EVALUATION OF PREEMERGENCE HERBICIDES FOR SEEDLING JOHNSONGRASS (*SORGHUM HALEPENSE* (L.) PERS.) CONTROL

By

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CHAPTER I

INTRODUCTION

Johnsongrass (*Sorghum halepense* (L.) Pers.) is a widely distributed, perennial grass which has become a major weed problem along many Oklahoma highways. At present, numerous areas are infested by both seed and subterranean rhizomes from which new plants originate. Rapidly growing johnsongrass seedlings may generate 64.6 meters of rhizomes in 152 days, while seed yields of up to 243 grams (81,000 seeds) per plant have been documented (42, 59). Although eradication by chemical or mechanical means appears improbable, successful rhizomatous and seedling johnsongrass control has been achieved utilizing postemergence and preemergence herbicide applications respectively (2, 3, 13, 23). Timing of herbicide treatments to rights-of-way vegetation varies as Oklahoma State Highway Department manpower availability fluctuates throughout the year.

This research was conducted to (1) evaluate several preemergence herbicides for seedling johnsongrass control, (2) determine the influence of date of application on herbicide performance, and (3) observe herbicide phytoactivity to common bermudagrass (*Cynodon dactylon* (L.) Pers.), a prominant species existing adjacent to the roadside.

CHAPTER II

REVIEW OF LITERATURE

Cytological and genetical evidence supports the hypothesis that johnsongrass (Sorghum halepense (L.) Pers.) evolved as a result of the spontaneous chromosome doubling of a natural hybrid between Sorghum vulgare and Sorghum virgatum in the Mediterranean region of North Africa (10, 67).

Although it is generally agreed that johnsongrass became established within the United States early in the nineteenth century, documentation of the initial introduction and subsequent distribution was hampered by the use of more than 40 common names for the weed species. A letter written by Herbert Post of Selma, Alabama in 1874 to George Vasey, an employee of the U. S. Department of Agriculture, prompted the adoption of johnsongrass as the national common name, derived from that of William Johnson an agriculturalist of Marion Junction, Alabama (62). The first report on the control of johnsongrass was published by C. R. Ball in 1902 (7, as cited in 62).

Growth and Development

Timing of herbicide applications for the effective control of an annual or perennial weed is usually dependent upon some critical stage in the life cycle. A number of researchers have monitored the growth and development of the johnsongrass plant.

Oyer, Gries, and Rogers (70) noted the similarity between johnsongrass plants grown from both seeds and rhizomes under Indiana conditions. Growth of rhizomes originated from the apical or axillary buds of rhizomes produced the previous year. Upon reaching the soil line, these new rhizomes became aerial culms and generated crowns and tillers. Rhizome initiation of seedling plants occurred at the seven-leaf growth stage. Development of rhizomes appeared more closely correlated to topgrowth than time from seeding.

McWhorter (59) reported the presence of a rhizome spur on a number of johnsongrass seedlings as early as 18 days after emergence. Rhizome expansion was generally slow in comparison to topgrowth. Seed stalk initiation from newly formed crowns occurred at an average of 27 days following emergence, with early bloom stage at 46 days. Rhizome production accelerated with the start of blooming, however as leaf growth rate increased, the rate of increase decreased progressively. One-hundred-forty-two days following emergence, the average johnsongrass plant produced 64.6 m and 8070 g of rhizomes. One dissimilarity between plants originating from rhizomes and those grown from seed was the availability of an energy reserve within the rhizome during the first 19 to 24 days of growth.

During an investigation of the early development of johnsongrass grown during an Israeli warm season, Horowitz (41) observed the initiation of rhizome formation, tillering, and flowering approximately 2 months following planting of both single-node rhizome fragments and seed. The minimum temperature for rhizome formation was between 15 C and 20 C, with a maximum of nearly 30 C. Rhizome sprouting was slow below 20 C and greatest at 28 C.

The spatial development of johnsongrass from small plants grown without weed competition was mapped at a later date (42). Plants spread by rhizomes from which aerial shoots arose, and tillering on all sides resulting in the formation of clumps. Johnsongrass seedlings were removed. Patches encompassed a mean area of 17 m^2 after 2.5 years. Seed production averaging 84 g (28,000 seeds) and a shoot density of $190/m^2$ was recorded during the second summer of growth.

Seedling johnsongrass development as influenced by planting date was examined by Keeley and Thullen (49). When seed was planted at monthly intervals from March through October, emergence as early as mid-March at a soil temperature of 15 C at 5 cm was reported. Decreasing temperatures enhanced seedling emergence and establishment, as plantings of April through August generated 10 to 20 times greater total fresh weight than those of September or March. Seedlings emerging in September produced rhizomes and a number of viable seeds before the "killing" frost of November. The potential for production of 2 generations from seed during the warm season is evident.

In order to determine the effect of light intensity and temperature on growth and development of johnsongrass, McWhorter and Jordan (64) observed plants grown at 9, 13, and 19 klux illumination, at 24 C, 32 C, and 40 C for 4, 8, and 12 weeks. Maximum growth and development after 12 weeks occurred at 19 klux and 32 C, while most leaf growth was obtained at 9 klux and 32 C. Development of rhizomes and roots increased with greater light intensity. Results indicate that johnsongrass changes morphologically when subjected to varying environmental conditions.

Based on observations of johnsongrass growth under controlled conditions, Ingle and Rogers (45) suggest that rhizome production is a function of topgrowth and not specifically linked to flowering. Both light and temperature influenced rhizome sprouting, with vegetative growth proportional to photoperiod. Flowering decreased when plants were grown under 8-hr. rather than 12-hr. daylight, and was lacking at both the 14-hr. and 16-hr. photoperiod.

Friedman and Horowitz (30) demonstrated the phytotoxicity of johnsongrass subterranean residues. Aqueous extracts from soil incubated with rhizome fragments for 2 and 4 months inhibited radicle extension of wheat (cv. Dwarf 68), black mustard (cv. Alsace), and barley (cv. Esperanza). The bioactivity of soil from which incubated residues had been removed after 1, 2, and 3 months was also analyzed (43). Retarded germination and topgrowth suppression of barley (*Hordeum distichum* L. cv. Esperanza) resulted due to subterranean tissue decay.

Variation

Numerous investigators report that johnsongrass hybridizes with additional sorghum species to form genetically variable ecotypes (10, 18, 34).

Differences in floret production from 87 to 352 sessile spikelets for panicles of 16 johnsongrass strains were reported by McWhorter (61). Branchlet number and arrangement within panicles also varied. Incidence of seed shattering ranged from 1% to 73%. Fluctuations in plant height from 128 cm to 212 cm and culm densities from $65/m^2$ to $226/m^2$ were recorded for 37 morphologically distinct ecotypes.

Both foreign and domestic johnsongrass ecotypes varied in response to postemergence, topically-applied dalapon (2,2-dichloropropionic acid) (60). Leaf length and width, culm density, and plant height appeared independent from degree of herbicidal control.

Research conducted by Burt (17) on the growth and development of johnsongrass clones from 4 regions within the United States supports the theory of the existence of latitudinal ecotypes. Plants obtained from southern regions flowered later than those of the higher latitudes. Variations in culm number, plant height, and rhizome, shoot, and root weight were detected. A correlation between dalapon susceptibility and johnsongrass source was not apparent.

The morphological development and anatomy of 3 dalapon resistant and 3 susceptible johnsongrass ecotypes was compared by McWhorter and Jordan (63). Lower dry and wet rhizome and culm weights, and fewer rhizome nodes were produced by the 12 tolerant strains, while rhizome internodes were shorter and moisture content at 8 to 10 weeks was lower in plants susceptible to dalapon. Proof that these variables are directly linked to ecotype susceptibility or resistance is lacking.

Variations in seed dormancy and germination in 44 johnsongrass ecotypes were examined by Taylorson and McWhorter (88). Seed germination in darkness at 35 C was lower than 10% for 29 strains and between 10% and 20% for 5 morphologically distinct species. With alternating temperatures of 25 C to 40 C, dark germinations of 79% for a Mississippi ecotype, and 44% for a California selection were recorded after 14 days. Seed of one ecotype yielded a 61% dark germination at 20 C after a 5 C pretreatment for 20 days followed by a 2-hr. high temperature shift to 40 C. In comparison, seed germinations of 2% with no temperature shift or prechill treatment, and 11% following a 2 week, 10 C pretreatment with no temperature shift were observed for the same clone. When prechilled seeds of both a Mississippi and Arkansas strain were subjected to a temperature shift and exposed to red light, a 50% germination reduction was evident. Consistent similarities of dark germination of seed collected from 12 vegetatively propagated johnsongrass ecotypes in each of 2 years suggest the probable genetic regulation of seed dormancy.

A 50 year seed longevity investigation was initiated in 1972 on a Bosket sandy loam soil (59% sand, 32% silt, 9% clay, pH 7.7) at Stoneville, Mississippi (26). Johnsongrass seed displayed a mean viability of 62% for 8, 23, and 38 cm soil depths after 30 months. Preemergence herbicidal applications which successfully control seedlings reduce the potential for johnsongrass infestation.

Atrazine

Several substituted _s_-triazines exihibit both preemergence and postemergence herbicidal activity. Atrazine (2-chloro-4-ethylamino-6-isopropylamino-_s_-triazine) is utilized for the control of many annual broadleaf weeds and grasses in certain crops, rangeland, and turfgrass. Selectivity may be attributed to metabolism and detoxication of the herbicide within the plant (81).

Negi, Funderburk, Jr., and Davis (68) researched the metabolism of C^{14} labelled (specific activity 15 microcurries/mg) and unlabelled atrazine in susceptible and tolerant species. Hydroxyatrazine as well as atrazine was detected in all plants following a preemergence application of 1 lb/A. Susceptibility was directly correlated with undegraded herbicide, rather than absorption.

The role of N-dealkylation and atrazine resistance in higher plants was contemplated by Shimabukuro (80). Atrazine metabolism was observed in highly susceptible soybean (*Glycine max* Merril. var. Hawkeye) and wheat (*Triticum vulgare* Vill. var. Justin), intermediatly susceptible pea (*Pisum sativum* L. var. Little Marvel), and resistant sorghum (*Sorghum vulgare* Pers. var. North Dakota 104) and corn (*Zea mays* L. North Dakota KE 47101). Initial metabolite production via N-dealkylation of either substituted alkylamine group of the parent molecule occurred in all species. In sorghum, resistance appeared as a direct result of rapid metabolism of dealkylation products to non-phytoxic, water-soluble atrazine derivatives, while tolerance demonstrated by corn was closely linked to hydroxylation reactions.

Further research elucidated the principal mode of action of the substituted -*s*-chlorotriazine (81). Inhibition of the Hill reaction and noncyclic photophosphorylation was observed, yet cyclic photophosphorylation remained unaffected. Although chloroplasts of both resistant and susceptible species contained atrazine, metabolism outside the chloroplast appeared responsible for recovery of photosynthesis and reduced inhibitor concentration within.

An investigation to determine the effect of atrazine on nitrogen metabolism of johnsongrass was conducted by Gramlich and Davis (33). Preemergence atrazine treatments of 2, 4, and 16 lb/A were applied to a Norfolk sandy loam soil planted to johnsongrass. Plants subjected to the high application rate and harvested after 13 and 28 days contained significantly less nitrogen (mg/plant) than untreated checks. Atrazine treatments of 2 and 4 lb/A did not affect nitrogen percentages of plants removed 28 days after application.

Dissipation of atrazine from the same soil type by corn, sorghum, and johnsongrass was measured by Sikka and Davis (82). Residues remaining in the soil at a 0 to 6 in. depth resulting from preemergence atrazine applications of 2, 4, and 16 lb/A were significantly less for johnsongrass and corn field plots than corresponding fallow areas after 1, 2, 3, and 6 months.

Birk and Roadhouse (11) described persistence and mobility of atrazine in a Guelph loam soil. June 8, 1960 applications of 10 lb ai/A generated soil residue levels of .06 lb/A at a 4 to 6 in. depth on August 24, 1960, and 0.73 lb/A at 0 to 4 in. on May 22, 1961. Both rainfall amount and intensity appeared critical to soil penetration of this relatively water-insoluble (33 ppmw [6] at 27 C) chemical.

Atrazine adsorption from aqueous solution by muck soil (pH 3.2), bentonite (pH 4.1, 8.2), a cation exchanger (pH 3.7), and an anion exchanger (pH 6.1) was investigated by Harris and Warren (36). Herbicide was adsorbed by both the anion and cation exchanger, as well as the organic soil. Increasing bentonite pH led to decreased atrazine adsorption, with greater adsorption by bentonite (pH 8.2) at 0 C than 50 C.

Following a review of soil and climatic effects on herbicide dissipation, Burnside et al. (16) proposed that soil textural variation influenced atrazine residue levels greater than climatic differences across Nebraska from 1962 to 1968. Herbicide carryover was less in fine rather than coarse-textured soils of eastern Nebraska.

According to Kearny, Sheets, and Smith (48) soil type and temperature influence atrazine vaporization. More than half of a 3 lb/A application to Bosket loam, Cecil sandy loam, and Tifton loamy sand was lost after 72-hr. at 45 C. Greater herbicide losses were recorded from moist rather than dry Tifton loamy sand at the same temperature.

Buchanan and Hiltbold (14) considered the influence of soil incorporation and timing of application on persistence and activity of atrazine. April and May treatments of 2.8 and 5.6 kg/ha to Cahaba fine sandy loam soil degraded more rapidly than those of February and March. Atrazine displayed an average 20 day half-life from February to July. In contrast, prevention of cucumber seedling growth for 9 weeks at 25 C following applications of 4 lb ai/A to an Arrendondo loamy fine sand (pH 5.1) was previously reported (15).

