EFFECTS OF PREEMERGENT HERBICIDES ON NEWLY SEEDED COMMON BERMUDAGRASS (*CYNODON DACTYLON*)

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(*CYNODON DACTYLON*)

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LITERATURE REVIEW OF PREEMERGENT HERBICIDE RESEARCH

INTRODUCTION

Interest in the development and usage of turf-type seeded bermudagrasses (*Cynodon dactylon* L. Pers.) is growing. This is evidenced by the number of entries found in the 1986, 1992, 1997, and 2002 National Bermudagrass Tests conducted by the National Turf Evaluation Program (NTEP). The number of total bermudagrass entries increased from 28 varieties in 1986 to 42 varieties in 2002 (NTEP, 2002). During this same period, the percentage of the varieties tested that were seeded types were 25, 38, 64 and 69% in the 1986, 1992, 1997 and 2002 NTEP Bermudagrass trials, respectively. Interest in seeded varieties remains high and is believed to be due to the reduced costs of seed establishment versus production, shipping, and handling costs associated with vegetatively propagated varieties. However, one of the draw backs of using seeded bermudagrass is the sensitivity of juvenile bermudagrass to herbicides used for early establishment weed control. The demand for seeded varieties will continue to fuel the need for further research addressing cultural practices used in management of these varieties, including weed control utilizing preemergent herbicides.

The goal of the turfgrass manager is to provide optimum growing conditions that favor the desired turfgrass (Turgeon, 1985). Those same conditions are conducive to other weed species that are in direct competition for nutrients, water, sunlight, and establishment space. Additionally, the aesthetic appearance of seeded stands is compromised by visual disruption of stand uniformity (Beard, 1973). One method utilized to reduce weed species competition is the use of preemergent herbicides for suppression or direct control. Over 22 preemergent herbicide products are currently labeled for use on turf bermudagrass (Anonymous, 2001).

Traditionally, turfgrass managers have been limited in the use of preemergent herbicides because they not only inhibit the germination and development of weed species, they also inhibited the development of seed established turf stands. Early research with preemergent herbicides dealt mainly with either cool season grasses established by seed or sod and later with bermudagrass that was established by vegetative means. These early research studies were eventually followed by studies directly examining preemergent herbicide effects on seeded bermudagrass varieties.

DCPA

DCPA was one of the earliest preemergent herbicides labeled for use in turfgrass management. DCPA affects cell division and DCPA is classified as a mitotic disrupter herbicide (Vaughn and Lehnen, 1991, Anonymous, 1994). Ashton and Monaco, (1991) stated DCPA inhibits growth of bermudagrass shoots, roots and rooting from nodes of bermudagrass. Early studies initiated to explore the effects of DCPA on bermudagrass were focused on responses of vegetatively propagated varieties. Bingham (1967) found that DCPA applied at 5.6 kg ha $^{-1}$ and 11.2 kg ha $^{-1}$ in greenhouse studies reduced the production of fresh root mass and stolon development. The DCPA rates of 5.6 and 11.2 kg ha $^{-1}$ reduced fresh stolon development by 58.6 and 79.3 percent and root fresh weights were reduced 98.2 and 99.9 percent respectively when compared to controls 60 days after treatment (DAT). Fullerton et al. (1970) found that 'Tifgreen' hybrid bermudagrass (*Cynodon dactylon* [L.] Pers.x *C. transvaalensis* Burtt-Davy) plots established from sprigs and treated with DCPA at 11.2 kg ha $^{-1}$ also reduced root weights when compared to non-treated plots (harvested 30, 60, 90 and 120 DAT). Study results indicated no significant differences in the amount of verdure or stolons harvested from treated plots versus non-treated plots. In prolonged studies examining the effect of DCPA on the root systems of established hybrid bermudagrass cultivars 'Tifway', Tifgreen, 'Tifdwarf' and 'Ormond', Johnson (1980) found DCPA applied annually and continuously from 1975 through 1979 at 11.2 kg ha $^{-1}$ did not affect root development of any of the bermudagrass cultivars.

DITHIOPYR

Dithiopyr belongs to the pyridine family of preemergent herbicides and is classified as a mitotic disrupter herbicide (Anonymous, 1994). Symptoms of dithiopyr exposure are similar to dinitroaniline herbicide exposure, however, dithiopyr exhibits a mode of action different than those of the dinitroaniline family in that microtubules do form during mitosis but are shortened and ineffectual, resulting in failure of cell division (Vaughn and Lehnen, 1991 and Armbruster et al. 1991).

Early research on dithiopyr initiated by Kasi et al. (1987) utilized rates of 0.27, 0.36, 0.54, and 1.08 kg ha $^{-1}$ applied to established bermudagrass. The same rate plus rates of 2.16 and 4.32 kg ha $^{-1}$ were applied to mature zoysiagrass (*Zoysia species* Steud.). Results of visual injury ratings indicated 'Himerkorai' zoysiagrass was tolerant of dithiopyr rates up to 4.32 kg ha $^{-1}$ and Tifgreen bermudagrass was only tolerant of rates up to 0.54 kg ha $^{-1}$. Experiments conducted by Johnson and Bundschuh (1993) examined the effect of emulsifiable concentrate (EC) dithiopyr applications on three cool-season grasses, tall fescue (*Festuca arundinacea* Schreb.), perennial ryegrass (*Lolium perenne* L.) and creeping bentgrass (*Argostis palustris* L.), as they relate to an acceptable time interval between seeding and actual application. Visual estimates of percent cover were recorded for 0.56 and 0.84 kg ha^{-1}. Application time intervals evaluated were 12, 8, 4, and 2 weeks before seeding (WBS). Percent cover ratings taken 10 weeks after seeding measuring effect on overseeded tall fescue suggest that dithiopyr applications did not cause differences in percent cover within rates and application dates. However, observation trends over two years indicate overall percent cover at 2 WBS was slightly reduced. Results of dithiopyr applications to perennial ryegrass indicate the 0.54 kg ha^{-1} rate could be used safely at 2 WBS. Dithiopyr at 0.84 kg ha^{-1} required application at 8 WBS for optimum cover development. Application of dithiopyr at 0.54 kg ha^{-1} to creeping bentgrass indicated an 8 WBS interval was required to prevent significant cover reduction. At 0.84 kg ha^{-1}, a 12 WBS interval was required between treatment and seeding.

Johnson (1994) studied the effect of dithiopyr EC applied at 0.8 and 1.6 kg ha^{-1} in 1992 and 1993 to mature Tifway bermudagrass. Parameters observed were turf quality and shoot density. Conclusions from this research were that dithiopyr was safe to use on Tifway bermudagrass at the 0.8 kg ha^{-1} rate and that turf quality and shoot density were unacceptable at the 1.6 kg ha^{-1} rate.

Fry et al. (1997) examined the effects of dithiopyr, applied as a preemergence herbicide, at 0.6 kg ha^{-1} on buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) parameters that included density, vigor, foliar cover and herbage mass produced.

Dithiopyr applications were made two days after seeding 'Sharp's Improved' buffalograss into 1 x 2-m plots. Density and vigor were rated at 4 weeks after treatment (WAT) and foliar cover was rated at 8 and 12 WAT. Herbage mass was rated at 12 WAT. Dithiopyr applications significantly reduced seedling density by 93%, 94% and 99% at three test sites when compared to untreated plots. Visual ratings for vigor of treated plots were significantly lower at the three test locations when compared to untreated plots. The 0.6 kg ha^{-1} dithiopyr rate significantly lowered visual foliar cover ratings below untreated plot ratings at two of three test locations 8 WAT. At 12 WAT, the same foliar cover trend was observed at each of the three test locations. Herbage mass production measurements taken 12 WAT indicated the 0.6 kg ha^{-1} dithiopyr rate significantly reduced yield at one location by 100% and had no significant yield reduction at the second test location.

