11 g ha^{-1} provided control of 25-cm

johnsongrass comparable to 18 to 35 g ha^{-1} while decreasing the chances of corn injury. Corn injury from DPX-79406 has been erratic (35,46,52,64). This research suggests that 4- to 5-leaf corn is susceptible to injury from DPX-79406 at 27 g ha^{-1} or greater. However, despite considerable injury, grain yields were not adversely affected. Applications to 8- to 9-leaf corn resulted in negligible injury. Future research should further address the effect of application rate and timing of DPX-79406 upon grain yield.

In conclusion, DPX-79406 controls johnsongrass, comparing favorably to nicosulfuron and primisulfuron. Maximum control is achieved by applying DPX-79406 to 25-cm johnsongrass. The optimum rate of DPX-79406 to provide acceptable johnsongrass control while mimimizing injury is between 6 and 11 g ha^{-1}.

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APPENDICES

APPENDIX A

ENVIRONMENTAL DATA

APPENDIX A

Table A-1. Daily rainfall at Springfield, April to September 1990.

DATE	APR	MAY	JUN	JUL	AUG	SEP
	(cm)					
1						
2		0.18	0.20	0.41		
3		0.97	2.51			
4						
5		0.48			2.64	
6	0.84				0.86	
7	0.20	0.08	0.84			
8						0.38
9						0.10
10	0.33	0.48	0.18			
11	0.84					1.50
12		0.05		2.39		1.04
13		0.23		1.52		0.99
14				0.15	0.18	
15	0.66					0.13
16	0.05					
17	0.03	6.02				
18	1.04					
19			0.71			
20						0.69
21	0.46	0.79	0.99			
22	0.05	0.69	1.52	0.18		3.89
23			0.36	1.50		
24					0.03	
25						
26						
27						
28	0.36	4.45				
29	0.18	0.25				
30					0.23	
31						
TOTAL	5.03	14.66	7.32	6.15	3.94	8.71

Table A-2. Daily rainfall at Springfield, April to September 1991.

DATE	APR	MAY	JUN	JUL	AUG	SEP
	(cm)					
1				0.46		0.99
2			1.50			
3				0.33		
4	0.15	0.18				
5	0.79	0.13	0.28	0.51		2.01
6		2.06				0.30
7						
8	2.16		0.08			
9	0.58	1.58		0.51		0.25
10	0.91			0.13		0.25
11		0.30		0.05		
12		2.16	2.01			
13	0.58		0.10			
14	1.42			0.91		
15	0.99					
16			0.33			
17		0.89				
18					1.02	
19	0.76		0.10			0.91
20		0.46				
21	0.08	1.17	0.25			
22			1.19			
23		0.05	0.13			0.03
24		0.05			0.03	0.20
25			0.61			1.22
26		1.07			0.15	
27		4.39			0.61	
28	0.36	2.69				
29	0.97					
30	0.28				0.03	
31					1.60	
TOTAL	10.03	17.17	6.58	2.90	3.40	6.17

Table A-3. Daily rainfall at Spring Hill, April to September 1990.

DATE	APR	MAY	JUN	JUL	AUG	SEP
	(cm)					
1	0.13					
2	0.05	0.79				
3	0.03	1.42	1.52			
4		0.08				
5		3.58			0.94	
6	0.66	0.10			0.86	
7	0.56	0.10				
8						
9						
10	0.23	0.81				
11	0.58			1.91		0.46
12		0.05		8.66		0.13
13		1.37		1.52		0.03
14				2.69		0.10
15	0.64		0.43			1.27
16	0.03					
17	0.30	2.06				
18	0.79		0.18			
19			0.10	0.84		
20		1.88				
21	1.47	2.97	4.32	0.66		
22	0.94	1.93	1.19	0.61		3.18
23		0.05		1.19		
24				0.25		
25						
26						
27		0.25				
28	1.40	0.30				
29	0.18	0.10				
30						
31						
TOTAL	7.98	17.86	7.75	18.34	1.80	5.16

Table A-4. Daily rainfall at Spring Hill, April to September 1991.

DATE	APR	MAY	JUN	JUL	AUG	SEP
	(cm)					
1						
2			0.13			
3				1.19		
4		0.25		0.86		
5	0.61	2.01	2.21	1.35		
6		0.08				0.03
7						
8	1.02				3.48	
9	0.86	1.57		2.36	0.05	0.10
10	1.02	0.08		0.23	2.79	0.79
11		0.15		0.10		0.03
12	1.14	0.15	0.48			
13	1.17	7.72		0.23		
14	2.11	0.05	0.33	0.03		
15	3.10				0.08	
16			0.51			0.15
17						
18		0.30		0.10	1.63	0.15
19	4.11	0.33		0.05	0.18	0.43
20	0.51	0.23			0.03	0.03
21			0.10			
22			0.30			
23			2.11			0.03
24			0.05		0.03	1.78
25			0.03	0.81		3.81
26		3.51	0.08		0.33	
27		2.11			2.06	
28	0.86	1.55			0.03	
29	5.38	0.86			0.23	
30	0.36				0.03	
31						
TOTAL	22.25	20.96	6.32	7.32	10.92	7.32

Table A-5. Daily rainfall at Knoxville, April to September 1990.