Carbon dioxide evolution from 2 atrazine treated (10 ppmw) soils was traced by McCormick and Hiltbold (57). Herbicide inactivation occurred in direct proportion to degradation of soil organic matter. Glucose additions as well as increasing temperatures accelerated herbicide decomposition suggesting incidental involvement in microbial metobolism. After 40 days, 0.35% ring carbon evolved as carbon dioxide from Decatur clay loam soil.

Preemergence atrazine plus chloroacetamide herbicide combinations are effective for the control of numerous annual grass and broadleaf weeds (4, 77).

Metolachlor

Pillai and Davis (73) determined the effect of metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide) on respiration and photosynthesis of chlorella at 25 C. Metolachlor concentrations of 1 x 10^{-4} M reduced photosynthesis 33% after 120 min. Accelerated respiration of chlorella and mitochondria isolated from bean (*Phaseolus vulgaris* L.) seedlings occurred at concentrations ranging from 1 x 10^{-8} to 1 x 10^{-5} M. Further investigation (74) revealed a significant loss of previously absorbed ^{32}P from cotton (*Gossypium hirsutum* L.) roots following exposure to 10^{-4} and 10^{-5} M concentrations, while roots of soybean appeared unaffected. Herbicide susceptibility was directly correlated to loss of ^{32}P.

Diner, Truelove, and Davis (25) report the inhibition of phosphatidyl choline synthesis and reduced total lipid production in cotton (var. DPL M-8) root tips at 10^{-4} M metolachlor concentrations.

Absorption and translocation of ^{14}C-metolachlor, or its radiolabelled metobolites, was examined by Ahrens and Davis (1). In sorghum (*Sorghum bicolor*, 'Funks BR-79') and corn (var. Pioneer 3369A) seedlings, labelled material moved from the 1 x 10^{-4} M herbicide concentration through roots to shoots within 3 h. Greatest accumulation was visible in major veins of older leaves. Herbicide was readily translocated to soybean shoots, with slight accumulation in the culm apex, cotyledons, and younger leaves.

Pillai, Davis, and Truelove (75) found germination inhibition of peanut (*Arachis hypogaea* L. 'Florunner'), barley (var. Barsoy), and oat (*Avena sativa* L. 'Coker 227') at metolachlor concentrations of 1 x 10^{-4} M. Exposure to 1 x 10^{-5} M herbicide concentrations reduced soybean (var. Ransom), radish (*Raphanus sativus* L. 'Scarlet Globe'), English pea (*Pisum sativum* L. 'Thomas Laxton'), and cucumber (*Cucumis sativus* L. 'Ashley') root length more than 33%. Decreased leucine uptake by cucumber root tips was observed at the same concentration. Preemergence metolachlor treatments of 1 kg/ha exhibited no effect on barley and corn seedling establishment when applied to the root and seed zone. Reduced seedling height and dry weight occurred in both species following application to the shoot region.

The effect of varying metolachlor concentration and duration on oat (var. Victory) and pea (var. Alaska) root growth, cell division, and cell enlargement was analyzed by Deal and Hess (24). Lateral root growth suppression was noted in both oat and pea seedlings exposed to metolachlor concentrations of 1 x 10^{-6} M for 6 h, and 5 x 10^{-6} M for 24 h respectively. Oat cell division was hindered at a 1 x 10^{-7} M concentration after 30 h, compared to significant inhibition in peas at a concentration of 1 x 10^{-5} M after 48 h. Herbicide treatment appeared to repress the onset of mitosis. Metolachlor concentrations of 5 x 10^{-5} M significantly reduced (31%) oat coleoptile cell enlargement.

Metolachlor dissipation from Dunbar fine sandy loam and Cecil sandy loam soil was observed by Skipper, Gossett, and Smith (83). Approximate residue levels of 2 ± lb/A were detected 3 and 5 weeks following herbicide applications of 6 lb/A to the Dunbar soil (1.6% organic matter). No apparent metolachlor residue remained in the Cecil soil (2.3% organic matter) at 4 or 8 weeks after treatments of 6 and 4 lb/A. Leaching appeared to be a significant factor in dissipation and reduced phytotoxicity of metolachlor (water solubility 530 ppm [6] at 20 C).

The role of microbial decomposition in metolachlor persistence and activity is obscure. A general pattern of metolachlor metabolism by resting cells of the soil fungus Chaetomium globosum was proposed by McGahan and Tiedje (58). The compounds 2-chloro-N-(2'-ethyl-6'-methylpenyl)acetamide and 2-chloro-N-(2'-ethyl-6'-methylphenyl)-N-(2-hydroxy-1-methylethyl)acetamide were identified as degradation products. Forty-four percent of the parent molecule was present following a 144 h incubation period.

Higgins, Schnappinger, and Pruss (39) suggest that overall performance of preemergence metolachlor applications may be dependent on soil organic matter content.

Alachlor

Alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide), another member of the chloroacetamide herbicide group, inhibits emergence and establishment of various annual grass and broadleaf weed seedlings including goosegrass (*Eleusine indica* (L.) Gaertn.), barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.), and redroot pigweed (*Amaranthus retroflexus* L.) (5).

Absorption and translocation of ^{14}C-alachlor in wheat and soybean was compared by Chandler, Basler, and Santelmann (19). Uptake and translocation of root-applied alachlor was lower for soybean (resistant) than wheat (susceptible), with greater accumulation in older leaves of both species. Absorption equilibrium by excised wheat root tissue was reached after 4-hr., while excised leaf tissue absorption proceeded beyond 32-hr.

The effects of alachlor on wheat nitrogen metabolism were also determined (20). Plants exposed to 0.5 mM alachlor concentrations for 17-hr. displayed decreased nitrate levels. Amino acid content and nitrate reductase activity decreased with increased exposure time. Herbicide concentrations of 0.5, 0.05, and 0.005 mM did not inhibit the Hill reaction in isolated wheat chloroplasts.

Growth responses of oat seedlings to varying alachlor concentrations were recorded by Chang, Marsh, Jr., and Jennings (21). Growth repression occurred over a 10^{-3} to 10^{-6} M herbicide concentration range.

A 10^{-3} M gibberellic acid treatment 24-hr. prior to alachlor (5×10^{-6} M) exposure reduced the extent of growth inhibition, while indoleacetic acid applications demonstrated no effect. Additional investigation (54) revealed the restriction of mitotic activity, root elongation, and cortical cell enlargement by 10^{-4} M herbicide concentrations. Leucine uptake and incorporation into protein was reduced, while membrane permeability and respiration remained unaltered. Decreased water utilization following sub-lethal alachlor applications was apparently due to impaired root growth (55).

According to Rao and Duke (78), alachlor hinders the gibberellic acid-induced synthesis of alpha-amylase and protease in deembryonated seed of barley (var. Schuyler). A 3.7×10^{-5} M alachlor concentration reduced the manufacture of protease and alpha-amylase 55% and 26% respectively, at an optimum gibberellic acid concentration (2.9 μM). Although inhibition of protease and alpha-amylase production was reversed at gibberellic acid concentrations of 5.8 and 14.5 μM, seed germination and plant growth remained suppressed.

Eshel (27) examined alachlor phytotoxicity, site of uptake, and mobility in clay (pH 7.4), clay loam (pH 8.0), sand (pH 7.5), and sandy loam (pH 8.1) soils. Severe reductions in total dry weight and root growth of cotton (var. Acala 4-42) occurred after herbicide absorption from the root zone. Additions of 2 in. water to soil surfaces following 1 and 2 kg/ha alachlor (water solubility 242 ppm [6] at 25 C) treatments leached most of the herbicide to a 2 to 3 in. depth, with extent of movement greater in sand and sandy loam than clay soil.

Research conducted by Hargrove and Merkle (38) demonstrates the influence of relative humidity and soil temperature on alachlor decomposition and volatilization. As relative humidity within a closed system at 38 C or 46 C declined, herbicide degradation rate accelerated, apparently due to decreased soil water film thickness and greater surface acidity. Minimum alachlor loss from a Sawyer fine sandy loam soil at 46 C was recorded between 51% and 79% relative humidity.

Alpha-chloroacetanilide herbicide dissipation rates under field conditions were determined by Beestman and Deming (9). Alachlor exihibited a half-life of 7.8 ± 0.3 days and 469 ± 5 days in viable and sterilized Ray silt soil respectively. The significant contribution of microbial decomposition to alachlor loss from soils is evident. In contrast, herbicide volatilization from air-dry Wabash silty clay soil exposed to a constant 3.2 kph, 21 C air stream for 5 weeks was less than 11%. Vaporization from continuously moist soil under similar conditions was 7.5 times greater. Photodecomposition and leaching of the herbicide was insignificant.

Alachlor degradation by the plant pathogenic fungus *Rhizoctonia solani* Kuehn was reported by Smith and Phillips (84). Although the species was incapable of utilizing the herbicide as the sole carbon source in nutrient media, alachlor was degraded following the addition of sugar.

Metribuzin

Preplant incorporated, preemergence, and postemergence metribuzin (4-amino-6-*tert*-butyl-3-(methylthio)-as-triazin-5(4*H*)-one) applications provide effective control of annual grasses and such troublesome broadleaf weeds as cocklebur (*Xanthium pensylvanicum* Wallr.), jimsonweed (*Datura stramonium* L.), and velvetleaf (*Abutilon theophrasti* Medic.) (6).

Fedtke (28) recorded the effects of the photosynthesis-inhibiting, asymetric triazine on potato (*Solanum tuberosum* L.) and wheat metabolsim. Greater soluble amino acid, protein, and nitrate concentrations in tissue of potato accompanied enhanced nitrate reductase activity following exposure to 1 ppm metribuzin. A similar response was noted when plants were grown under low light intensity. Decreased rates of photosynthesis and respiration and lower reducing sugar content occurred in treated plants of both species.

The influence of sub-lethal metribuzin concentrations on the photosynthetic membrane system of the unicellular alga *Bumilleriopsis filiformis* was investigated by Böger and Schlue (12). Cells cultivated in 2.5 x 10^{-7} M metribuzin concentrations exhibited decreased rates of photosynthesis. Recovery of photosynthetic activity occurred following cell transfer to untreated nutrient medium. Metribuzin concentrations of 3 x 10^{-7} M inhibited photosynthetic reactions of normally grown cultures by 50%.

Absorption, translocation, and metabolism of metribuzin in sugarcane (*Saccharum officinarum* L.) was traced by Hilton et al. (40). Unknown metabolites were deposited in the leaves following root absorption of labelled material and apoplastic transport in the water-nutrient system. Less than 10% of the ^{14}C was measured by gas chromatography as parent molecule and products of deamination (DA), 6-*tert*-butyl-3-(methylthio)-1,2,4-triazin-5(4H)-one; hydrolysis (DK), 4-amino-6-*tert*-butyl-1,2,4-triazine-3,5(2,4H)-dione; and the combination of deamination and hydrolysis (DADK), 6-*tert*-butyl-1,2,4-triazine-3,5(2,4H)-dione.

Tolerance of various tomato (*Lycopersicon esculentum* Mill.) cultivars to 0.5 mg/L metribuzin concentrations was documented by Stephenson, McLeod, and Phatak (86). Although herbicide susceptibility decreased with increasing seedling age at time of exposure, differential tolerance appeared dependent on rate of detoxication by conjugation within tomato leaves. Acropetal translocation and root uptake of metribuzin-carbonyl-^{14}C was similar in both 'Heinz 1706' (susceptible) and 'Fireball' (tolerant) seedlings.

Fortino, Jr. and Splittstoesser (29) determined the effect of temperature, relative humidity, and light on the toxicity of 0.3 and 0.6 kg/ha postemergence metribuzin applications to tomato (vars. Campbell 28, Campbell 1327, Heinz 1435). Herbicide tolerance decreased when plants were grown under high humidity (80%), high temperature (25.5 C), and low light intensity (5.3-klux) prior to treatment. After 24-hr., 3.5% of foliar-applied $0.1^{u}C$ metribuzin-^{14}C was absorbed by treated leaflets on the third true leaf of 'Campbell 28' plants, 15 cm in height.

Response of soybean (var. Lee 68) and hemp sesbania (*Sesbania exaltata* L.) grown in ^{14}C-metribuzin treated Commerce fine sandy loam soil was compared by Hargroder and Rogers (37). Autoradiographs indicated that soybean (tolerant) absorbed less herbicide than sesbania (susceptible). Radioactivity was rapidly transported and accumulated in all hemp sesbania leaves, while ^{14}C-metribuzin and (or) its metabolites were concentrated in roots and lower leaves of soybean. Differential susceptibility to metribuzin displayed by both species was attributed to variation in absorption, translocation, and metabolism of the herbicide.

Smith and Wilkinson (85) suggest that diverse-intraspecific responses of soybean cultivars to metribuzin may result from variable capacities for herbicide detoxication to a glucose conjugated metabolite. Further investigation revealed significant changes in total fatty acid content of oil from seed of metribuzin treated soybean cultivars (35).

The effect of herbicide rate, soil organic matter, and rainfall after treatment on soybean tolerance to preemergence metribuzin applications was examined by Coble and Schrader (22). Phytotoxicity increased when a uniform 1.25-cm simulated rainfall was administered immediately following metribuzin (water solubility 1220 ppm [6] at 20 C) treatment and every third day thereafter. Regardless of rainfall pattern, soybean tolerance to metribuzin improved with increasing soil organic matter content and decreased application rate.

Hyzak and Zimdahl (44) computed the soil-temperature-dependent degradation of metribuzin in air-dried San Luis sandy loam soil under laboratory conditions. The as-triazinone exihibited a soil half-life of 16, 46, and 377 days at 35 C, 20 C, and 5 C respectively. Metribuzin applied at 1.12 and 2.24 kg/ha to Bay Farm clay soil in the field remained in the upper 5 cm of the soil profile, with degradation paralleling that observed in the laboratory at 20 C. Nonbiological degradation of metribuzin in 4 relatively dry Manitoba soils at 15 C was reported by Webster, Sarna, and MacDonald (92).