ISOXABEN

Isoxaben is an amide herbicide with preemergent capabilities that was discovered in 1979 and introduced into the herbicide market by Eli Lilly and Company in 1984 (Anonymous, 1994). Isoxaben is readily adsorbed into roots and is limited in leaf uptake. The mode of action exhibited by isoxaben is inhibition of cell wall biosynthesis (Ashton and Monaco, 1991).

At the time of this writing, limited information was available regarding research involving isoxaben and bermudagrass. Research by McCarty et al. (1995) studied the effect of isoxaben applications on regrowth of St. Augustine (*Stenotaphrum secundatum* [Walt.] Kuntze) stolons in sod production settings where alternating 45 cm wide strips of established sod were harvested leaving 8 cm strips of sod on each side of harvested strips.

Isoxaben was applied at 0.6 and 1.1 kg ha^{-1} and parameters of phytotoxicity, turfgrass density, number of unrooted stolons, tensile strength and root weight were recorded. Phytotoxicity was rated visually 2 weeks after treatment and both rates of isoxaben did not significantly affect turf color when compared to control plots. Isoxaben treatments had no effect at 4 months after treatment (MAT) and increased turfgrass density rating at 6 and 14 MAT at one test location. At a second test location both rates had no effect on turfgrass density. The high rate of isoxaben (1.1 kg ha^{-1}) increased the number of unrooted stolons by 5 to 24 % through 8 MAT at one test location and showed the same effect through 4 MAT at the second test location. The lower rate (0.6 kg ha^{-1}) had no effect when compared to control plots. Tensile strength ratings were variable between the two test locations. At the first location, the 1.1 kg ha^{-1} isoxaben rate significantly reduced tensile strength while the lower rate (0.6 kg ha^{-1}) had no effect. At the second test location, both rates significantly increased tensile strength of treated plots compared to control plots. Both the 0.6 and the 1.1 kg ha^{-1} isoxaben rates had no effect upon root weight. Conclusions from this research were that isoxaben could result in a reduction of stolon rooting and that further research is warranted due to the inconsistencies of data from the two test location in regard to tensile strength issues. McCarty et al. (1995) also concluded isoxaben at both rates did not impede root development if allowed to recover for 14 MAT.

Dotray and McKenney (1996) conducted experiments with isoxaben applied to established buffalograss at 1.1 kg ha^{-1}. Two-year-old established buffalograss stands were treated with a 1.1 kg ha^{-1} rate of isoxaben and injury was visually rated 6 and 15 WAT. Greenup, density, living ground cover and quality were rated, pooled and reported as percent injury compared to untreated plots. Biomass was determined at the end of the growing season by harvesting a 10-cm-diameter circle randomly selected in each plot. Neither injury nor biomass was significantly affected by the 1.1 kg ha^{-1} rate of isoxaben applied to established buffalograss and the researchers' conclusion was that this rate was safe for use on established buffalograss.

METOLACHLOR

Metolachlor belongs to the chloroacetamide family of preemergent herbicides and was synthesized by Ciba-Giegy Limited in 1972 (Anonymous, 1994). The mode of action attributed to metolachlor in grasses is adsorption through emerging shoots and inhibition of cell division, cell enlargement, epicuticular wax formation, and alteration of membrane structure and function (Ashton and Monaco, 1991; Wilkinson, 1981).

Bovey and Voigt (1983) examined the effects of metolachlor applied as a preemergent treatment applied one day after planting on weeping lovegrass (*Eragrostis curvaula* [Schrad.]) at rates of 0.3, 0.6, 1.1, 2.2, and 4.5 kg ha^{-1}. Injuries by preemergent applications were evaluated visually by determining the percent of plants failing to emerge or percent desiccation of emerged plants compared to controls. Results indicated significant phytotoxicity at all rates of metolachlor applied as a preemergent application.

McCarty et al. (1995) studied the effect of metolachlor applications on regrowth of St. Augustine stolons in sod production settings where alternating 45 cm wide strips of established sod were harvested leaving 8 cm strips of sod on each side of harvested strips. Metolachlor was applied at 1.1 and 2.2 kg ha^{-1} and parameters of phytotoxicity, turfgrass density, number of unrooted stolons, tensile strength and root weight were recorded.

Phytotoxicity was rated visually 2 WAT and both rates of metolachlor did not significantly affect turf color when compared to control plots. Both rates of metolachlor significantly increased turfgrass density 4, 6 and 10 MAT when compared to control plots. Both rates of metolachlor did not significantly increase the number of unrooted stolons when compared to control plots. Sod tensile strength was insignificant for both rates at one location and actually significantly increased sod tensile strength at a second test location when measured 14 MAT. Both rates of metolachlor did not significantly affect root weights at one test location and significantly increased root weights at the second test location when compared to untreated plots. Conclusions were that metolachlor at 1.1 and 2.2 kg ha^{-1} can safely be used on St. Augustine remaining after sod harvest.

Dotray and McKenney (1996) conducted experiments with metolachlor applied to established buffalograss at 4.5 kg ha^{-1} and metolachlor applied to seeded buffalograss at 3.4 kg ha^{-1}. Two-year-old established buffalograss stands were treated with a 4.5 kg ha^{-1} rate and injury was visually rated 6 and 15 WAT. Greenup, density, living ground cover and quality were rated, pooled and reported as percent injury compared to untreated plots. Metolachlor at 4.5 kg ha^{-1} produced significant injury compared to untreated plots. Biomass was determined at the end of the growing season by harvesting a 10-cm-diameter circle randomly selected in each plot. The 4.5 kg ha^{-1} rate of metolachlor significantly reduced the amount of biomass produced when compared to untreated plots.

Seeded buffalograss plots were treated with metolachlor at 3.4 kg ha^{-1} 24 hours after seeding in 1993 and 1994. Stand density was visually rated and reported as percent coverage compared to untreated plots. Metolachlor significantly reduced stand density 4 and 10 WAT in 1993 and in 1994 at 4, 16 and 21 WAT when compared to untreated plots. Biomass harvested as mentioned previously was significantly reduced by the 3.4 kg ha^{-1} metolachlor rate when compared to untreated plots.

OXADIAZON

Oxadiazon is a preemergent herbicide that has been utilized in research addressing herbicidal effect on bermudagrass. Oxadiazon, as a soil applied application, is absorbed readily by emerging shoots and to a lesser extent by roots (Anonymous, 1994). Ashton and Monaco (1991) stated that oxadiazon appears to function by affecting the young shoots of plants as they come in contact with the herbicide and to a lesser extent can be transmitted to the roots of susceptible plants when applied as a postemergent application. Phytotoxicity is also a common occurrence with young plants treated with oxadiazon and sublethal rates may produce bronzing of young leaves (Anonymous, 1994).

Work by Lermanian et al. (1980) utilized four seeded bermudagrass strains and applications of oxadiazon at 0.79, 2.03, 3.28 and 4.52 kg ha^{-1} immediately after seeding. Extreme toxicity resulted in 0.8 % survival of planted seeds and oxadiazon was excluded from further testing. Early research by Breuninger and Schmidt (1981) found that root contact of established Tifway bermudagrass plugs with oxadiazon at 3.4 kg ha^{-1} resulted in a 7% root mass reduction and a 10% reduction in clipping yields relative to the control when harvested 6 weeks after treatment. Bingham and Schmidt (1983) found that a 3.4 kg ha^{-1} oxadiazon application did not affect root development, shoot growth or phytotoxicity appearance of 'Midiron' and Tifway hybrid bermudagrass or 'Tufcote' common bermudagrass sod 28 DAT. Conclusions were that oxadiazon at a 3.4 kg ha^{-1} rate can be used during bermudagrass establishment from sod.