DATE	APR	MAY	JUN	JUL	AUG	SEP
			(cm)			
1						
2		2.41		0.66		
3			0.20			
4		1.58	0.36			
5		1.02			4.75	
6	0.18				1.07	
7	1.83	0.10				
8						0.08
9						
10		1.83	0.74			
11	1.09	0.05		0.10		
12				0.25		
13				1.65		5.59
14				8.48	0.69	0.05
15	0.58		0.13	3.89		3.43
16						
17		3.05				
18	0.91	0.03				
19						
20		0.05		0.08		0.10
21	0.18	0.10		0.10		
22	0.48	0.20		1.02	1.32	2.11
23			1.22	1.07	0.25	
24					0.03	
25						
26						
27		1.85				
28		1.14				
29	1.30	1.85				
30					0.18	
31						
TOTAL	6.55	15.27	2.64	17.30	8.28	11.35

Table A-6. Daily rainfall at Knoxville, April to September 1991.

DATE	APR	MAY	JUN	JUL	AUG	SEP
	(cm)					
1		0.08	0.41			
2						
3			1.73	2.16		2.87
4			1.25	0.08		
5	0.99			2.36		
6	0.10	0.79		0.25		
7						0.74
8					2.41	
9	1.19	0.25			3.12	
10	0.64	0.03			2.72	
11				0.05	0.15	0.18
12		1.47				0.61
13	0.86	2.97	2.82	1.30		
14	0.08				0.15	
15	0.10		0.03		2.29	
16				0.64	0.03	
17		0.38		0.13		
18			0.89	0.08	0.36	
19	0.89					2.92
20	0.86	3.73	0.03		2.16	0.76
21	0.03	0.05				
22			0.13			
23			0.97			
24						
25			0.31	0.56		3.89
26			3.12		0.48	0.53
27		0.79	0.03	0.03	1.68	
28	0.86	2.29				
29	0.10	0.76		0.25		
30	1.45	0.56			1.75	
31						
TOTAL	8.15	14.15	11.68	7.87	17.30	12.50

APPENDIX B

COMMON AND CHEMICAL NAMES OF HERBICIDES

APPENDIX B

Table B-1. Common and chemical names of herbicides referred to in this thesis.

COMMON/TRADE NAME	CHEMICAL NAME
alachlor (Lasso)	2-chloro-N-(2,6-diethyl-phenyl)-N-(methoxy-methyl)acetamide
atrazine (AAtrex, Atrazine)	6-chloro-N-ethyl-N'-(1-methylethyl) -1,3,5-triazine-2,4-diamine
bensulfuron (Londax)	2-[[[[[(4,6-dimethoxy-2-pyrimidinyl) amino]carbonyl]amino]sulfonyl]methyl] benzoic acid
chlorimuron (Classic)	2-[[[[(4-chloro-6-methoxy 2-pyrimidinyl)amino]carbonyl]amino] sulfonyl]benzoic acid
chlorsulfuron (Glean)	2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzene-sulfonamide
dichlormid (safener)	2,2-dichloro-N,N-di-2-propenylacetamide
dietholate (extender)	0,0-diethyl 0-phenol phosphorothioate
DPX-E9636	N-((4,6-dimethoxypyrimidin-2-yl)-amino-carbonyl)-3-(ethysulfonyl)-2-pyridinesulfonamide
EPTC (Eradicane, Eptam, Genep)	S-ethyl dipropylthiocarbamate
fluazifop-P (Fusilade 2000)	(R)-2-[4-[[5-(triflouro-methyl)-2-pyridinyl]oxy]phenoxy]propanoic acid
glyphosate (Roundup,Rodeo)	N-phosphonomethyl glycine
metsulfuron (Ally, Escort)	methyl 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino]carbonyl] amino] sulfonyl]benzoate

Table B-1. Common and chemical names of herbicides referred to in this thesis (continued)

COMMON/TRADE NAME	CHEMICAL NAME
nicosulfuron (Accent)	2-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino] carbonyl]amino]sulfonyl]-N,N-dimethyl-3-pyridinecarboxamide
primisulfuron (Beacon)	2-[[[[[4,6-bis(diflouromethoxy)-2-pyrimidinyl]amino]carbonyl]amino] sulfonyl]benzoic acid
quizalofop (Assure)	(±)-2-[4[(6-chloro-2-quinoxa(inl)oxy] phenoxy]propanoic acid
sethoxydim (Poast, Poast Plus)	2-[1-(ethoxyamino)butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one
sulfometuron (Oust)	2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino] carbonyl]amino]sulfonyl]benzoic acid
thifensulfuron (Pinnacle)	3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)triazin-2-yl)amino]carbonyl] amino]sulfonyl]-2-thiophenecarboxylicacid
triasulfuron (Amber)	2-(2-chloroethoxy)-N-[[(4-methyl-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]benzene-sulfonamide

VITA

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