The influence of soil pH on metribuzin activity in soil was determined by Ladlie, Meggit, and Penner (51). Reduced mobility, phytotoxicity, and microbial degradation occurred with decreasing soil pH (6.7 to 4.6) apparently resulting from protonation of the amine group of the herbicide molecule and subsequent adsorption to soil colliods. Greater metribuzin persistence was noted in field soils at all soil pH levels as sampling depth increased (52).

Savage (79) evaluated sorption equilibria and metribuzin mobility in 16 soil types as a function of soil properties. Both herbicide adsorption and movement were correlated with clay and organic matter proportion and soil moisture content at 0.33 and 15 bars tension. Metribuzin adsorption in Bosket sandy loam soil increased significantly with the addition of organic matter to a 6% level. Supplemental clay colloid appeared to decrease the organic fraction adsorbing capacity.

The effect of 100 ppmw metribuzin applications on soil microbial activity was examined by Marsh, Davies, and Grossbard (56). Stimulation of nitrogen mineralization and temporary inhibition of CO_2 evolution was recorded in herbicide treated Boddington Barn soil.

Oryzalin

Oryzalin (3,5-dinitro-$\underline{N}^4$,$\underline{N}^4$-dipropylsulfanilamide), a substituted dinitroaniline herbicide, interrupts normal root and shoot development of numerous plant species (76).

Bartels and Hilton (8) report mitotic aberrations and loss of cortical and spindle microtubules in root cells of wheat (var. Mediterranean, C.I. 5303) and corn (var. yellow dent, U.S. 13) seedlings following exposure to 1 x 10^{-4} M oryzalin concentrations. Since oryzalin did not bind to or prevent polymerization of microtubule protein, a possible mode of action appeared to be the interruption of microtubule subunit synthesis or maintenance.

The effects of oryzalin on isolated spinach (*Spinacia oleracea* L.) chloroplasts and mung bean (*Phaseolus aureus* Roxb.) mitochondria were observed by Moreland, Farmer, and Hussey (65). In chloroplasts, exposure to 60 $\underline{u}$M herbicide saturation concentrations suppressed both photoreduction and coupled phosphorylation with ferricyanide as oxidant and water the electron donor. Severe inhibition of mitochondrial electron transport with malate as substrate occurred following oryzalin application. Oxygen uptake and evolution of herbicide-treated spinach leaf discs and mung bean root tips and hypocotyls was also monitored (66). Oryzalin at 0.6 mM impaired respiration and photosynthesis both in vivo and in vitro.

According to Wang, Grooms, and Frans (91), 80 uM oryzalin concentrations interfered with the energy generating pathway of succinate oxidation in isolated mitochondrial fractions from soybean (var. Lee) hypocotyls.

Cellular responses of snap bean (var. Tenderette) and soybean (var. Corsoy) to oryzalin in a Plano silt loam soil medium were analyzed by Struckmeyer, Binning, and Harvey (87). Snap bean tissue from the swollen and brittle culm region of plants exposed to 3.4 kg/ha herbicide concentrations exhibited large, proliferated, and malformed cells. Enlarged, thin-walled primary xylem cells contained no starch. Elongated ray cells intersected vasular tissue of culms from soybean seedlings treated with 1.7 kg/ha oryzalin. Xylem elements differentiated following herbicide application appeared small and somewhat disorganized.

Uptake and intracellular binding of ^{14}C-oryzalin in pea (tolerant) and corn (sensitive) root segments was compared by Upadhyaya and Noodeñ (89). Although radiolabelled material was rapidly absorbed by root segments of both species, the accumulation ratio (internal concentration/external concentration) at 0.5 uM oryzalin concentrations was greater in corn (40) than pea (20). Oryzalin binding occurred in the particulate fraction of corn root extracts, with no apparent herbicide metabolism during the 4-hr. incubation period. Inhibition of corn root elongation and induction of swelling within the elongation zone may be distinct responses to the substituted dinitroaniline (90).

Maftoun and Bassiri (53) noted delayed seedling emergence, decreased absorption of total phosphorus and nitrogen, and growth suppression of chickpea (Cicer arietinum L.) grown in Maharloo and Kooshkak soil treated with 2 and 4 ppm oryzalin.

Numerous researchers have demonstrated the influence of environmental factors on oryzalin phytoactivity.

Twenty-six-and-six-tenths percent of radioactive-labelled 1 kg/ha oryzalin applications to air-dried Hagerstown clay loam soil thin layer plates following a 7 day irradiation was recorded by Parochetti and Dec, Jr. (71). No vapor loss of oryzalin (1.68 kg/ha) occurred from moist Lakeland soil at 50 C exposed to a constant 50 ml/minute air flow (72).

Jacques and Harvey (46) determined the influence of soil moisture on dinitroaniline herbicide phytotoxicity to oat (var. Dal) seedlings. In Plano silt loam soil containing 16.7% and 30.4% w/w water, oryzalin concentrations of 0.25 ppmw reduced mean root length 18% and 70% respectively. Oryzalin activity was reduced more at the 16.7% soil moisture level than trifluralin (α,α,α-trifluoro-2,6-dinitro-N, N-dipropyl-p-toluidine), benefin (N-butyl-N-ethyl-α,α,α-trifluoro-2,6-dinitro-p-toluidine), isopropaline (2,6-dinitro-N,N-dipropylcumidine), and dinitramine (N^4,N^4-diethyl-α,α,α-trifluoro-3,5-dinitrotoluene-2,4-diamine). An oat (var. Dal) primary root bioassay revealed that oryzalin remained biologically active for longer periods of time under cool, dry soil conditions (47). Nelson, Meggitt, and Ladlie (69) propose that effectiveness of oryzalin applications to the soil surface is dependent upon the quantity of water utilized to activate the herbicide.

Oryzalin mobility in "sandy hamra" (0.5% organic matter, pH 7.35) soil with and without surfactant was investigated by Koren (50). In air-dried soil, oryzalin (water solubility 85 ppm at 25 C) treatments of 45 kg/ha surface-applied in a 250 l/ha spray volume leached to an approximate 19 cm soil depth following a simulated rainfall of 30 ml water to each 687.2 cm^3 column. Depth of oryzalin soil penetration increased with the addition of surfactant (Tronic, Wetting Agent Ciba, or Triton X-100) at a 2% spray volume concentration.

Persistence of oryzalin in Weld loam soil (1.45% organic matter, pH 6.7) was described by Gingerich and Zimdahl (31). The aerobic half-lives for the herbicide were 1.4 months and 4.35 months at 30 C and 15 C respectively. Oryzalin degradation proceeded 4 times faster under anaerobic soil conditions.

Golab et al. (32) observed the behavior of ^{14}C-oryzalin in Crosby silt loam soil. Approximately 55% of the applied radioactivity remained within a 0 to 6 in. soil depth 12 months after the 3 lb/A herbicide treatment. Twenty-five percent of the initial radioactivity was extracted with an aqueous methanol-acetone mixture. In addition to the parent molecule, major metabolites identified by thin layer chromatography-radioactive analysis were 3,5-dinitro-$\underline{N}^4$-propylsulfanilamide (Or-2); 2-ethyl-7-nitro-1-propyl-5-sulfamoylbenzimidazole (Or-13); and 2-ethyl-7-nitro-5-sulfamoylbenzimidazole (Or-14). No degradation product comprised more than a few percent of the total radioactivity.

CHAPTER III

METHODS AND MATERIALS

Field investigations to determine the effectiveness of several preemergence herbicides for seedling johnsongrass control and phytotoxicity to established bermudagrass (*Cynodon dactylon* (L.) Pers.) stands were conducted on the Agronomy Research Station at Stillwater, Oklahoma.

Field Investigation I

Seedling Johnsongrass Control

Three commercial herbicide formulations were applied to johnsongrass seed in Kirkland silt loam (Thermic Udertic Paleustoll) soil with a pH of 6.3, and 1.6% organic matter content. An untreated check was utilized as a standard. Herbicides and rates evaluated are presented in the Appendix, Table I.

Johnsongrass seed was planted May 1, 1979, at a 16.8 kg/ha rate in 3 rows 30.5 cm apart. The Planet Jr. Planter (orifice #18) deposited seed at a 1.3 cm to 1.6 cm soil depth on the 0 to 2% slope. Tillage operations prior to seeding included plowing to a 20 cm depth, and rototilling the top 10 cm of soil.

Atrazine and the atrazine plus metolachlor combination were applied to the soil surface immediately using a hand-held, 2-nozzle boom, CO_2 sprayer calibrated to deliver 1122.6 l/ha solution through 8004 spray tips at 0.77 km/hr and 1.4 bars pressure. Appropriate quantities of metolachlor granules were distributed uniformly over the corresponding 0.835 m^2 treatment areas. Rainfall accounted for the only water received by the plots.

A randomized complete block field design was employed with 3 replications. Borders 91.4 cm in width encircled individual replications with 91.4 cm by 91.4 cm interior plots aligned north to south.

Herbicide effectiveness was determined by occular estimates of seedling johnsongrass control recorded May 31, and June 22, 1979. Method of evaluation was based on a scale of 0 to 10 with 10 indicating superior, and 0, no control.

Phytotoxicity to Bermudagrass

Duplicate herbicide treatments were applied May 1, 1979 as described previously, to actively growing bermudagrass turf of uniform quality 4.4 cm in height on Kirkland silt loam soil (pH 7.0, 2.1% organic matter) with less than 2% slope. No supplemental irrigation was provided.

The investigation was conducted as a randomized complete block design with 61 cm borders dividing each of 3 replications. Plots 91.4 cm by 91.4 cm were in line north to south within the replications.

Herbicide phytotoxicity to bermudagrass as determined by occular analysis of plant shoots on May 4, May 8, and May 15, 1979, was classified on a 1 to 10 scale with 10 representing total discoloration, and 1, no effect.

Field Investigation II

Seedling Johnsongrass Control

Five herbicides administered at 3 rates and 5 application dates were evaluated for control of seedling johnsongrass (Appendix, Table II).

The experiment was conducted according to a split plot design with the main plots in a randomized block. The main plot treatment factor was herbicide treatment and the sub-plot treatment factor was application date. Three replications were aligned north to south over the test site. Borders 91.4 cm wide encircled each of sixteen 91.4 cm by 508 cm main plots containing five 91.4 cm by 101.6 cm sub-plots arranged at random in line east to west.

Johnsongrass seed was planted November 15, 1979 at a 1.3 cm to 1.6 cm depth in Kirkland silt loam soil (pH 6.8, 1.4% organic matter) with less than 2% slope using a Planet Jr. planter to distribute 16.8 kg/ha at 4 km/hr in 3 rows 30.5 cm apart. Seedbed preparation entailed plowing and rototilling to a 20 cm and 10 cm soil depth respectively.

Emulsifiable concentrate, wettable powder, and liquid herbicide formulations were applied in water using a hand-held, 2-nozzle boom, CO_2 sprayer calibrated to deliver 935.5 l/ha through 8004 spray tips at 1.7 bars pressure and 1.5 km/hr. Granular metolachlor applications were broadcast uniformly using a perforated, cylindrical shaker 8.9 cm in diameter. The 22.9 m by 24.9 m experimental area was not irrigated.

Herbicide evaluation was based on johnsongrass plant number per main plot and sub-plot recorded June 4, 1980, approximately 51 days following seedling emergence.

Phytotoxicity to Bermudagrass

Duplicate herbicide treatments were applied August 29, 1980 to actively growing bermudagrass turf 3.8 cm in height on Kirkland silt loam soil (pH 6.2, 1.7% organic matter) with 0 to 2% slope. Metribuzin, alachlor, oryzalin, and the atrazine plus metolachlor combination were applied in water using a hand-held, 2-nozzle boom, CO_2 sprayer. Herbicide solutions of 374.2 l/ha were dispatched through 8001.5 spray tips at 1.4 km/hr and 1.7 bars pressure. A perforated cylindrical shaker 8.9 cm in diameter was used to uniformly distribute the granular metolachlor formulation. The entire experimental area received 0.6 cm irrigation water on August 30, 1980 to supplement natural rainfall.

The investigation was conducted as a randomized complete block design with three replications. Borders 91.4 cm in width encircled each replication with 91.4 cm by 101.6 cm interior plots randomly aligned north to south.

Herbicide phytotoxicity was determined September 5, and September 19, 1980 by occular examination of bermudagrass shoots. Method of evaluation was based on a 1 to 10 scale with 10 indicating total dessication and 1, no herbicidal effect.

Daily precipitation and maximum and minimum air temperatures from data recorded at the Agronomy Research Station are reported for the duration of field investigations I and II in the Appendix, Table III.

CHAPTER IV

RESULTS AND DISCUSSION

Field Investigation I

Seedling Johnsongrass Control

Analysis of variance of data obtained May 31, 1979, as presented in the Appendix, Table IV indicates highly significant differences at the 1% level among herbicide treatments, while no significant differences occurred among the three replications.

Atrazine plus metolachlor applied at 3.00 + 3.75 kg ai/ha and atrazine treatments of both 2.27 and 4.54 kg ai/ha exhibited highest (9.67) and lowest (1.67) evaluation means respectively (Figure 1).

No significant differences (.05) in seedling johnsongrass control were detected among 2.27, 2.55, and 2.84 kg ai/ha metolachlor treatments and atrazine plus metolachlor combinations of 2.00 + 2.50, and 3.00 + 3.75 kg ai/ha as determined by Duncan's multiple range test (Appendix, Table V). No significant differences at the 5% level were apparent among atrazine treatments of 2.27 and 4.54 kg ai/ha and the untreated check.

Significant differences at the 1% level among herbicides evaluated for control of johnsongrass seedlings are evident upon analysis of variance of data recorded June 22, 1979, and presented in the Appendix, Table VI.