Visual ratings of early spring growth made by Johnson (1983) on 'Tifdwarf' hybrid bermudagrass putting greens showed oxadiazon at 4.5 kg ha^{-1} applied twice annually for 6 years severely retarded turf growth, reduced ground cover and sod uniformity. However, root mass measured from plugs collected from treated plots was unaffected by annual applications of oxadiazon at 4.5 kg ha^{-1}. Additional research by Johnson (1985) showed rooting of established Tifdwarf, Tifway, Tifgreen and Ormond hybrid bermudagrass stands were unaffected by annual applications of oxadiazon at 4.5 and 13.5 kg ha^{-1}. Conclusions were that oxadiazon does not inhibit root growth of established bermudagrass.

Bingham and Hall (1985) examined the effects of multiple rates of oxadiazon on sprig establishment of 'Vamont' common bermudagrass as well as on Midiron and Tifway hybrid bermudagrass. Data collected on Vamont and Midiron, the two studied, showed oxadiazon applied at 2.2, 3.4, and 4.5 kg ha^{-1} on the day of sprigging did not inhibit shoot growth. Vamont and Tifway root development, as measured by the force required to uproot the sod, were unaffected by rates up to 4.5 kg ha^{-1}. Midiron root development was reduced by 42% at 2.2 kg ha^{-1} but higher rates did not cause further reduction of root strength.

PENDIMETHALIN

Pendimethalin belongs to the dinitroaniline family of preemergent herbicides and is classified as a mitotic disrupter herbicide (Anonymous, 1994). Pendimethalin has been researched as a preemergent herbicide since its introduction in the early 1970's (Anonymous, 1994). Application of pendimethalin has encompassed use on a wide range of crops including turfgrasses (Ashton and Monaco, 1991).

Early work with pendimethalin (Turner et al., 1990) examined the herbicidal effect of pendimethalin on mature and immature centipedegrass (*Eremochloa ophiuroides* [Munro] Hack.) in 1986 and 1987. Parameters measured were stand reduction (measured visually), tensile strength of sod, root density and root length development. Rates of pendimethalin used in the study were 1.7 and 3.4 kg ha^{-1}. Visual ratings were made 6 WAT following a single application of both rate in subsequent years. Data indicated pendimethalin caused no significant reduction in visual quality for both years. Measurements of tensile strength 2, 4, and 8 WAT following 1.7 and 3.4 kg ha^{-1} pendimethalin applications in consecutive years showed no significant reduction in tensile strength for both years. Root density showed no significant reduction in 1986 at 2, 4, and 8 WAT. In 1987, root density was reduced at 2 WAT by the 1.7 and 3.4 kg ha^{-1} pendimethalin rates. At 4 and 8 WAT, pendimethalin showed no significant reduction in root density. In both years and at both application rates, pendimethalin showed no significant reduction in root length measurements.

Johnson and Murphy (1991) studied the effect of pendimethalin applied at 3.4 and 10.1 kg ha^{-1} to 'Kentucky 31' tall fescue (*Festuca arundinacea* Schreb.). Applications were made the following February to stands planted in September, October and November of 1988 and 1989. The parameters of turf quality and turf density were measured visually. Turf quality ratings indicated that September planted plots treated with the 3.4 kg ha^{-1} rate had slightly reduced turf quality while October and November plantings had moderately reduced turf quality across both years. Pendimethalin applied at 10.1 kg ha^{-1} reduced turf quality slightly in the September planted plots, but severely reduced turf quality in the October and November planted plots across both years. Turf density ratings reflected the same trend over both years at both application rates.

Landschoot et al. (1993) evaluated preemergent herbicides including pendimethalin for their effects on root growth of mature Kentucky bluegrass (*Poa pratensis* L.) and tall fescue turfgrass in a greenhouse experiment in 1990 and 1991. Application of pendimethalin was at 1.7 kg ha^{-1} to established turf plots and plugs were pulled and moved to the greenhouse. Roots harvested 47 DAT indicated the 1.7 kg ha^{-1} pendimethalin rate significantly reduced root mass in both 1990 and 1991 on Kentucky bluegrass samples when compared to controls. Root mass data collected 47 DAT from tall fescue samples treated with the 1.7 kg ha^{-1} pendimethalin rate showed no significant root mass reduction in both 1990 and 1991 when compared to controls.

Fishel and Coats (1993) initiated research on mature common bermudagrass sod to examine the effect of several preemergent herbicides, including pendimethalin, on bermudagrass root growth in 1990 and 1991. Pendimethalin was applied at 3.4 kg ha^{-1} and cores were taken from treated plots 2, 4, 8 WAT. In 1990 pendimethalin reduced root mass production at all three treatment dates. In 1991 reduced root mass production was reported at 2 and 4 WAT. In 1991, at 8 WAT, no reduction in root mass production was observed. Lack of effect at 8 WAT in 1991 was attributed to herbicide degradation due to extremely wet conditions during the treatment to harvest period.

PRODIAMINE

Prodiamine is a preemergent herbicide belonging to the dinitroaniline family and is classified as a mitotic disrupter herbicide (Anonymous, 1994). Dinitroaniline herbicides have been routinely recommended for weed control in bermudagrass (Beard, 1973 and 1982; Turgeon, 1985). As a result of their herbicidal uses, dinitroaniline herbicides have been the focus of preemergent herbicide research since their introduction in the 1960's (Ashton and Monaco 1991). While this preemergent herbicide family has a long history in weed control, prodiamine is a relatively new entry to the family (Anonymous, 1994).

Early work with prodiamine (Dernoeden et al., 1988) examined the effects of prodiamine applied at 0.28, 0.42, 0.56, 0.84, 1.12 and 2.24 kg ha^{-1} on cover, overall quality and root development of plugs harvested from an unknown cultivar of established perennial ryegrass. Plots treat three times (April 22, May 20, and August 5, 1987) with the 0.28, 0.42, 0.56, 0.84, 1.12 and 2.24 kg ha^{-1} rates showed reduced cover at the two highest rates of prodiamine (1.12 and 2.24 kg ha). On the last of the three treatment dates, overall quality ratings indicated only the highest prodiamine rate (2.24 kg ha^{-1}) exhibited inferior quality when compared to all other treatments. Root mass data collected from plots treated with 0.56, 1.12 and 2.24 kg ha^{-1} (other treatments not evaluated) indicated significant reductions in root weights.

Hummel et al. (1990) examined the effect of prodiamine on root mass, stand density and quality of 0.3, 0.6, 1.1, 2.2, and 4.5 kg ha^{-1} applications made to mature 'Nugget' Kentucky bluegrass. All rates reduced root mass, stand density and quality when compared to controls.

Fermanian and Haley (1994) also examined the effects of prodiamine on established Kentucky bluegrass and overseeded seedling survival. Application rates of 0.3, 0.4, 0.6, 0.8, 1.1, 1.4, 1.7, 2.0 and 2.2 kg ha^{-1} were utilized. Quality reduction occurred on bluegrass less than one year old receiving a single application at 1.4, 1.7, 2.0 and 2.2 kg ha^{-1}. Rates of 0.8 and 2.2 kg ha^{-1} applied in the fall for three consecutive years significantly reduced the number of overseeded Kentucky bluegrass seedlings two years after planting. In a follow up study, prodiamine applied at 0.8, 1.1, 1.4, 1.7, 2.0 and 2.2 kg ha^{-1} once, during the previous fall, significantly reduced the number of surviving overseeded seedlings 56 days after planting. Conclusions were that prodiamine rates of less than 0.8 kg ha^{-1} should be used if overseeding is to be practiced.

Han et al. (1995) initiated experiments on 14 established tall fescue varieties to examine the effect of 0.8 and 1.7 kg ha^{-1} applications on root mass and root length. Conclusions from this research indicated there was no significant effect at 0.8 kg ha^{-1} but the 1.7 kg ha^{-1} rate significantly reduced both root mass and root length of all varieties 4 weeks after treatments.

Johnson (1994) treated established Tifway bermudagrass with prodiamine at 0.8 and 1.6 kg ha^{-1} to determine effects on turf quality and shoot density. Visual ratings of these two parameters through the course of the experiment indicated that both rates of prodiamine were not injurious to established Tifway bermudagrass.

QUINCLORAC

Quinclorac is an auxin herbicide with both postemergent and preemergent capabilities that is readily adsorbed by germinating seeds, roots and leaves. Quinclorac affects sensitive grasses through inhibition of root and shoot growth (Grossman, 1998). Quinclorac was discovered by BASF and has been researched in the United States since 1982 (Anonymous, 1994).

Johnson (1995) studied the effects of multiple rates of quinclorac applied singly and as split applications to established common bermudagrass stands in 1993 and 1994 as part of a weed control efficacy trial. Rates of quinclorac utilized included 0.28, 0.43, 0.56, and 0.84 kg ha^{-1}. Split rates were 0.28 + 0.28, 0.43 + 0.28, and 0.43 + 0.43 kg ha^{-1}. Visual ratings were gathered on injury 7 DAT and at 14, 28, 42, and 49 DAT. In 1993, injury was rated as acceptable with applications of quinclorac at 0.28 or 0.43 kg ha^{-1} and followed by a split application of 0.28 kg ha^{-1} 2 or 4 weeks later. Injury was unacceptable when the split application was made 6 weeks after the initial applications of either rate. Injury from the latest split application dates was attributed to higher temperatures at that time. Injury from split rates of 0.43 + 0.43 kg ha^{-1} were rated as unacceptable. At rates greater than or equal to 0.56 kg ha^{-1} injury was rated as unacceptable. In 1994, at 10 DAT, injury was unacceptable at all rates. However, maximum injury from split applications was less when either 0.28 or 0.43 kg ha^{-1} was applied as an initial treatment followed by 0.28 kg ha^{-1} at a 2 week interval instead of a 6 week interval. Johnson (1995) concluded that quinclorac caused varying degrees of injury depending upon rate and follow up split application timing.

Dotray and McKenney (1996) conducted experiments with quinclorac applied to seeded buffalograss at 0.6 kg ha^{-1}. Seeded buffalograss plots were treated with quinclorac at 0.6 kg ha^{-1} 24 hours after seeding in 1993 and 1994. Stand density was visually rated and reported as percent coverage relative to untreated plots. Quinclorac significantly reduced stand density 4 and 10 WAT in 1993 and in 1994 at 4, 16 and 21 WAT when compared to untreated plots. Biomass was determined at the end of the growing season by harvesting a 10-cm-diameter circle in each plot. The 0.6 kg ha^{-1} rate of quinclorac significantly reduced the amount of biomass produced when compared to untreated plots. The authors concluded that seeded buffalograss was sensitive to quinclorac and that quinclorac should not be used as a preemergence on newly seeded buffalograss.

Substantially more information is available regarding the effect of preemergent herbicides on mature and sodded turfgrasses relative to seed established bermudagrass. Increased usage of bermudagrass seed in establishment justifies that additional work be performed on seeded bermudagrass tolerance to herbicides. With this in mind, the objectives of this research were to examine the effect of preemergent herbicides on seedling bermudagrass color, shoot density, clipping yield, and root mass; and to address these effects on bermudagrass seedlings.

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CHAPTER II

EFFECTS OF PREEMERGENT HERBICIDES ON NEWLY SEEDED BERMUDAGRASS

ABSTRACT

One of the major challenges in establishing bermudagrass (*Cynodon dacylon* [L.] Pers.) by seed is the severe competition bermudagrass can experience from warm-season annual weeds during the establishment phase. Weedy summer annual grasses can be controlled using preemergent herbicides, however, the sensitivity of juvenile bermudagrass to these herbicides is a concern. Field (1991-1992) and green house studies (1993) were conducted at Stillwater, OK to determine the preemergent herbicide having the least injurious effect on seedling bermudagrass and the age at which the product could be applied. The first objective was to field screen eight preemergent herbicides applied at 0, 2, 4, 6, 8 and 10 weeks after planting (WAP) for effects on visual appearance, clipping yield, shoot density, verdure and root mass of 'Cheyenne' common bermudagrass. The second objective of this work was to test the effects of reduced rates (2.9, 5.9, 8.9, 11.8 kg ha^{-1} = 1/4, 1/2, 3/4 and 1x label rates, respectively) of DCPA, the most promising preemergent herbicide, on Cheyenne using the same response parameters. Sprayable oxadiazon WP (3.4 kg ha^{-1}), metolachlor (4.5 kg ha^{-1}) and quinclorac (1.1 kg ha^{-1}) were phytotoxic to all ages of common bermudagrass. No other treatments produced a significant phytotoxic effect. DCPA (11.8 kg ha^{-1}), quinclorac, prodiamine (0.8 kg ha^{-1}) and oxadiazon G (3.4 kg ha^{-1}) did not reduce clipping yields. Isoxaben (1.5 kg ha^{-1}) and oxadiazon WP reduced clipping yields when applied 2WAP in 1991. Pendimethalin (3.4 kg ha^{-1}) and the low rate of dithiopyr (0.6 kg ha^{-1}) reduced clipping yields when applied

2WAP in 1992. The high rate of dithiopyr (1.1 kg ha^{-1}) reduced clipping yields at 2WAP in 1991 and at all dates in 1992. Metolachlor reduced clipping yields of all age groups of bermudagrass. Herbicide treatments did not affect shoot density or dry root mass production in the field. In the greenhouse experiments DCPA did not produce any phytotoxicity. Clipping yields in both greenhouse experiments were similar in that the highest rate caused the largest reduction in yield. DCPA treatments often increased shoot mass yields (verdure) compared to the control but results were inconsistent across greenhouse experiments. Shoot density effects were inconsistent across both greenhouse experiments. While DCPA was identified as the safest herbicide to apply to seeded bermudagrass as early as 2WAP, additional field work is needed on lower use rates of all products tested not only for safety to seedling bermudagrass but for efficacy in control of summer annual weeds.

INTRODUCTION

One of the major challenges in establishing bermudagrass (*Cynodon dacylon* [L.] Pers.) by seed is the severe competition from warm-season annual weeds during establishment phase. Weeds of greatest concern are usually annual grasses such as smooth crabgrass (*Digitaria ischaemum* [Schreb.] Muhl.), hairy crabgrass (*Digitaria sanguinalis* [L.] Scop.) and goosegrass (*Eleusine indica* [L] Gaertn.). Weedy summer annual grasses can be effectively controlled using preemergent herbicides, however, the sensitivity of juvenile bermudagrass to these herbicides is a concern.

At least 22 preemergent herbicide products (16 separate active ingredients) are currently US EPA Registered for use by commercial/professional applicators on turfgrass stands (Anonymous, 2001d). The most widely used active ingredients include pendimethalin, prodiamine, oryzalin, dithiopyr, benefin, trifluralin, siduron, metholachlor and DCPA. Of these products, only Tupersan (active ingredient siduron) and Dacthal (active ingredient DCPA) have labeling statements that indicate that they could be used (acceptable risk implied) on seedling turfgrasses. Siduron is known to be highly phytotoxic to bermudagrass and thus its US EPA Label contains statements warning the user against its use on bermudagrass areas (Anonymous, 1999).

DCPA is labeled for use on seedling turfgrasses (Anonymous, 2001b) at 11.8 kg ha^{-1} and has no restriction on application to bermudagrass or to bermudagrass seedling stands. The remaining preemergent herbicides have labels with suggested delayed turf reseeding intervals in a general form or restrictions on the age or developmental stage of turf to which it should be applied.