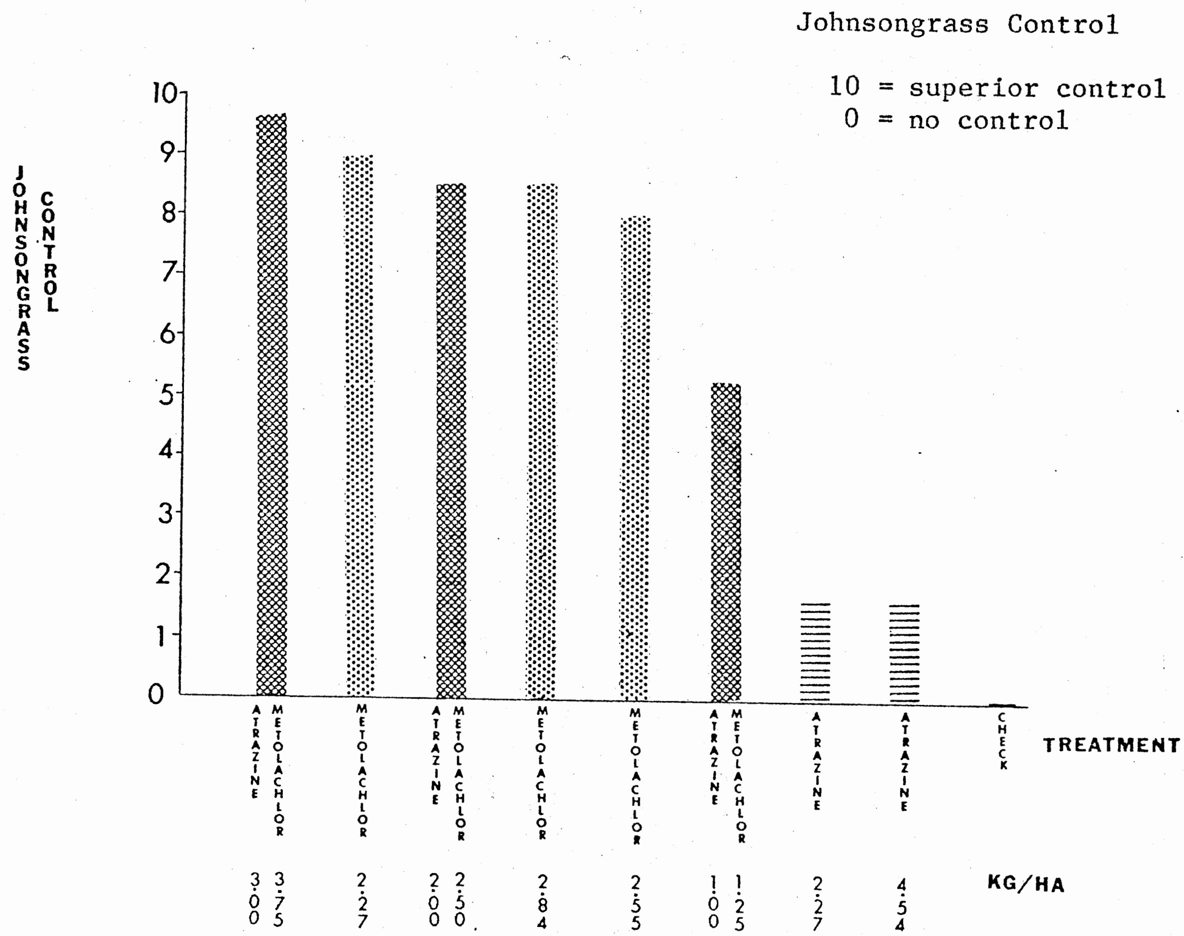

Figure 1. Herbicide Evaluation Means for Seedling Johnsongrass Control, May 31, 1979

Atrazine plus metolachlor applications of 3.00 + 3.75 kg ai/ha yielded the highest mean (9.67), with the 2.27 kg ai/ha atrazine treatment mean of 0.33 lowest (Figure 2).

Metolachlor at 2.27, 2.55, and 2.84 kg ai/ha, and atrazine plus metolachlor treatments of 1.00 + 1.25, 2.00 + 2.50, and 3.00 + 3.75 kg ai/ha afforded significantly greater (.05) seedling johnsongrass control than atrazine applied at 2.27 and 4.54 kg ai/ha, and the untreated check as demonstrated by Duncan's multiple range test (Appendix, Table VII).

<u>Phytotoxicity to Bermudagrass</u>

Visual inspection of treated bermudagrass shoots on May 4, May 8, and May 15, 1979, following May 1, 1979 foliar applications of 2.27 and 4.54 kg ai/ha atrazine, 2.27, 2.55, and 2.84 kg ai/ha metolachlor, and 1.00 + 1.25, 2.00 + 2.50, and 3.00 + 3.75 kg ai/ha atrazine plus metoachlor revealed no phytotoxic effect.

Field Investigation II

<u>Seedling Johnsongrass Control</u>

Analysis of variance of herbicide evaluation data collected June 4, 1980 is presented in the Appendix, Table VIII. Highly significant differences at the 1% level are noted for herbicide treatment and application date means, and herbicide treatment x application date interaction. Error terms in the statistical examination of the split plot field design utilized are designated Error a and Error b for clarity.

Oryzalin applied at 4.54 kg ai/ha displayed the lowest mean johnsongrass seedling count total, with the 0.28 kg ai/ha metribuzin treatment mean of 30.67 highest (Figure 3).

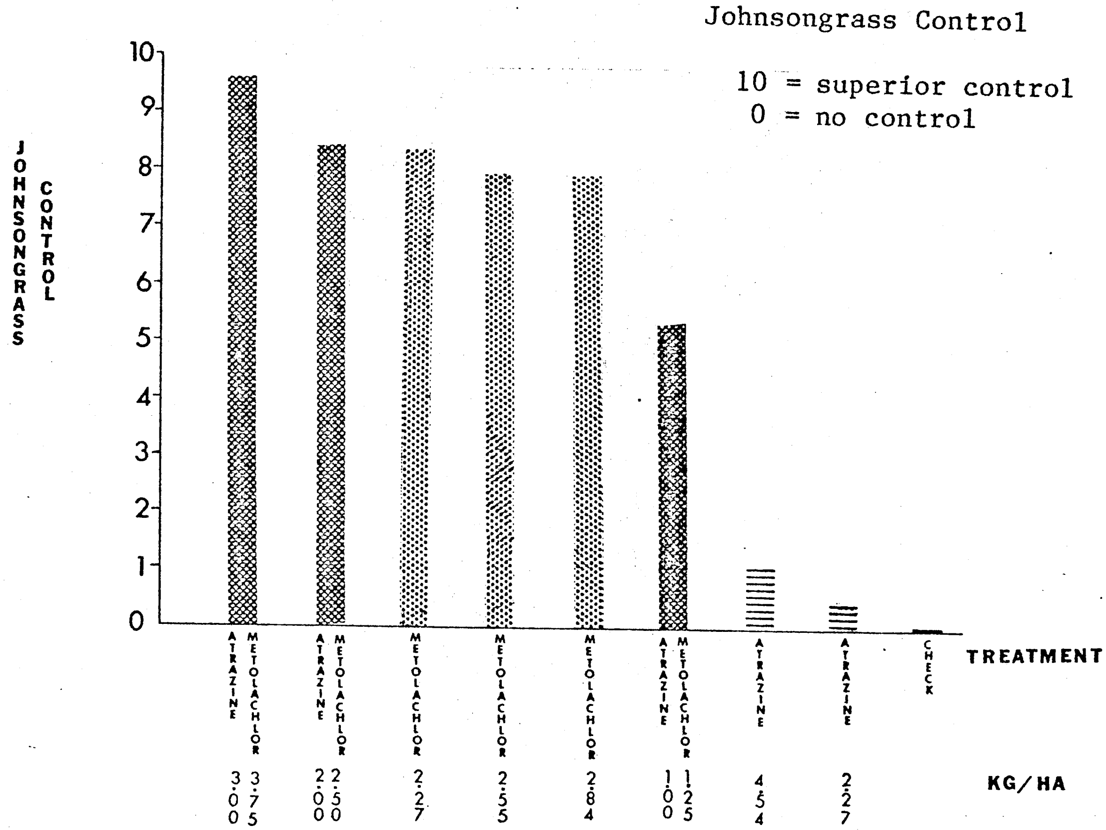

Figure 2. Herbicide Evaluation Means for Seedling Johnsongrass Control, June 22, 1979

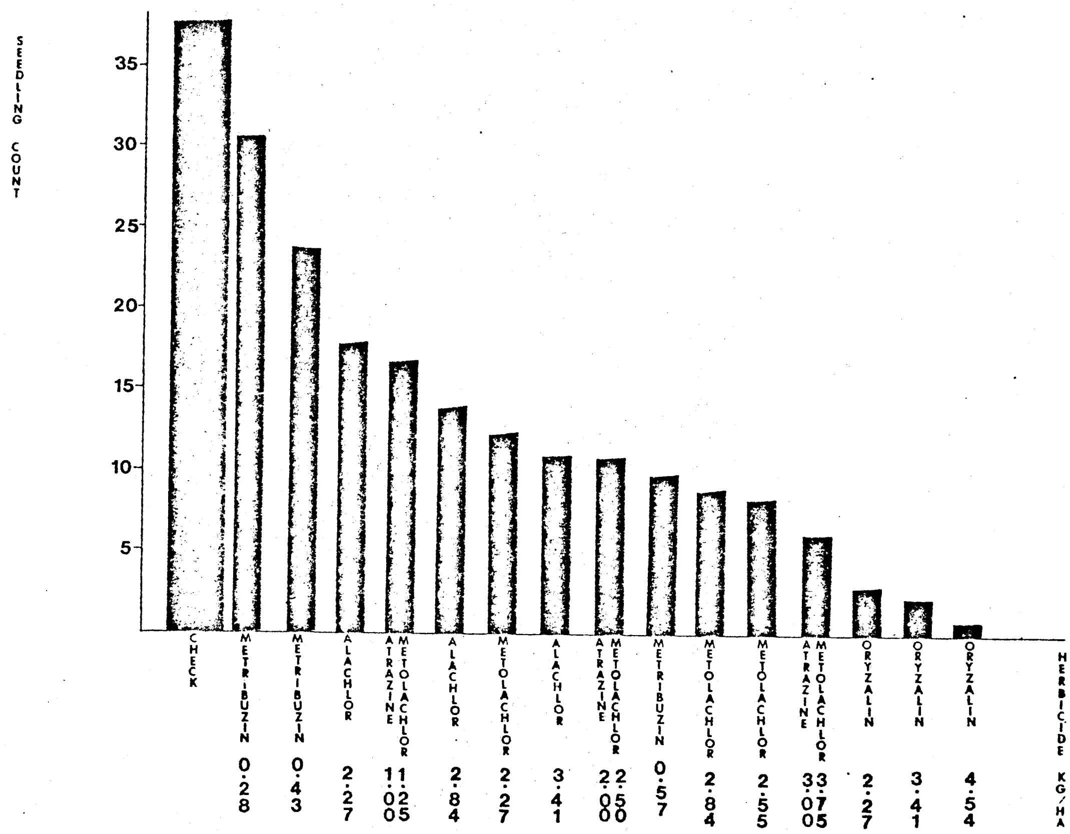

Figure 3. Mean Seedling Johnsongrass Counts for Herbicide Treatments

Metolachlor applications of 2.55 and 2.84 kg ai/ha, oryzalin at 2.27, 3.41, and 4.54 kg ai/ha, and atrazine plus metolachlor at 3.00 + 3.75 kg ai/ha provided most acceptable (75%+) seedling johnsongrass control. No significant differences at the 5% level occurred among these treatments as evidenced by Duncan's multiple range test (Appendix, Table IX). The 0.28 kg ai/ha metribuzin application did not differ significantly (.05) in comparison to the untreated check.

Mean seedling johnsongrass counts computed for each of five application dates (Figure 4) were subjected to Duncan's multiple range test (Appendix, Table X). The March 21, 1980 mean of 7.98 johnsongrass seedlings per sub-plot was significantly lower at the 5% level than all others. No significant difference (.05) was apparent among the January 16, and February 20, 1980 means of 11.48 and 12.13 respectively, which were significantly lower at the 5% level than mean counts for November 26, and December 19, 1979.

Herbicide treatment x application date interaction as depicted in Figures 5 and 6 suggests variable johnsongrass control among herbicide families resulting from increased treatment rates and decreasing time from application to seedling emergence.

Metribuzin treatments of 0.57 kg ai/ha exhibited lower mean seedling johnsongrass counts in comparison to the 0.28 and 0.43 kg ai/ha rates for respective dates, however higher means were recorded for February 20 than January 16, 1980 applications of 0.28, 0.43 and 0.58 kg ai/ha (Figure 7).