Example cases of the reseeding delay precautions found on preemergent herbicide labels include those of oryzalin, having a 90-120 d delay (Anonymous, 2002) and pendimethalin, having a 3 months [~90 d] suggested delay (Anonymous, 2001c). Concerning the age at which seedling stands can be treated with preemergent herbicides, bermudagrass is not distinguished from other turfgrasses and restrictions on treating immature turf are not species specific. Example cases of restrictions on treating over immature turf include those for pendimethalin, "on newly planted areas application should not be applied until the turfgrass has filled in and been mowed at least four times" (Anonymous, 2001c); prodiamine, "injury is likely if applied before the secondary roots are in the second inch of soil" or a suggested time delay of "60 d after seeding or until after the 2nd mowing, whichever is longer" (Anonymous, 2001a); oxadiazon G, "do not apply to newly seeded areas" (Anonymous, 2000) and oryzalin, "Apply only to healthy, well-established turf that has a well-anchored root system" (Anonymous, 2002).

Early research with preemergent herbicides dealt mainly with either cool season grasses established by seed or sod and later with bermudagrass that was established by vegetative means. Fermanian et al. (1980) is the only researcher to have examined the direct effects of preemergent herbicides on newly seeded bermudagrass.

Bingham (1967) found that DCPA applied at 5.6 kg ha $^{-1}$ and 11.2 kg ha $^{-1}$ reduced bermudagrass root mass and stolon development. Johnson (1980) found that DCPA applied annually from 1975-79 at 11.2 kg ha^{-1} did not effect root development of four hybrid bermudagrasses (*C. dactylon* [L.] x *C. transvaalensis* Burtt-Davy). In seeming contrast to this, Fullerton et al. (1970) found that an application of DCPA at 11.2

kg ha $^{-1}$ reduced root mass but not verdure or stolon production in 'Tifgreen' hybrid bermudagrass established from sprigs.

Kasi et al. (1987) found that established Tifgreen bermudagrass was only tolerant of dithiopyr rates from 0.27 up to 0.54 kg ha^{-1}. Johnson (1994) concluded that a dithiopyr EC formulation was safe to use on 'Tifway' hybrid bermudagrass at the 0.8 kg ha^{-1} rate but that turf quality and shoot density were unacceptable using the 1.6 kg ha^{-1} rate. Fry et al. (1997) found that dithiopyr reduced seedling density of 'Sharp's Improved' buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) by 93% to 99% when used at 0.6 kg ha^{-1} 2 days after planting (DAP), with significantly lowering foliar cover at three test sites 12 weeks after treatment (WAT).

Research by McCarty et al. (1995) studied the effect of isoxaben applications on regrowth of St. Augustine (*Stenotaphrum secundatum* [Walt.] Kuntze) stolons in sod production settings. The high rate of isoxaben (1.1 kg ha^{-1}) increased the number of unrooted stolons by 5 to 24 % through 4 WAT or 8 months after treatment (MAT) depending upon the location. The 0.6 kg ha^{-1} rate had no effect on unrooted stolons and both rates had no effect upon root weight. Dotray and McKenney (1996) found that buffalograss biomass measured at the end of the growing season was not significantly affected by a 1.1 kg ha^{-1} rate of isoxaben applied to an established 2-year old stand.

Bovey and Voigt (1983) found that metolachlor applied at 0.3, 0.6, 1.1, 2.2, and 4.5 kg ha^{-1} at 2 d after seeding resulted in significant phytotoxicity to weeping lovegrass (*Eragrostis curvaula* [Schrad.]) seedlings. McCarty et al. (1995) concluded that metolachlor at 1.1 and 2.2 kg ha^{-1} could safely be used on St. Augustine regrowth after sod harvest. The rates used had no effect on turf color at 2 WAT or on the number of unrooted stolons and treatments increased turfgrass density 4, 6 and 10 MAT.

Dotray and McKenney (1996) found that metolachlor applied at 4.5 kg ha^{-1} on mature buffalograss reduced biomass production at season's end. Seeded buffalograss plots treated with metolachlor at 3.4 kg ha^{-1} 24 hr after seeding reduced year-end biomass and stand density 4 through 10 WAT in 1993 and 4 through 21 WAT in 1994.

Fermanian et al. (1980) found that oxadiazon at 0.79, 2.03, 3.28 and 4.52 kg ha^{-1} applied immediately after seeding caused extreme toxicity and only 0.8 % survival of plants. Breuninger and Schmidt (1981) found that oxadiazon applied to established Tifway bermudagrass at 3.4 kg ha^{-1} resulted in a 7% root mass reduction and a 10% reduction in clipping yields 6 weeks after treatment. Bingham and Schmidt (1983) concluded that oxadiazon at a 3.4 kg ha^{-1} rate could be used during bermudagrass establishment from sod as it did not affect root development, shoot growth or appearance of 'Midiron' or Tifway hybrid bermudagrasses or 'Tufcote' common bermudagrass sod 28 DAT. Oxadiazon applied twice annually at 4.5 kg ha^{-1} for 6 years on 'Tifdwarf' hybrid bermudagrass putting greens severely retarded turf growth, reduced ground cover and sod uniformity (Johnson, 1983). When oxadiazon was applied only once annual at 4.5 kg ha^{-1}, Johnson (1983) found no negative effect on bermudagrass putting green root mass. Johnson (1985) later showed that rooting of established Tifdwarf, Tifway, Tifgreen and 'Ormond' hybrid bermudagrasses were unaffected by annual applications of oxadiazon at 4.5 and 13.5 kg ha^{-1}.

Oxadiazon applied at 2.2, 3.4, and 4.5 kg ha^{-1} on the day of sprigging did not inhibit shoot growth of 'Vamont' common bermudagrass, Midiron and Tifway bermudagrasses (Bingham and Hall, 1985). In this study Vamont and Tifway root development was unaffected by rates up to 4.5 kg ha^{-1}, whereas Midiron root development was reduced by 42% at 2.2 kg ha^{-1}.

Early work with pendimethalin (Turner et al., 1990) examined herbicidal effect on stand reduction (measured visually), sod tensile strength, root density and root length development. Rates of pendimethalin included 1.7 and 3.4 kg ha^{-1}. Visual ratings were made 6 WAT following a single application of both rates in subsequent years. Data indicated no significant reduction in visual quality for both years. Measurements of tensile strength 2, 4, and 8 WAT following 1.7 and 3.4 kg ha^{-1} applications in consecutive years showed no significant reduction for both years. No significant reduction in root density was observed in 1986 at 2, 4, and 8 WAT. In 1987, root density was reduced at 2 WAT by the 1.7 and 3.4 kg ha^{-1} rates. No significant reduction in root density was observed at 4 and 8 WAT. No significant reduction in root length measurements was observed in both years at the two application rates.

Johnson and Murphy (1991) studied the effect of pendimethalin applied at 3.4 and 10.1 kg ha^{-1} to 'Kentucky 31' tall fescue (*Festuca arundinacea* Schreb.). Applications were made the following February to stands planted in September, October and November of 1988 and 1989. September planted plots treated with the 3.4 kg ha^{-1} rate had slightly reduced turf quality while October and November plantings had moderately reduced turf quality. Pendimethalin applied at 10.1 kg ha^{-1} reduced turf quality slightly in the September planted plots, but severely reduced turf quality in the October and November planted plots.

Landschoot et al. (1993) evaluated preemergent herbicides including pendimethalin for their effects on root growth of mature Kentucky bluegrass (*Poa pratensis L.*) and tall fescue turfgrass in a greenhouse experiment in 1990 and 1991. Application of pendimethalin was at 1.7 kg ha^{-1} to established turf plots and plugs were pulled and moved to the greenhouse. Roots harvested 47 DAT indicated the 1.7 kg ha^{-1} pendimethalin rate significantly reduced root mass in both 1990 and 1991 on Kentucky bluegrass. Root mass at 47 DAT from tall fescue samples treated with the 1.7 kg ha^{-1} pendimethalin rate showed no significant root mass reduction in both 1990 and 1991.