Mean seedling johnsongrass counts decreased progressively as 2.27, 2.84, and 3.41 kg ai/ha alachlor treatments were administered from November 26, 1979 through March 21, 1980, barring applications of 2.27

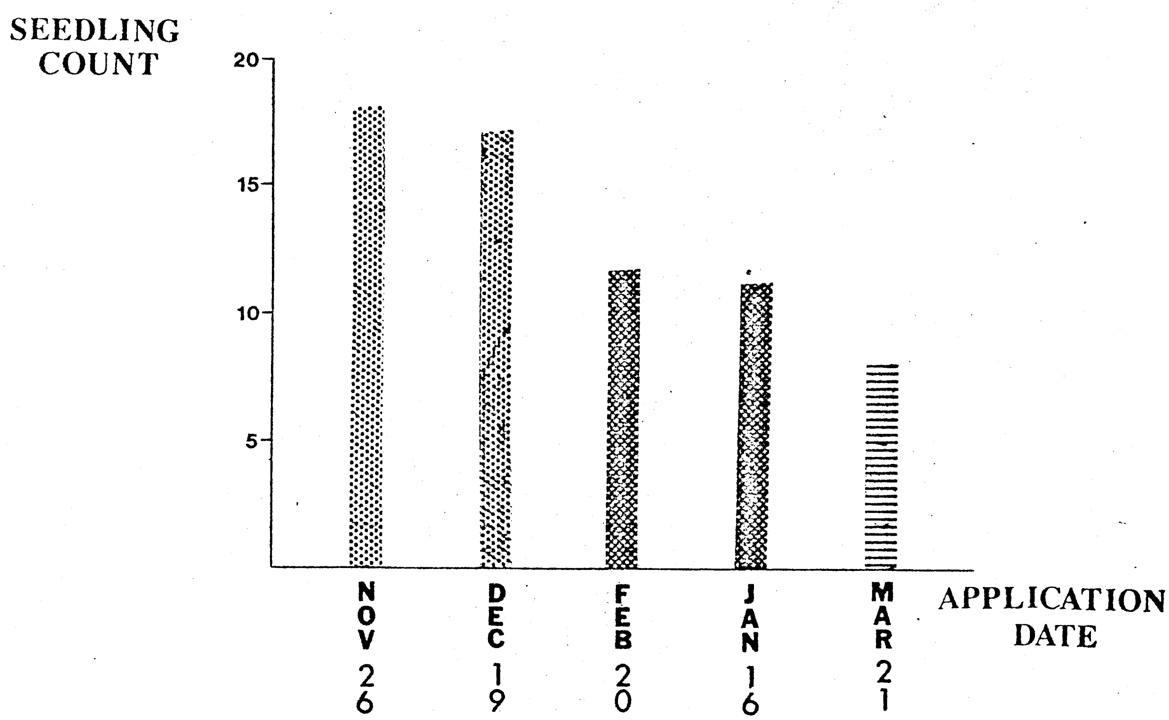

Figure 4. Mean Seedling Johnsongrass Counts for Herbicide Application Dates in 1979 and 1980

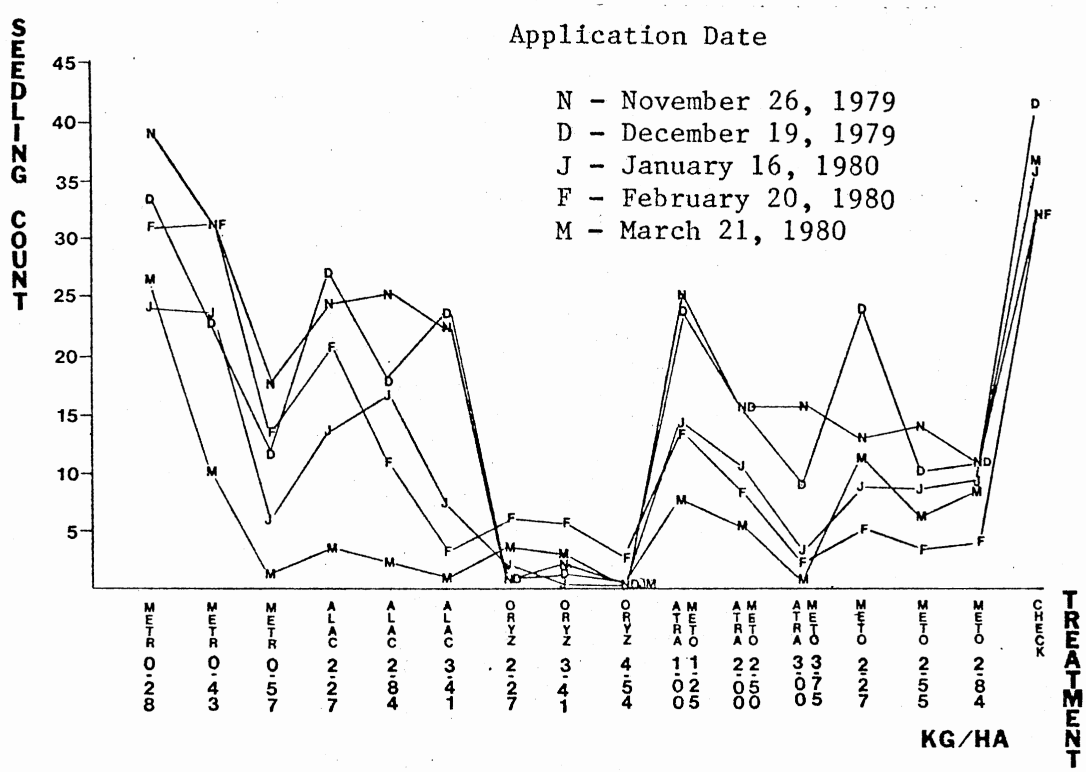

Figure 5. Mean Effect of Herbicide Treatment x Application Date Interaction for Seedling Johnsongrass Control

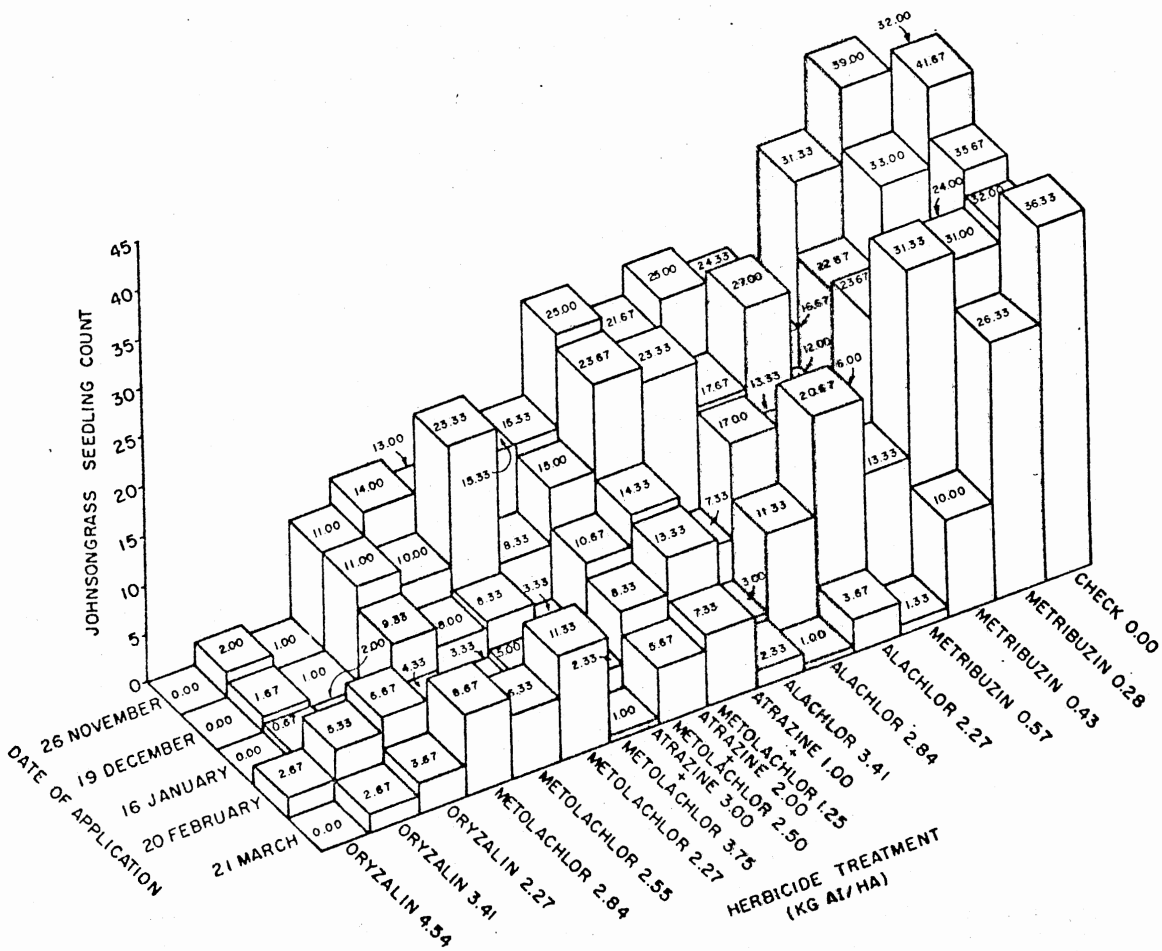

Figure 6. Mean Effect of Herbicide Treatment and Application Date on Seedling Johnsongrass Control

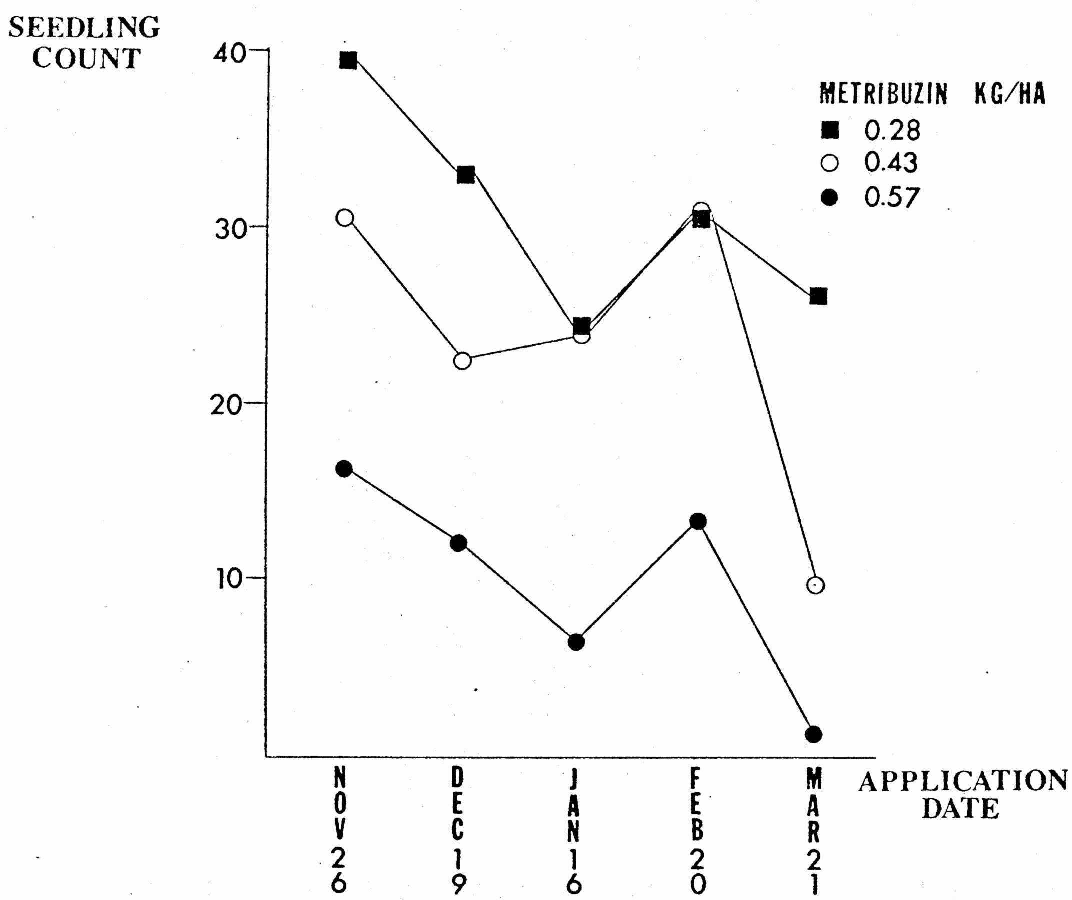

Figure 7. Mean Effect of Metribuzin Treatments and Application Date on Seedling Johnsongrass Control

and 3.41 kg ai/ha on December 19, 1979 and 2.27 kg ai/ha on February 20, 1980 (Figure 8).

Atrazine plus metolachlor treatments of 1.00 + 1.25, 2.00 + 2.50, and 3.00 + 3.75 kg ai/ha generated lower mean counts with advancing date of application (Figure 9). Declining mean seedling johnsongrass counts are noted for each date as herbicide rate increases with the November 26, 1979 application of 3.00 + 3.75 kg ai/ha an exception.

Successive November 26, 1979 through February 20, 1980 metolachlor treatments of 2.27, 2.55, and 2.84 kg ai/ha depressed mean seedling johnsongrass counts excluding December 19, 1979 applications at the 2.27 and 2.84 kg ai/ha rates (Figure 10). Higher mean counts were observed for the three March 21, 1980 herbicide treatments in contrast to February 20, 1980 applications.

The graphic illustration presented in Figure 11 suggests consistent seedling johnsongrass control following 2.27, 3.41 and 4.54 kg ai/ha oryzalin treatments applied on November 26, December 19, 1979, January 16, February 20, and March 21, 1980. Reductions in mean counts were recorded for specific application dates as herbicide rate increased, excepting 3.41 kg ai/ha treatments of November 26, and December 19, 1979.

In order to facilitate additional herbicide treatment comparisons, data compiled June 4, 1980 was statistically analyzed by date of application as independent randomized, complete blocks with three replications and subjected to Duncan's mutliple range test. Significant differences at the 1% level were detected among herbicide treatments for specific application dates and March 21, 1980 replications as demonstrated in the Appendix, Tables XI, XII, XIII, XIV and XV.

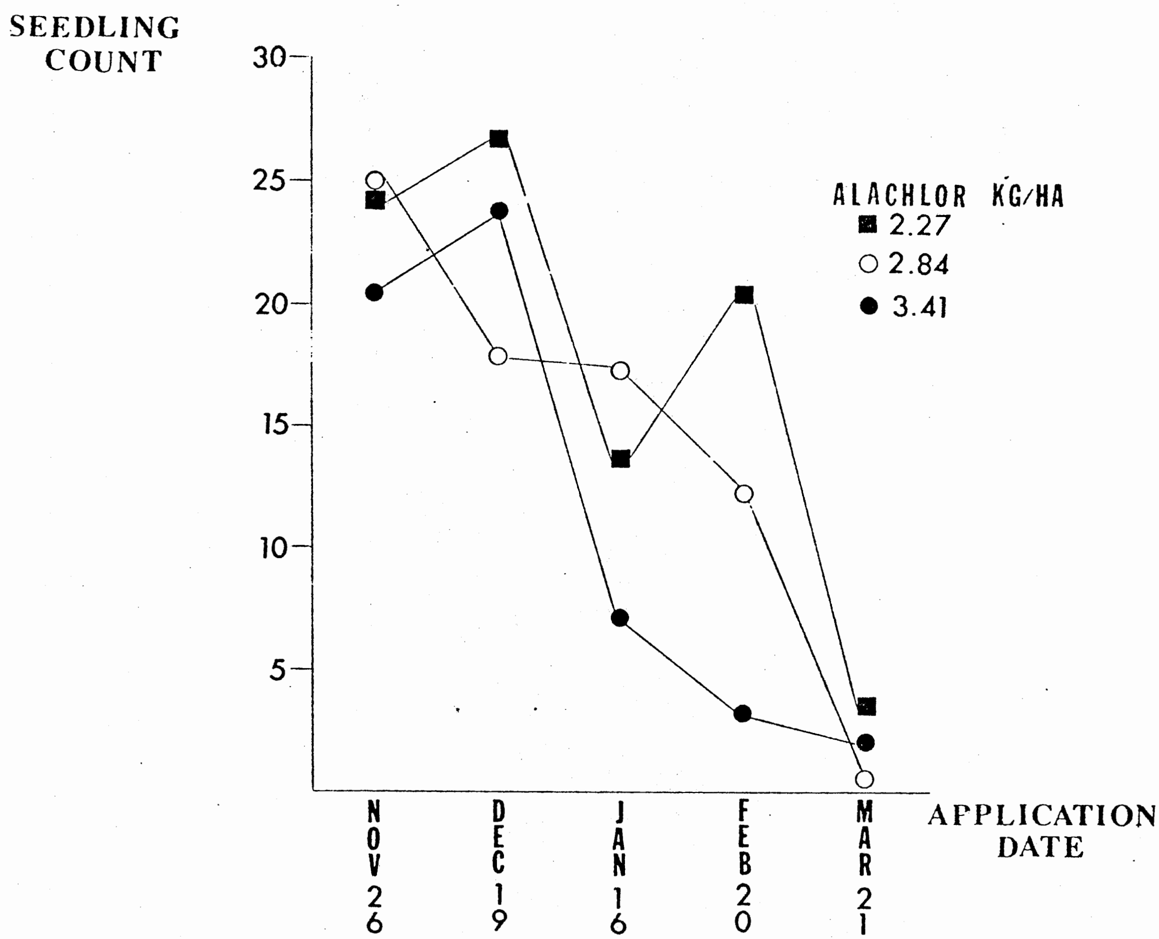

Figure 8. Mean Effect of Alachlor Treatments and Application Date on Seedling Johnsongrass Control

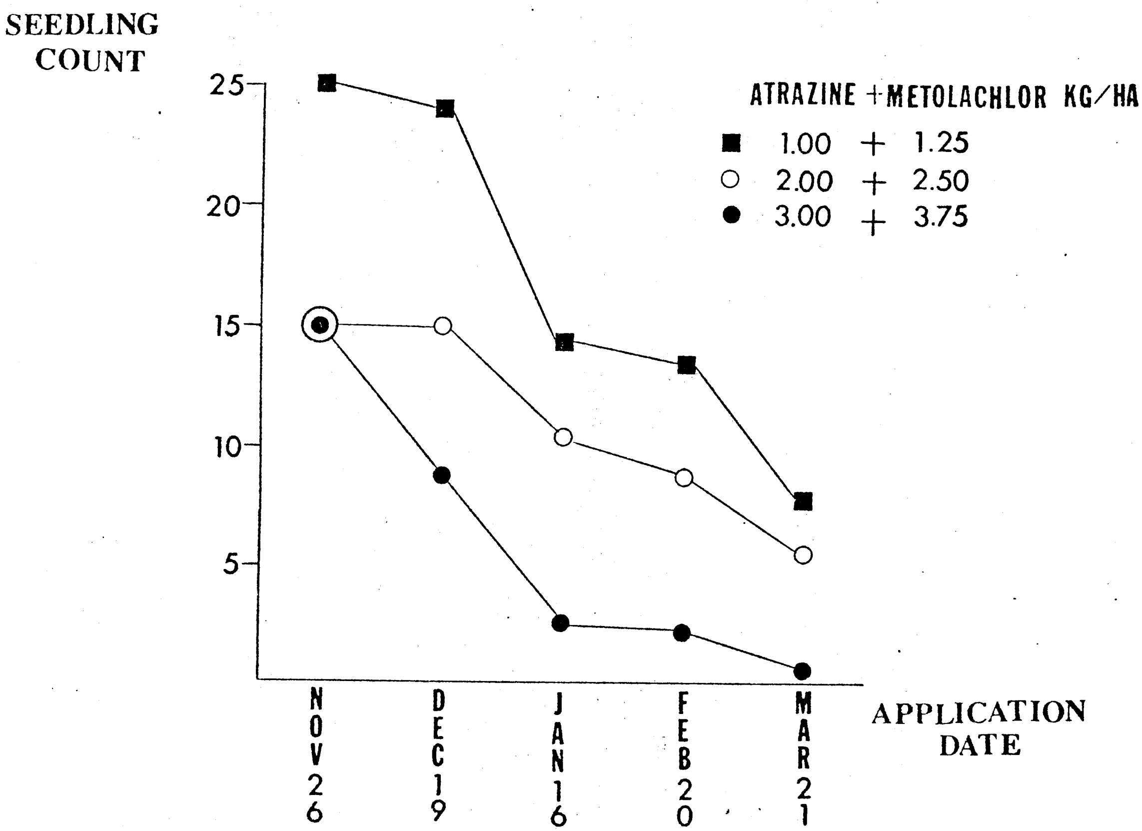

Figure 9. Mean Effect of Atrazine Plus Metolachlor Treatments and Application Date on Seedling Johnsongrass Control

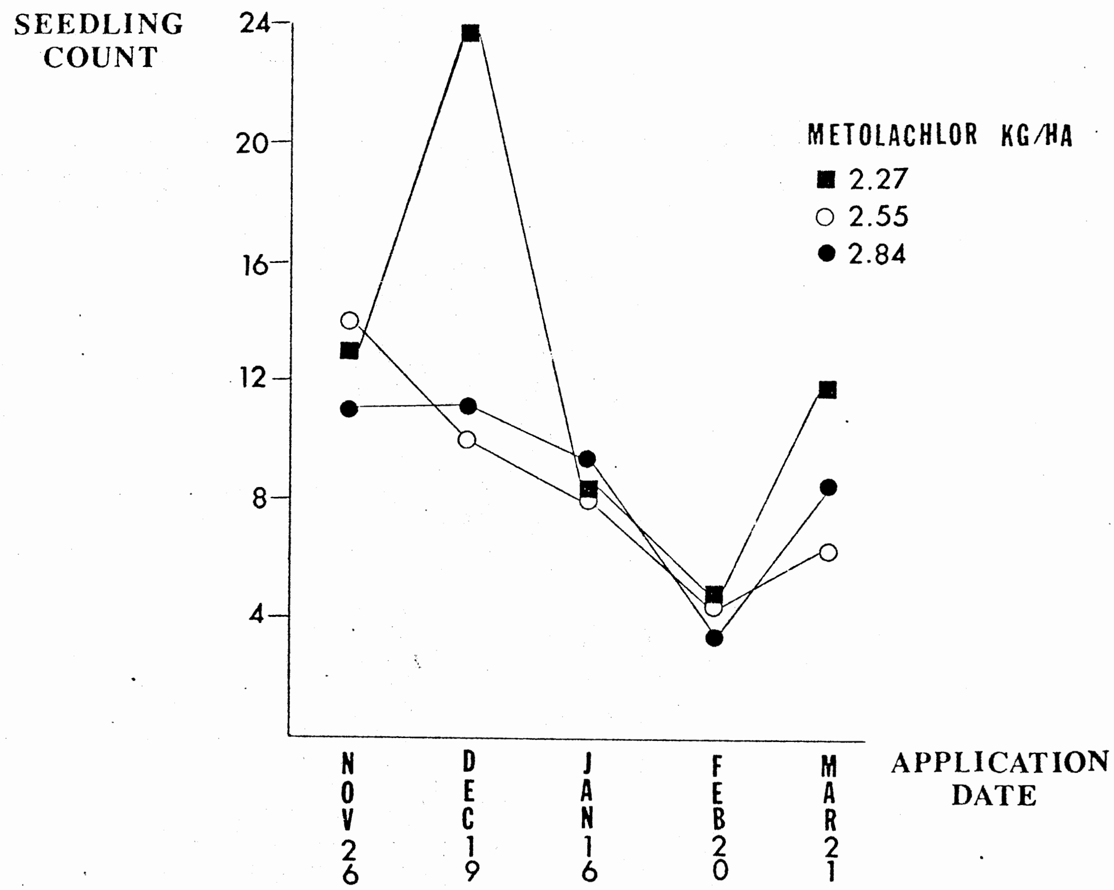

Figure 10. Mean Effect of Metolachlor Treatments and Application Date on Seedling Johnsongrass Control

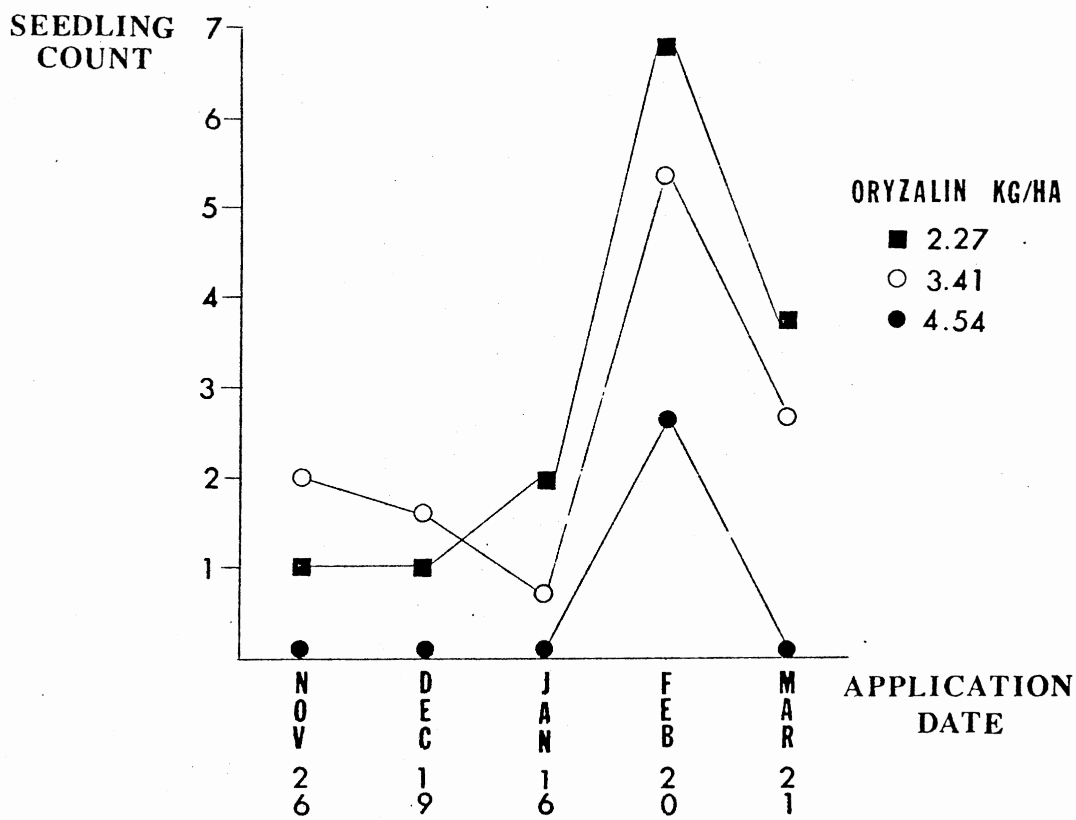

Figure 11. Mean Effect of Oryzalin Treatments and Application Date on Seedling Johnsongrass Control

Oryzalin applications of 4.54 kg ai/ha significantly reduced (.05) mean seedling johnsongrass counts more than the three alachlor, metribuzin, and atrazine plus metolachlor treatments of November 26, 1979 (Appendix, Table XVI). Seedling johnsongrass control following 2.27, 3.41, and 4.54 kg ai/ha oryzalin, and 2.27, 2.55, and 2.84 kg ai/ha metolachlor applications did not vary significantly at the 5% level.

No significant differences (.05) in seedling johnsongrass control occurred among 2.55 and 2.84 kg ai/ha metolachlor, 2.00 + 2.50 and 3.00 + 3.75 kg ai/ha atrazine plus metholachlor, 2.27, 3.41 and 4.54 kg ai ha oryzalin, and 0.57 kg ai/ha metribuzin treatments applied December 19, 1979, January 16, and February 20, 1980, as determined by Duncan's multiple range test (Appendix, Tables XVII, XVIII, and XIX).

A significant decrease (.05) in mean seedling johnsongrass counts is evidenced as a result of March 21, 1980 herbicide applications when compared to the untreated check (Appendix, Table XX). The mean seedling johnsongrass count of 11.5 displayed by replication three was significantly higher at the 5% level than mean counts of both replication 1 and 2 (Appendix, Table XXI).

Phytotoxicity to Bermudagrass

Occular estimates of phytoactivity recorded September 5, 1980 following August 29, 1980 foliar applications to common bermudagrass turf 3.8 cm in height are presented in the Appendix, Table XXII. Highly significant differences (.01) among the sixteen herbicide treatments are denoted by analysis of variance of data (Appendix, Table XXIII).