Fishel and Coats (1993) initiated research on mature common bermudagrass sod to examine the effect of several preemergent herbicides, including pendimethalin, on bermudagrass root growth in 1990 and 1991. Pendimethalin was applied at 3.4 kg ha^{-1} and cores were taken from treated plots 2, 4, 8 WAT. In 1990 pendimethalin reduced root mass production at all three treatment dates. In 1991 reduced root mass production was reported at 2 and 4 WAT. In 1991, at 8 WAT, no reduction in root mass production was observed. Lack of effect at 8 WAT in 1991 was attributed to herbicide degradation due to extremely wet conditions during the treatment to harvest period.

Early work with prodiamine (Dernoeden et al., 1988) examined the effects of prodiamine applied at 0.28, 0.42, 0.56, 0.84, 1.12 and 2.24 kg ha^{-1} on cover, overall quality and root development of plugs harvested from an unknown cultivar of established perennial ryegrass. Plots treated three times (April 22, May 20, and August 5, 1987) with the 0.28, 0.42, 0.56, 0.84, 1.12 and 2.24 kg ha^{-1} rates showed reduced cover at the two highest rates of prodiamine (1.12 and 2.24 kg ha^{-1}). On the last of the three treatment dates, overall quality ratings indicated only the highest prodiamine rate (2.24 kg ha^{-1};

exhibited inferior quality when compared to all other treatments. Root mass data collected from plots treated with 0.56, 1.12 and 2.24 kg ha^{-1} (other treatments not evaluated) indicated significant reductions in root weights.

Hummel et al. (1990) found that prodiamine reduced root mass, stand density and quality when applied at 0.3, 0.6, 1.1, 2.2, and 4.5 kg ha^{-1} to mature 'Nugget' Kentucky bluegrass. Fermanian and Haley (1994) found that quality reduction occurred on Kentucky bluegrass less than one year old when receiving a single application at 1.4, 1.7, 2.0 and 2.2 kg ha^{-1}. Rates of 0.8 and 2.2 kg ha^{-1} applied in the fall for three consecutive years reduced the number of overseeded Kentucky bluegrass seedlings two years after planting. Prodiamine applied at 0.8, 1.1, 1.4, 1.7, 2.0 and 2.2 kg ha^{-1} once, during the previous fall, significantly reduced the number of surviving overseeded seedlings 56 days after planting. Fermanian and Haley (1994) concluded that prodiamine rates of less than 0.8 kg ha^{-1} should be used if overseeding of Kentucky bluegrass is to be practiced. Han et al. (1995) initiated experiments on 14 established tall fescue varieties to examine the effect of 0.8 and 1.7 kg ha^{-1} application of prodiamine on root mass and root length. Conclusions from their research indicated no significant effect at 0.8 kg ha^{-1} but the 1.7 kg ha^{-1} rate significantly reduced both root mass and root length of all varieties at 4 WAP. Johnson (1994) treated established Tifway bermudagrass with prodiamine at 0.8 and 1.6 kg ha^{-1} and found it non-injurious to established Tifway bermudagrass.

Johnson (1995) studied the effects of multiple rates of quinclorac applied singly and as split applications to established common bermudagrass stands. He concluded that quinclorac caused varying degrees of injury depending upon rate and follow up split application timing. Dotray and McKenney (1996) found that quinclorac at 0.6 kg ha^{-1}

applied 24 hr after seeding buffalograss significantly reduced stand density from 4 to 10 WAT in one year and 4 to 21 WAT in another, as well as reduce biomass production as measured at the end of the growing season. Dotray and McKenney (1996) concluded that quinclorac should not be used as a preemergent herbicide on newly seeded buffalograss due to its sensitivity.

In summary, review of the literature revealed that substantially more information was available regarding the effect of preemergent herbicides on mature and sodded turfgrasses as compared to use on seed established bermudagrass. Additionally, the original field research backing the herbicide label use suggestions on immature turf does not appear to be public domain accessible. With the increased interest in establishment of bermudagrass by seed and the identified gap in available information, we felt that research in seedling bermudagrass tolerance to preemergence herbicides was justified. The first objective of this research was to evaluate under field conditions the effect of 8 preemergent herbicides applied at 0, 2, 4, 6, 8 and 10 weeks after planting (WAP) on the phytotoxicity response, clipping yield, shoot density, verdure and root mass of 'Cheyenne' common bermudagrass. The second objective of this work was to test the effects of reduced rates (0, ¼, ½, ¾ and 1X label rates) of the most promising preemergent herbicide on Cheyenne, using the same response parameters as in Objective I.

MATERIALS & METHODS

FIELD STUDIES

Field experiments were conducted at the Oklahoma State University Turfgrass Research Center, Stillwater, OK during the summers of 1991 and 1992. The soil was an Easpur sandy loam (fine-sandy, mixed, thermic Fluventic Haplustoll) composed of 53% sand, 30% silt and 17% clay, with 1.1% organic matter and a pH of 6.6. Soil was disked, rototilled, treated with methyl bromide at 488 kg ha^{-1} and sealed with a polyethylene cover for 48 hr prior to removal. One day prior to planting, soil was amended with 48.8 kg N ha^{-1}, 9.7 kg P ha^{-1} and 24.3 kg K ha^{-1}. The site was otherwise maintained with 48.9 kg N ha^{-1} $month^{-1}$ using a 34-0-0 (N-P-K) source.

Experimental areas 15.2 x 30.5 m were seeded on 19 July 1991 and 16 July 1992 using 0.45 kg ha^{-1} pure live seed of Cheyenne bermudagrass. Seed was incorporated in two directions using leaf rakes. Plots were irrigated by hand during the initial establishment phase to minimize desiccation and displacement of seed. Later supplemental additions of water were made through pop-up rotary sprinklers to insure totals of 1.9 cm water wk^{-1}. Shoots emerged five days after planting in 1991 and 1992. Plots were maintained at a mowing height of 1.9 cm using a rotary vacuum mower.

HERBICIDE TREATMENTS

In 1991, the following herbicide treatments were applied to 1.5 x 1.5 m plots at 0, 2, 4, 6, 8, and 10 wks after planting (WAP); DCPA, dimethyl 2,3,5,6-tetrachloro-1,4-benzenedicarboxylate at 11.77 kg ha^{-1}; Isoxaben, *N*-[3-(1-ethyl-1- methylpropyl)-5-isoxazolyl]-2,6-dimethoxybezamide at 1.49 kg ha^{-1}; dithiopyr, *S,S*-dimethyl 2-

(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinecarbothioate at 1.12 kg ha^{-1}; oxadiazon, 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3*H*)-one at 3.36 kg ha^{-1}; pendimethalin, *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzanamine at 3.36 kg ha^{-1}; quinclorac, 3,7-dichloro-8-quinolinecarboxylic acid at 1.12 kg ha^{-1}; prodiamine, N^3,N^3-di-*n*-propyl-2,4-dinitro-6-(trifluromethyl)-*m*-phenylenediamine at 0.84 kg ha^{-1}. The treatment rates chosen were the high end rates in effect on commercial or experimental labels in 1991. In 1992 the experiment was repeated, and the herbicide treatments from the previous year as well as dithiopyr at 0.56 kg ha^{-1}, oxadiazon in a granular form at 3.36 kg ha^{-1} and metolachlor at 4.48 kg ha^{-1} were included. The specific formulations of herbicides used in this research were: DCPA, 75% wettable powder (WP); isoxaben, 75% dry flowable (DF); dithiopyr, 0.12 kg l^{-1} emulsifiable concentrate (EC); oxadiazon, 2% dry granule (G) and 50% WP; pendimethalin, 60% water dispersible granule (DF); quinclorac, 75% DF; prodiamine, 65% DG; and metolachlor, 0.94 kg l^{-1} EC. Treatments were replicated three times in a randomized complete block design. A CO_2 pressurized hand boom sprayer with three 8005 low pressure flat fan nozzles was used to deliver the sprayable treatments at 514.4 L ha^{-1}. One hr after application, all plots were watered to remove materials from leaf surfaces. Subsequent weekly irrigations were also used to remove materials from the leaves.

PHYTOTOXICITY

Phytotoxicity was measured using a 1-9 visual rating scale (1 = no observed effect and 9 = complete necrosis of shoots and a straw colored appearance) on the day of herbicide treatment and every other day for 2 wks, for a total of 7 rating dates. No 0 WAT ratings were taken on 0WAP treatments as there was no phytotoxicity, as germination had not occurred.

CLIPPING YIELD

Clippings were collected 2, 4, 6, 8, and 10 WAP using a rotary vacuum mower set at 1.9 cm. Plots were mowed twice weekly after the initial herbicide application with yields taken 4 days after the first weekly mowing. Clippings were collected from a 96.5 x 55.9 cm area in the center of each plot. Clippings were dried at 58.7 ± 7.0C for four days prior to weighing.

SHOOT DENSITY

In 1991 live shoot density was by manually counting shoots and recording the results. The 1991 shoot density records were subsequently lost. In 1992, live shoot density was measured and recorded 30 DAT on the 2, 4, 6, 8 and 10 WAP treatments. Three 5.7 cm dia. plugs were taken at random from the 2 WAP treatment plots whereas three 10.2 cm dia. plugs were taken from the 4 through 10 WAP plots. All plugs were frozen and shoots were counted at a latter date. The mean shoots dm^{-2} from the three samples for each replicate were utilized in the analysis.

ROOT YIELDS

In both 1991 and 1992, six 2.5 cm dia. X 15.2 cm length plugs were collected 30 DAT to measure root mass. Verdure and thatch were separated from plugs at the soil line.

Plugs were frozen and later soaked in a solution of sodium hexametaphosphate (SHMP) and water (Smucker et al., 1982). The SHMP was used to disperse clay particles from root material. Roots were separated from soil using a vortex root washer (Gillisons Variety Fabrication, Inc; 3033 Benzie Hwy., Benzonia, MI 49616). Pooled samples of root materials were dried for three days at a temperature of 48.9 ± 7.0C prior to recording dry mass.

STATISTICAL ANALYSIS - FIELD STUDIES

Data was analyzed using an analysis of variance procedure, Proc ANOVA (SAS Institute, 1985). A separate ANOVA was conducted on data from each year (Experiment) because the herbicide treatments were not identical for the two Experiments. For analysis of phytotoxicity data, the analysis was set up as a split block-split in time, with bermudagrass age (WAP) x blocks as main plots, herbicide treatments as subplots and sampling dates as sub-sub plots. As pooling of data over sampling dates was performed for the clipping yield variable and only a single sampling date was involved with measurement of shoot and root mass production, when analyzing these parameters, a split-block arrangement of treatments was utilized with WAP x blocks as main plots and herbicide treatments as subplots. When effects were found significant at the $P \leq 0.05$ level in the ANOVA, Fisher's least significant difference test was used to separate treatment means.

During establishment, pots were irrigated by hand to minimize isplacement of seed. Later supplemental additions of water were made d stationary sprinklers to insure totals of 1.9 cm water wk^{-1}. Day length : 14 hrs by supplementing natural sunlight with artificial light from HID erged six days after planting. Turf in pots was maintained through t a height of 2.5 cm, using hand held shears, as soon as canopy growth of the pots. Clippings were collected weekly to measure clipping yield.

e treatment (0WAT) and every other day for 2 wks, for a total of 7 rating

ELD

gs were collected as soon as shoot growth exceeded 2.5 cm in height. Pots vice weekly as needed after the initial herbicide application with yields fter the first weekly clipping, if present. Clipping samples consisted of the removed from the pot when the 2.5 cm mowing height was maintained. dried at 58.7 ± 7.0C for four days prior to weighing.

ignificant at the $P \leq 0.05$ level in the ANOVA, Fisher's least

ce test was used to separate treatment means. As DCPA herbicide rate

titative variable, when the herbicide rate or WAP x herbicide rate

int at $P \leq 0.05$ level in the ANOVA, single degree of freedom T-tests

ate treatment means from the non-treated control.

on and quinclorac treatments resulted in phytotoxicity at 5 DAT on 6 while phytotoxicity was present at 9 DAT for oxadiazon and dithiopyr 3 DAT only oxadiazon exhibited symptoms of phytotoxicity in 6 WAP bermudagrass was treated at 8 WAP, oxadiazon caused phytotoxicity 1 nd 9 DAT quinclorac was the only treatment that showed phytotoxicity. ects were gone by 13 DAT on 8WAP treated turf.

d at 10 WAP had no phytotoxicity present at 1 and 13 DAT. At 5 DAT, adiazon and quinclorac exhibited phytotoxicity. By 9 DAT, only

s phytotoxicity rating the evening after morning application of herbicides.
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ırf was treated at 6 WAP, oxadiazon WP produced phytotoxicity at 1 T in 1992 as compared to 5 through 13 DAT in 1991. Oxadiazon WP was ent to result in phytotoxicity at 13 DAT on the 6 WAP age group of turf in clorac treatment on this age of turf resulted in phytotoxicity at 5 and 9 'hereas in 1992 phytotoxicity was only detected at 5 DAT. The atment resulted in phytotoxicity at 5 and 9 DAT with no phytotoxicity r 13 DAT when used at 6 WAP in 1992.

ΛP, oxadiazon WP was the only treatment to result in phytotoxicity at 1 Γ in 1992. In 1991, the oxadiazon WP treatment only caused phytotoxicity

0.7	0.6	0.4	0.1	NS	0.8	0.7	0.7	0.1	0.3	0.1	0.3

cale 1= no observed effect, 9= total necrosis of leaves with straw colored appearance of plant material.
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	0.3	0.5	0.4	0.2	NS	0.1	0.3	0.3

cale 1= no observed effect, 9= total necrosis of leaves with straw colored appearance of plant material.
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he G formulations may be from the placement of the granules on the soil sed to placement of the WP formulation on the leaf surface prior to

tic effects observed in 1991 and in 1992 with the 1.1 kg ha^{-1} quinclorac nt with those observed by Johnson (1995) who utilized lower rates of , 0.43, 0.56, and 0.84 kg ha^{-1}, and determined that damage to established ands was dependant upon the rate of quinclorac applied.

otoxicity observed in this experiment when using the high 1.1 kg ha^{-1} corresponded well with the findings of Kasi et al. (1987) who found that g yield by 64%, 56%, 21% and 20%, respectively, when compared to here was no significant difference between yields from dithiopyr and reated plots when used on this age group. Turf treated with oxadiazon and elds significantly greater than that of turf treated with dithiopyr and it 2 WAP. While clipping yields from oxadiazon and isoxaben treated ficantly lower than that from the control plots, yields were similar to clorac treated turf. At 4 WAP, there were no significant reductions or ipping yields from turf treated with any herbicide.

tions: EC = emulsifiable concentrate, WP = wettable powder, DG = water dispersible granule, DF = dry

nting.
 same letter are not significantly different at the $P \leq 0.05$ level using the LSD test. NS = no statistical

respectively as compared to the control.

AP the application of all treatments except dithiopyr at the high rate (1.1

etolachlor resulted in no effect on clipping yields. Metolachlor and

high rate (1.1 kg ha^{-1}) significantly reduced clipping yields by 83% and

ely, compared to the control when applied at 4 WAP in 1992. The only

ment to reduce clipping yields when applied to 6 WAP turf in the 1992

s metolachlor. Metolachlor application reduced clipping yields by 66%

control. Turf treated with DCPA, isoxaben, dithiopyr

	45.49ab	67.40ab	63.11ab	38.02a	26.16a
	11.43	9.83	12.88	9.36	7.19

ions: EC = emulsifiable concentrate, WP = wettable powder, DG = water dispersible granule, DF = dry

nting.

e same letter are not significantly different at the $P \leq 0.05$ level using the LSD test. NS = no statistical ide application. Thus, the 1991 work may have allowed for improved negative effect of oxadiazon (WP) on clipping yields as compared to en used 2 WAP. Results from oxadiazon testing correspond well with the ianian et al. (1980) in that newly seeded bermudagrass exhibited city to oxadiazon (25% EC formulation) at 3.28 kg ha^{-1}. Our work rmudagrass at 2 WAP is slightly more tolerant of oxadiazon as opposed plication to the soil surface immediately after planting bermudagrass seed ack of toxicity expression at 4, 6, 8 and 10 WAP is supported by research l. (1983) who found that a 3.4 kg ha^{-1} rate did not visibly affect shoot a^{-1} dithiopyr rate reduced yield at one location by 100% and had no

d reduction at another test location. No explanation for this variability was

t al. (1997).