Atrazine plus metolachlor at rates of 3.00 + 3.75 and 2.00 + 2.50 kg ai/ha, and 0.57 and 0.43 kg ai/ha metribuzin exhibited a phytotoxic effect on bermudagrass shoots. Extent of phytotoxicity varied significantly at the 5% level among the four herbicide applications as determined by Duncan's multiple range test (Appendix, Table XXIV) with damage resulting from 3.00 + 3.75 kg ai/ha atrazine plus metolachlor $>$ 0.57 kg ai/ha metribuzin $>$ 2.00 + 2.50 kg ai/ha atrazine plus metolachlor $>$ 0.43 kg ai/ha metribuzin.

Injury manifest as bermudagrass leaf blade tip discoloration and subsequent dessication appeared moderate, as no phytotoxic herbicidal effects were registered on September 19, 1980.

CHAPTER V

SUMMARY AND CONCLUSIONS

Field Investigation I

Seedling Johnsongrass Control

Three commercial herbicide formulations applied May 1, 1979, at various rates on a Kirkland silt loam soil were evaluated May 31, and June 22, 1979 for control of johnsongrass seedlings. Highly significant differences (.01) are evident among herbicide treatments upon analysis of variance of data, while no significant differences occurred among the three replications.

Metolachlor applications of 2.27, 2.55, and 2.84 kg ai/ha, and atrazine plus metolachlor at 2.00 + 2.50 and 3.00 + 3.75 kg ai/ha appraised May 31, 1979 did not differ significantly at the 5% level as determined by Duncan's multiple range test.

Atrazine plus metolachlor at 1.00 + 1.25, 2.00 + 2.50, and 3.00 + 3.75 kg ai/ha, and metolachlor treatments of 2.27, 2.55, and 2.84 kg ai/ha demonstrated significantly greater (.05) seedling johnsongrass control than atrazine applications of 2.27 and 4.54 kg ai/ha.

Phytotoxicity to Bermudagrass

Duplicate herbicide treatments administered May 1, 1979 to common bermudagrass turf 4.4 cm in height exhibited no phytotoxic effect.

Field Investigation II

Seedling Johnsongrass Control

Effectiveness of 5 preemergence herbicides, each at 3 rates, applied on 5 dates was determined for seedling johnsongrass control. Analysis of variance of data recorded June 4, 1979 revealed highly significant differences (.01) for treatment and application date means, and treatment x application date interaction.

Oryzalin applications of 4.54, 3.41, and 2.27 kg ai/ha, metolachlor at 2.84 and 2.55 kg ai/ha, and atrazine plus metolachlor at 3.00 + 3.75 kg ai/ha provided the most acceptable control of johnsongrass seedlings (75%+). No significant differences at the 5% level were observed among these treatments.

The order of mean seedling johnsongrass counts for individual application dates from smallest to largest was March 21, 1980, January 16, 1980, February 20, 1980, December 19, 1979, and November 26, 1979. No significant difference (.05) occurred among January 16, 1979, and February 20, 1980 means, which were significantly higher (.05) than the March 21, 1980 mean seedling count (7.98). November 26 and December 19, 1979 means were significantly higher (.05) than all others.

Significant (.01) treatment x application date interaction suggests variable johnsongrass control among herbicide families with increasing treatment rates and advancing date of application. With few exceptions, lower mean johnsongrass counts were observed for alachlor, metribuzin, and atrazine plus metolachlor treatments as time from herbicide application to seedling emergence decreased. Oryzalin at 2.27, 3.41, and 4.54 kg ai/ha afforded consistent seedling johnsongrass control following

November 26, December 19, 1979, January 16, February 20, and March 21, 1980 applications. Mean seedling counts were reduced for specific dates with increasing oryzalin rates, excluding November 26, and December 19, 1979 applications of 3.41 kg ai/ha.

Oryzalin at 4.54 kg ai/ha significantly reduced (.05) mean seedling johnsongrass counts more than the 3 alachlor, metribuzin, and atrazine plus metolachlor treatments applied November 26, 1979.

No significant differences (.05) in seedling johnsongrass control occurred among 4.54, 3.41, and 2.27 kg ai/ha oryzalin, 2.84 and 2.55 kg ai/ha metolachlor, 0.57 kg ai/ha metribuzin, and 3.00 + 3.75 and 2.00 + 2.50 kg ai/ha atrazine plus metolachlor treatments applied December 19, 1979, January 16, and February 20, 1980.

March 21, 1980 herbicide applications significantly reduced (.05) mean seedling johnsongrass counts in comparison to the untreated check.

Phytotoxicity to Bermudagrass

Analysis of variance of phytoactivity determinations recorded September 5, 1980 indicates highly significant differences at the 1% level among 16 herbicide treatments applied August 29, 1980 to actively growing common bermudagrass turf of uniform height (3.8 cm) and density on Kirkland silt loam soil (pH 6.2, 1.6% organic matter). Metribuzin at rates of 0.57 and 0.43 kg ai/ha, and atrazine plus metolachlor at 3.00 + 3.75 and 2.00 + 2.50 kg ai/ha demonstrated a phytotoxic effect on bermudagrass shoots. Leaf blade tip discoloration and subsequent dessication was observed. Order of treatments from greatest to least phytoactivity was 3.00 + 3.75 kg ai/ha atrazine plus metolachlor $>$ 0.58 kg ai/ha metribuzin $>$ 2.00 + 2.50 kg ai/ha atrazine plus metolachlor $>$ 0.43

kg ai/ha metribuzin. Injury produced by the asymetrical triazine, and substituted *s*-triazine plus chloroacetamide combination appeared moderate as no phytotoxic herbicidal effects were noted on September 19, 1980.

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APPENDIX

TABLE I

HERBICIDES, CHEMICAL NAMES, FORMULATIONS, AND APPLICATION RATES EVALUATED FOR SEEDLING JOHNSONGRASS CONTROL FIELD INVESTIGATION I

Herbicide	Chemical Name	Formulation*	Application Rates kg ai/ha
Metolachlor	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2 methoxy-1-methylethyl) acetamide	15G	2.27, 2.55, 2.84
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-triazine	4L	2.27, 4.54
Atrazine + Metolachlor		4.5L(2.00 + 2.50)	1.00 + 1.25, 2.00 + 2.50, 3.00 + 3.75

*G-granular, L-liquid

TABLE II

HERBICIDES, CHEMICAL NAMES, FORMULATIONS, AND RATES OF NOVEMBER 26, DECEMBER 19, 1979, JANUARY 16, FEBRUARY 20, AND MARCH 21, 1980 APPLICATIONS EVALUATED FOR SEEDLING JOHNSONGRASS CONTROL. FIELD INVESTIGATION II

Herbicide	Chemical Name	Formulation*	Application Rates kg ai/ha
Metribuzin	4-amino-6-*tert*-butyl-3-(methylthio)-as-triazin-5(4*H*)-one	50WP	0.28, 0.43, 0.57
Alachlor	2-chloro-2',6'-diethyl-*N*-(methoxymethyl)acetanilide	4EC	2.27, 2.84, 3.41
Oryzalin	3,5-dinitro-N^4,N^4-dipropylsulfanilamide	75WP	2.27, 3,41, 4.54
Metolachlor	2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide	15G	2.27, 2.55, 2.84
Atrazine + Metolachlor	2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide	4.5L 2 + 2.5	1.00, 2.00, 3.00 + + + 1.25, 2.50, 3.75

*WP-wettable powder; EC-emulsifiable concentrate; G-granular; L-liquid

TABLE III

DAILY AIR TEMPERATURE REGIME AND PRECIPITATION FOR THE DURATION OF FIELD INVESTIGATIONS I AND II RECORDED AT THE AGRONOMY RESEARCH STATION, STILLWATER, OKLAHOMA

Field Investigation I
May 1, 1979 - June 22, 1979

Day of Month	May Air Temperature °F Min.	May Air Temperature °F Max.	May Precipitation Inches	June Air Temperature °F Min.	June Air Temperature °F Max.	June Precipitation Inches
1	53	75		58	77	
2	54	67	0.10	56	77	
3	50	70	2.45	56	78	
4	44	53	1.45	63	84	
5	38	63	0.23	69	90	
6	56	73		65	80	0.02
7	59	83		65	87	0.30
8	67	85		78	92	
9	68	83		66	92	2.38
10	57	83	T	54	85	0.96
11	41	58	0.10	52	80	
12	40	58	T	58	83	
13	47	75		61	85	
14	50	78		69	90	
15	54	85		69	93	
16	61	89		70	90	
17	59	87		72	90	
18	59	84	T	71	87	
19	66	83	0.09	74	86	
20	65	87		70	86	
21	64	83	0.46	70	95	
22	58	63	0.61	70	92	0.32
23	54	72	T			
24	45	75				
25	44	72				
26	58	73	0.08			
27	59	76	T			
28	65	87				
29	61	81				
30	60	84				
31	56	79	T			

TABLE III (Continued)

Field Investigation II
Seedling Johnsongrass Control - November 15, 1979
Through June 4, 1980

Day of Month	November Air Temp. Min.	Max.	P*	December Air Temp. Min.	Max.	P*	January Air Temp. Min.	Max.	P*	February Air Temp. Min.	Max.	P*
1				24	46		26	49	T	9	25	
2				21	46		31	56		29	39	
3				25	46		27	51		29	51	
4				26	61		29	31		29	49	
5				32	63		25	33	T	29	44	
6				28	64		32	48	0.07	22	52	
7				31	59		21	63		27	46	
8				28	62		20	33		27	33	0.61
9				38	52		20	41		19	31	
10				39	65		22	49		9	29	
11				59	68		34	61	0.04	16	46	
12				26	67		29	46	0.02	14	43	
13				19	32		35	51	T	31	44	
14				21	47		31	62		40	57	
15	31	61		30	48		37	67		37	61	
16	29	70		24	51		39	67		15	37	
17	35	71		3	31		32	57		9	28	
18	50	72		12	39		36	55		10	38	
19	53	73		35	61		38	64	0.03	30	49	
20	52	77	0.56	23	60		37	48	0.68	32	56	
21	48	71	1.47	32	61		37	41	0.87	52	76	
22	33	54		34	65		35	43		31	63	
23	25	43		44	70		28	42		28	77	
24	26	54		35	48		38	55		35	53	
25	37	62		22	56		37	68		34	46	
26	32	59		23	61		34	52		21	42	
27	36	60		40	56		21	34		26	58	
28	31	51		43	54	1.38	16	27		37	74	
29	24	49	T	36	47	0.52	17	27		29	77	
30	17	33		34	40		18	30	0.10			
31				31	40		10	31	T			

TABLE III (Continued)

Field Investigation II Seedling Johnsongrass Control - November 15, 1979 Through June 4, 1980												
Day	March			April			May			June		
of	Air Temp.			Air Temp.			Air Temp.			Air Temp.		
Month	Min.	Max.	P*	Min.	Max.	P*	Min.	Max.	P*	Min.	Max.	P*
1	10	34	T	41	62		52	72	0.45	73	85	
2	0	24		45	66		56	74	0.07	76	86	
3	6	40		38	67	0.48	48	78		70	85	
4	36	55		36	60		58	80	0.16	70	87	
5	18	64		34	60		52	81	0.02			
6	25	42		55	71		53	82				
7	43	68		48	81	T	55	86				
8	33	59		44	79	0.03	48	71	T			
9	31	57		40	65		39	66				
10	31	67		35	67		59	74				
11	36	73		55	81		68	90				
12	33	49	0.55	37	67		64	92	0.62			
13	37	46		43	57		51	83				
14	34	58		33	55		48	71				
15	46	71		31	56		58	75				
16	64	70		40	77		54	62	1.75			
17	39	78		47	83		52	72				
18	34	54		45	65	0.16	55	73	0.99			
19	35	65		38	66		51	71				
20	49	71		48	79		55	77				
21	28	57	0.16	53	85		60	69	0.20			
22	40	63		52	87		55	72				
23	50	72	0.39	55	85		53	76				
24	35	55	1.35	57	84	1.48	57	79				
25	35	41		50	69	0.90	68	89				
26	38	48		45	51	2.31	74	93				
27	47	67	0.12	49	61		63	88	1.94			
28	49	55	0.16	45	67		66	80				
29	39	65	0.13	49	73		65	87	0.35			
30	37	48	0.02	48	80		68	85				
31	31	46					65	86				

TABLE III (Continued)

Field Investigation II
Phytotoxicity to Bermudagrass - August 29, 1980
through September 19, 1980

Day of Month	August Air Temperature°F Min.	August Air Temperature°F Max.	August Precipitation Inches	September Air Temperature°F Min.	September Air Temperature°F Max.	September Precipitation Inches
29	67	92				
30	72	97				
31	76	99	0.04			
1				81	95	
2				71	95	T
3				67	80	
4				71	96	
5				68	97	
6				70	97	
7				67	95	
8				71	93	
9				69	92	
10				64	95	
11				65	85	
12				70	94	
13				70	98	
14				70	99	
15				68	98	
16				73	98	
17				48	100	
18				54	80	
19				65	90	

*P = Precipitation in Inches
T = Trace

TABLE IV

ANALYSIS OF VARIANCE OF HERBICIDAL EVALUATION FOR SEEDLING JOHNSONGRASS CONTROL IN FIELD INVESTIGATION I, MAY 31, 1979

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	8	42.9259	11.8113**
Replication	2	0.9259	.2548
Error	16	3.6343	
Corrected Total	26	15.5157	

**Exceeds 1% Level of Significance

TABLE V

DUNCAN'S MULTIPLE RANGE TEST OF HERBICIDE TREATMENT MEANS FOR SEEDLING JOHNSONGRASS CONTROL, MAY 31, 1979. FIELD INVESTIGATION I

Grouping		Mean*	Herbicide	Application Rate kg ai/ha
	A	9.67	Atrazine + Metolachlor	3.00+ 3.75
	A	9.00	Metolachlor	2.27
B	A	8.67	Atrazine + Metolachlor	2.00+ 2.50
B	A	8.67	Metolachlor	2.84
B	A	8.00	Metolachlor	2.55
B		5.33	Atrazine + Metolachlor	1.00+ 1.25
	C	1.67	Atrazine	4.54
	C	1.67	Atrazine	2.27
	C	0.00	Check	0.00