1991 and 1992, pendimethalin exhibited the same trend in that significant

ield were exhibited at 2 WAP and those effects were not observed at 4, 6,

.

three new treatments added to the 1992 test, both dithiopyr (0.6 kg ha^{-1})

(G) resulted in a significant reduction in clipping yields at 2 WAP which luced the amount of biomass produced in treated buffalograss plots as

n-treated controls. Thus, our findings are contrary to those of Dotray and

)6).

ductions caused by metolachlor in our work are similar to results obtained

McKenney (1996) who found that a 4.5 kg ha^{-1} rate significantly reduced

ed in treated plots when compared to untreated plots.

as expected, our work found heightened sensitivity to preemergent

ients at 2 WAP, with treatment effects dissipating as bermudagrass plants of variance performed on root mass data collected from bermudagrass eated at 2, 4, 6, 8 and 10 WAP indicated that herbicide treatments had ass production and that a plant age effect was present (Table 9). In :lds collected 30 DAT reflected the ranking 2=8<4=6=10 WAP, while ›y WAP had the ranking 2=4<8≤10=6 (Table 10). Explanation for the t mass production may be due to the underdeveloped root growth of the 2 WAP treatment growth stage as compared to other harvest dates. elds from the 2 WAP and 8 WAP treatments may be partially ction in root growth of the 8 WAP treated turf, in that the 8 WAP turf

	192.52d
	250.72c
	335.46a
	305.72b
)	296.34b
0.05)	27.89

after planting.
ter treatment.
ed by the same letter are not significantly different at the $P \leq 0.05$ level
) test.

159.82a	119.35c
164.91a	158.35a
132.63b	140.75b
167.72a	145.51ab
17.40	17.30

er planting.

treatment.

by the same letter are not significantly different at the $P \leq 0.05$ level

) test.

ields. These differences may be due to the reduced amount of growing roots at these younger ages. The 6 WAP treatment root mass yield was r than that associated with the 8 and 10 WAP treatments, respectively. mperature exposure of the roots in 8WAP treatment plots may partially 1 behind this trend.

: a similarity between 1991 and 1992 root mass yield data, mainly that t production occurred from 2 through 6 WAP and that peak living root at 6 WAP in both years. Additional testing with more detailed attention nd II indicated there were significant treatment, age, experiment, and

ge effects (Table 11). The T-test$_{(0.05)}$ revealed that mean clipping yields of

ere significantly lower when 5.9, 8.9 and 11.8 kg ha^{-1} of DCPA were

ed to the untreated control (Table 12). Mean bermudagrass clipping yields

4.1, 6.9, 6.8, and 10.7%, respectively, when treated with DCPA at 2.9,

3 kg ha^{-1}.

significant experiment x age effect was present (Table 11) for clipping

general statistically trend was evident for both experiments (Table 13).

erall mean clipping yield increased significantly with increases in plant

riments. Lower overall yields in Experiment I may have been due to

5.9	1106.2*
2.9	1138.9
Control	1188.1
T[a] (0.05)	73.1

ıs followed by an asterisk are significantly different from that of the
≤ 0.05 level using the T-test.

:atment of Cheyenne at 4 WAP resulted in no differences in verdure

at the 5.9 kg ha^{-1} rate in Experiment I and at the 2.9 kg ha^{-1} rate in

oth of which were significantly greater than that of the controls. Yields

ng treatments applied 4 WAP were numerically larger than those from

oth experiments except at the 11.8 kg ha^{-1} rate in Experiment I which

ierically lower yield. Typically, data suggests yields should be close to or

han controls.

ot density indicated that all main and interactive effects were statistically

e 16.)

24 comparisons made over 2 experiments, 3 treatment dates and 5

shoot density from DCPA treated pots was numerically less than that

trol pots. As plants aged, they usually had increased herbicide tolerance,

ys so. In Experiment I and II at 2 WAP all DCPA application rates

uced shoot density relative to the control except for the highest rate in

'able 17). At 4 WAP, only the 11.8 kg ha^{-1} rate in Experiment I and the

n Experiment II significantly reduced shoot density. Results at 6 WAP

	Age (WAP)			Age (WAP)	
	4	6	2	4	6
	Shoots per pot				
*	301*	376*	476	480	518
*	313	326*	320*	447	527
*	372	458	298*	465	541
*	338	342*	298*	415*	542
	360	529	522	499	592
	49	103	64	62	80

er planting.
treatment.
s followed by an asterisk are significantly different from that of the
≤ 0.05 level using the T-test.

than from controls (Table 19) except for grass treated with the 8.8 kg

ı Experiment II. No statistically clear trends were present between the

concerning effects on 4 and 6 WAP treated turf. While DCPA did not

ce root matter yields at any rate when used 4 WAP in Experiment I, in

en used 4 WAP all but the 8.9 kg ha^{-1} treatment rate reduced root yields.

ted at 6 WAP, significant reduction in root dry matter production were

ites of 8.9 and 11.8 kg ha^{-1} in Experiment I and at all rates in

› clear conclusions regarding root mass production can be drawn based

und trends although numerical reduction in root mater production was

mg					
109*	405	446*	428*	944*	932*
99*	509	459*	467	965*	856*
91*	466	492	458*	938*	952*
106*	661	503	434*	977*	881*
275	502	586	555	1282	1162
36	163	101	93	190	133

ter planting.
r treatment.
s followed by an asterisk are significantly different from that of the
≤ 0.05 level using the T-test.

1.8 kg ha^{-1}), \$537.44 ha^{-1} for oxadiazon (3.4 kg ha^{-1}), \$162.86 ha^{-1} for g ha^{-1}) and \$122.76 ha^{-1} for pendimethalin (3.4 kg ha^{-1}). Speculatively iigh cost per ha for use of DCPA might cause a change in turf manager pehavior. Some end users may increase their tolerance (decrease quality weeds in newly seeded turf and cause them to change weed control preemergent approach to a postemergence approach treating the more mature bermudagrass. Another possible change might include a ce for seed established bermudagrass and use of a suitable vegetatively y. Oxadiazon G provides good weed control and acceptable safety to

10 WAP) of common bermudagrass. This susceptibility may exclude

deration for use on seedling bermudagrass at these high rates. No other

.ced a significant visual phytotoxic effect under field conditions. DCPA

uinclorac, prodiamine (0.8 kg ha^{-1}) and oxadiazon G (3.4 kg ha^{-1}) did not

yields. While isoxaben (1.5 kg ha^{-1}) and oxadiazon WP reduced clipping

lied 2 WAP in 1991; pendimethalin (3.4 kg ha^{-1}) and the low rate of

; ha^{-1}) reduced clipping yields when applied 2WAP in 1992. The high

(1.1 kg ha^{-1}) reduced clipping yields at 2WAP in 1991 and at all dates in

or reduced clipping yields of all age groups of bermudagrass and should d was a numerical increase in dry verdure production of treated pots controls. The small but at times significantly greater verdure yields of us controls may be due to inhibition of root growth by the herbicide and rsion of energy and internal materials necessary for growth from the root oot system. Shoot density was affected by the age of the plant and as y usually had increased herbicide tolerance and shoot density, though not lants aged, they occasionally had increased herbicide tolerance as merically lower percentage reduction in dry root matter production, ictably so. From these greenhouse observations, seeded bermudagrass at

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