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE VI

ANALYSIS OF VARIANCE OF HERBICIDAL EVALUATION FOR SEEDLING JOHNSONGRASS CONTROL IN FIELD INVESTIGATION I, JUNE 22, 1979

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	8	46.1667	12.2205**
Replication	2	1.4444	.3823
Error	16	3.7778	
Corrected Total	26	16.6410	

**Exceeds 1% Level of Significance

TABLE VII

DUNCAN'S MULTIPLE RANGE TEST OF HERBICIDE TREATMENT MEANS FOR SEEDLING JOHNSONGRASS CONTROL, JUNE 22, 1979. FIELD INVESTIGATION I

Grouping		Mean*	Herbicide	Application Rate kg ai/ha
	A	9.67	Atrazine + Metolachlor	3.00+ 3.75
B	A	8.33	Atrazine + Metolachlor	2.00+ 2.50
B	A	8.33	Metolachlor	2.27
B	A	8.00	Metolachlor	2.84
B	A	8.00	Metolachlor	2.55
B		5.33	Atrazine + Metolachlor	1.00+ 1.25
	C	1.00	Atrazine	4.54
	C	0.33	Atrazine	2.27
	C	0.00	Check	0.00

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE VIII

ANALYSIS OF VARIANCE OF SEEDLING JOHNSONGRASS COUNTS FOR EFFECTIVENESS OF PREEMERGENCE HERBICIDES ADMINISTERED AT THREE RATES AND FIVE APPLICATION DATES. FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Replication	2	84.1165	.747
Herbicide Treatment	15	1446.6744	12.85**
Error a	30	112.5744	
Application Date	4	812.4479	21.7717**
Herbicide Treatment x Application Date	60	71.1279	1.9061**
Error b	128	37.3167	
Corrected Total	239	157.0694	

**Exceeds 1% Level of Significance

TABLE IX

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE TREATMENTS. FIELD INVESTIGATION II

Grouping					Mean*	Herbicide	Application Rate kg ai/ha
			A		35.53	Check	0.00
	B		A		30.67	Metribuzin	0.28
	B		C		23.80	Metribuzin	0.43
	D		C		17.80	Alachlor	2.27
	D		C	E	16.73	Atrazine+ Metolachlor	1.00+ 1.25
	D		F	E	14.40	Alachlor	2.84
	D		F	E	12.20	Metolachlor	2.27
	D	G	F	E	11.53	Alachlor	3.41
	D	G	F	E	11.00	Atrazine + Metolachlor	2.00+ 2.50
	D	G	F	E	9.87	Metribuzin	0.57
H	D	G	F	E	8.87	Metolachlor	2.84
H		G	F	E	8.33	Metolachlor	2.55
H		G	F		6.07	Atrazine + Metolachlor	3.00+ 3.75
H		G			2.87	Oryzalin	2.27
H		G			2.47	Oryzalin	3.41
H					0.53	Oryzalin	4.54

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE X

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE APPLICATION DATES. FIELD INVESTIGATION II

Grouping	Mean*	Application Date
A	17.92	November 26, 1979
A	16.96	December 19, 1979
B	12.13	February 20, 1980
B	11.48	January 16, 1980
C	7.98	March 21, 1980

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE XI

ANALYSIS OF VARIANCE OF SEEDLING JOHNSONGRASS COUNTS
FOR EFFECTIVENESS OF PREEMERGENCE HERBICIDES
APPLIED NOVEMBER 26, 1979
FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	15	388.2444	6.5107**
Replication	2	27.5208	.4615
Error	30	59.6319	
Corrected Total	47	163.1418	

**Exceeds 1% Level of Significance

TABLE XII

ANALYSIS OF VARIANCE OF SEEDLING JOHNSONGRASS COUNTS
FOR EFFECTIVENESS OF PREEMERGENCE HERBICIDES
APPLIED DECEMBER 19, 1979
FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	15	418.1722	4.9181**
Replication	2	6.2708	.0738
Error	30	85.0264	
Corrected Total	47	187.9982	

**Exceeds 1% Level of Significance

TABLE XIII

ANALYSIS OF VARIANCE OF SEEDLING JOHNSONGRASS COUNTS
FOR EFFECTIVENESS OF PREEMERGENCE HERBICIDES
APPLIED JANUARY 16, 1980
FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	15	282.3542	6.9092**
Replication	2	14.3333	.3507
Error	30	40.8667	
Corrected Total	47	116.8081	

**Exceeds 1% Level of Significance

TABLE XIV

ANALYSIS OF VARIANCE OF SEEDLING JOHNSONGRASS COUNTS
FOR EFFECTIVENESS OF PREEMERGENCE HERBICIDES
APPLIED FEBRUARY 20, 1980
FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	15	348.8833	6.9332**
Replication	2	81.1875	1.6134
Error	30	50.3208	
Corrected Total	47	146.9202	

**Exceeds 1% Level of Significance

TABLE XV

ANALYSIS OF VARIANCE OF SEEDLING JOHNSONGRASS COUNTS FOR EFFECTIVENESS OF PREEMERGENCE HERBICIDES APPLIED MARCH 21, 1980 FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	15	203.5319	13.1884**
Replication	2	160.1458	7.1953**
Error	30	22.2569	
Corrected Total	47	114.7017	

** Exceeds 1% Level of Significance

TABLE XVI

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE TREATMENTS APPLIED NOVEMBER 26, 1979 FIELD INVESTIGATION II

Grouping				Mean*	Herbicide	Application Rate kg ai/ha
		A		39.00	Metribuzin	0.28
B		A		32.00	Check	0.00
B		A		31.33	Metribuzin	0.43
B		C		25.00	Alachlor	2.84
B		C		25.00	Atrazine + Metolachlor	1.00+ 1.25
B		C		24.33	Alachlor	2.27
B		C		21.67	Alachlor	3.41
D		C		16.67	Metribuzin	0.57
D		C	E	15.33	Atrazine + Metolachlor	3.00+ 3.75
D		C	E	15.33	Atrazine + Metolachlor	2.00+ 2.50
D	F	C	E	14.00	Metolachlor	2.55
D	F	C	E	13.00	Metolachlor	2.27
D	F	C	E	11.00	Metolachlor	2.84
D	F		E	2.00	Oryzalin	3.41
	F		E	1.00	Oryzalin	2.27
	F			0.00	Oryzalin	4.54

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE XVII

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE TREATMENTS APPLIED DECEMBER 19, 1979 FIELD INVESTIGATION II

Grouping				Mean*	Herbicide	Application Rate kg ai/ha
		A		41.67	Check	0.00
B		A		33.00	Metribuzin	0.28
B		A	C	27.00	Alachlor	2.27
B		D	C	23.67	Atrazine + Metolachlor	1.00+ 1.25
B		D	C	23.33	Alachlor	3.41
B		D	C	23.33	Metolachlor	2.27
B		D	C	22.67	Metribuzin	0.43
B	E	D	C	17.67	Alachlor	2.84
	E	D	C	15.00	Atrazine + Metolachlor	2.00+ 2.50
	E	D	C	12.00	Metribuzin	0.57
	E	D	C	11.00	Metolachlor	2.84
	E	D	C	10.00	Metolachlor	2.55
	E	D		8.33	Atrazine + Metolachlor	3.00+ 3.75
	E			1.67	Oryzalin	3.41
	E			1.00	Oryzalin	2.27
	E			0.00	Oryzalin	4.54

*Means with the same letter are not significantly different. Significance Level = 0.05

TABLE XVIII

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE TREATMENTS APPLIED JANUARY 16, 1980 FIELD INVESTIGATION II

Grouping			Mean*	Herbicide	Application Rate kg ai/ha
	A		35.67	Check	0.00
	B		24.00	Metribuzin	0.28
	B		23.67	Metribuzin	0.43
C	B		17.00	Alachlor	2.84
C	B	D	14.33	Atrazine + Metolachlor	1.00+ 1.25
C	B	D	13.33	Alachlor	2.27
C	E	D	10.67	Atrazine+ Metolachlor	2.00+ 2.50
C	E	D	9.33	Metolachlor	2.84
C	E	D	8.33	Metolachlor	2.27
C	E	D	8.00	Metolachlor	2.55
C	E	D	7.33	Alachlor	3.41
C	E	D	6.00	Metribuzin	0.57
	E	D	3.33	Atrazine + Metolachlor	3.00+ 3.75
	E	D	2.00	Oryzalin	2.27
	E		0.67	Oryzalin	3.41
	E		0.00	Oryzalin	4.54

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE XIX

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE TREATMENTS APPLIED FEBRUARY 20, 1980 FIELD INVESTIGATION II

Grouping		Mean*	Herbicide	Application Rate kg ai/ha
	A	32.00	Check	0.00
	A	31.33	Metribuzin	0.43
	A	31.00	Metribuzin	0.28
B	A	20.67	Alachlor	2.27
B	C	13.33	Metribuzin	0.57
B	C	13.33	Atrazine + Metolachlor	1.00+ 1.25
B	C	11.33	Alachlor	2.84
B	C	8.33	Atrazine + Metolachlor	2.00+ 2.50
	C	6.67	Oryzalin	2.27
	C	5.33	Oryzalin	3.41
	C	5.00	Metolachlor	2.27
	C	4.33	Metolachlor	2.84
	C	3.33	Metolachlor	2.55
	C	3.00	Alachlor	3.41
	C	2.67	Oryzalin	4.54
	C	2.33	Atrazine + Metolachlor	3.00+ 3.75

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE XX

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR HERBICIDE TREATMENTS APPLIED MARCH 21, 1980 FIELD INVESTIGATION II

Grouping			Mean*	Herbicide	Application Rate kg ai/ha
	A		36.33	Check	0.00
	B		26.33	Metribuzin	0.28
	C		11.33	Metolachlor	2.27
D	C		10.00	Metribuzin	0.43
D	C	E	8.67	Metolachlor	2.84
				Atrazine +	1.00+
D	C	E	7.33	Metolachlor	1.25
D	C	E	6.33	Metolachlor	2.55
				Atrazine+	2.00+
D	C	E	5.67	Metolachlor	2.50
D	C	E	3.67	Alachlor	2.27
D	C	E	3.67	Oryzalin	2.27
D	C	E	2.67	Oryzalin	3.41
D	C	E	2.33	Alachlor	3.41
D		E	1.33	Metribuzin	0.57
D		E	1.00	Alachlor	2.84
				Atrazine +	3.00+
D		E	1.00	Metolachlor	3.75
		E	0.00	Oryzalin	4.54

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE XXI

DUNCAN'S MULTIPLE RANGE TEST OF MEAN SEEDLING JOHNSONGRASS COUNTS FOR REPLICATIONS OF HERBICIDE TREATMENTS APPLIED MARCH 21, 1980. FIELD INVESTIGATION II

Grouping	Mean*	Replication
A	11.50	3
B	7.06	2
B	5.38	1

*Means with the same letter are not significantly different.
Significance Level = 0.05

TABLE XXII

DETERMINATION OF HERBICIDE PHYTOTOXICITY TO COMMON BERMUDAGRASS TURF. FIELD INVESTIGATION II

Date: September 5, 1980
Application Date: August 29, 1980
Method of Evaluation: 10 = total dessication
1 = no herbicidal effect

Treatment	Rate kg ai/ha	Replication 1	Replication 2	Replication 3
Metribuzin	0.28	1	1	1
	0.43	2	2	2
	0.57	3	3	3
Alachlor	2.27	1	1	1
	2.84	1	1	1
	3.41	1	1	1
Oryzalin	2.27	1	1	1
	3.41	1	1	1
	4.54	1	1	1
Atrazine + Metolachlor	1.00 + 1.25	1	1	1
	2.00 + 2.50	2	3	3
	3.00 + 3.75	5	6	6
Metolachlor	2.27	1	1	1
	2.55	1	1	1
	2.84	1	1	1
Check	0.00	1	1	1

TABLE XXIII

ANALYSIS OF VARIANCE OF EVALUATIONS FOR PHYTOTOXIC EFFECTS OF SIXTEEN HERBICIDE TREATMENTS APPLIED TO COMMON BERMUDAGRASS TURF ON AUGUST 29, 1980 FIELD INVESTIGATION II

Source	Degrees of Freedom	Mean Squares	F
Herbicide Treatment	15	4.8222	123.9640**
Replication	2	0.0833	2.1414
Error	30	0.0389	
Corrected Total	47	4.2647	

**Exceeds 1% Level of Significance

TABLE XXIV

DUNCAN'S MULTIPLE RANGE TEST OF SEPTEMBER 5, 1980
EVALUATIONS FOR PHYTOTOXIC EFFECTS OF SIXTEEN
HERBICIDE TREATMENTS APPLIED TO COMMON
BERMUDAGRASS TURF ON AUGUST 29, 1980
FIELD INVESTIGATION II

Grouping	Mean*	Herbicide	Application Rate kg ai/ha
A	5.67	Atrazine + Metolachlor	3.00+ 3.75
B	3.00	Metribuzin	0.57
C	2.67	Atrazine + Metolachlor	2.00+ 2.50
D	2.00	Metribuzin	0.43
E	1.00	Metribuzin	0.28
E	1.00	Alachlor	2.27
E	1.00	Alachlor	2.84
E	1.00	Alachlor	3.41
E	1.00	Oryzalin	2.27
E	1.00	Oryzalin	3.41
E	1.00	Oryzalin	4.54
E	1.00	Atrazine + Metolachlor	1.00+ 1.25
E	1.00	Metolachlor	2.27
E	1.00	Metolachlor	2.55
E	1.00	Metolachlor	2.84
E	1.00	Check	0.00

*Means with the same letter are not significantly different.
Significance Level = 0.05

VITA[2]

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Candidate for the Degree of

Master of Science

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