# BERMUDAGRASS, PLAINS BLUESTEM, AND WEEPING LOVEGRASS ESTABLISHMENT WITH SELECTED PREEMERGENCE HERBICIDES AND ADSORBENTS

By

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## TABLE OF CONTENTS

## LIST OF TABLES

Table Page



PART III

LIST OF FIGURES

Figure | Page

PART II

# INTRODUCTION

Each of the three parts of this dissertation is written as a complete and independent manuscript to be submitted for publication in a peer-review journal such as *Agronomy Journal*. The three parts are united under the general theme of bermudagrass [*Cynodon dactylon* (L.) Pers.], 'Plains' bluestem [*Bothriochloa ischaemum* var. *ischaemum* (L.) Keng.], and weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees.] establishment with selected preemergence herbicides and herbicide adsorbents.

# PART I

## WEEPING LOVEGRASS, PLAINS BLUESTEM, AND BERMUDAGRASS ESTABLISHMENT WITH SELECTED HERBICIDES

ABSTRACT

Establishment of seed propagated, warm-season grasses may be enhanced using selective preemergence herbicides. The objectives of these studies were to evaluate the effect of i) preemergence applications of eight selected herbicides, and ii) the time interval from preplant herbicide treatment to planting on stand establishment of weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees.], 'Plains' bluestem [*Bothriochloa ischaemum* var. *ischaemum* (L.) Keng.], and bermudagrass [*Cynodon dactylon* (L.) Pers.] from seed. The influence of four preemergence herbicides on stolon growth of bermudagrass established with sprigs was also investigated. Preemergence applications of pronamide [3, 5-dichloro(*N*-1,1-dimethyl-2-propynyl)benzamide] at 1.1 kg/ha, metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one] at 0.7 kg/ha, and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] at 1.3 kg/ha did not reduce root and shoot dry weight of the three species grown from seed in pots for 122 days. Oryzalin (3,5-dinitro-$N^4$,$N^4$-dipropylsulfanilamide) at 1.2 kg/ha, diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] at 2.7 kg/ha, sulfometuron methyl [Methyl 2-(((((4,6-dimethyl-2-pyrimidinyl) amino)-carbonyl)amino) sulfonyl)benzoate] at 0.1 kg/ha, and DCPA (dimethyl tetrachloroterephthalate) at 8.4 kg/ha were extremely toxic to seeds and emerging seedlings. The eight preemergence herbicide treatments exhibited variable persistence. Generally, fewer Plains bluestem and bermudagrass seedlings established when seeded 2 and 30 days after preplant herbicide treatment (DAT) in comparison to weeping lovegrass. A significant increase in seedling numbers occurred between the 2 and 30 DAT planting dates within atrazine, pronamide, and DCPA treatments at one of the two locations. When preemergence herbicides were applied to exposed soil encircling bermudagrass sprigs, diuron at 2.7, 5.4, and 8.1 kg/ha, sulfometuron methyl at 0.1, 0.2, and 0.3 kg/ha, and atrazine at 1.3, 2.7, and 4.0 kg/ha reduced stolon growth by 27 to 80 percent, and number of nodes per stolon by 32 to 81 percent. Oryzalin at 1.2, 2.5, and 3.7 kg/ha did not affect number of rooted nodes per stolon. The results indicate that phytotoxicity of selected herbicides on three warm-season grasses established from seed was influenced by herbicide treatment, species, and time interval from treatment to planting.

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Additional Index Words: Atrazine, *Bothriochloa ischaemum*, *Cynodon dactylon*, DCPA, Diuron, *Eragrostis curvula*, Metribuzin, Preemergence, Preplant, Pronamide, Stolon, Sulfometuron, Terbutryn.

# INTRODUCTION

Several warm-season grasses provide a practical vegetative ground cover for soil stabilization and erosion control throughout the South. Species including weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees.] and 'Plains' bluestem [*Bothriochloa ischaemum* var. *ischaemum* (L.) Keng.] are quickly established from seed. Other grasses, however, display variable germination and seedling emergence, and slow seedling growth (7). Use of selective preemergence herbicides at seeding may enhance establishment by reducing competition from annual grasses and broadleaf weeds.

Annual and perennial weeds influence the establishment and production of slowly establishing, seed propagated, warm-season grasses. Evers (4) demonstrated that metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one] and diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] promoted rapid establishment of dallisgrass (*Paspalum dilatatum* Poir.). Use of paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) to control early germinating weeds tripled bahiagrass (*Paspalum notatum* Flugge) yields during the establishment year (3). Similarly, a preemergence application of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] improved forage yields of switchgrass (*Panicum virgatum* L.) (12).

Information on the effect of preemergence herbicides on bermudagrass [*Cynodon dactylon* (L.) Pers.] seedlings is limited. Fermanian et al. (5) reported that metribuzin and terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine] were relatively non-toxic to bermudagrass established from seed of three $F_1$ generation hybrids. Terbutryn enhanced the effectiveness of seeded bermudagrass and improved erosion protection to roadside cut slopes. In Georgia, a two-week interval between treatment and seeding was required to minimize injury to common bermudagrass from an application of MSMA (monosodiumethanearsonate) plus metribuzin (9). Metribuzin at 0.6 kg/ha reduced ground cover of bermudagrass established from seed by 76 percent five weeks after planting.

Several Asiatic bluestems are tolerant of *s*-triazine herbicides. Frizzell (6) demonstrated that preemergence atrazine applications of 1.12 and 2.24 kg/ha selectively controlled weeds in Plains and 'Caucasian' [*Bothriochloa caucasica* (Trin.) C.E. Hubb] bluestem established from seed. Simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine] was more phytotoxic to all bluestem cultivars tested than atrazine. McMurphy (11) observed no apparent retarding effects on germination and seedling growth of bluestem cultivars following preemergence propazine [2-chloro-4,6-bis(isopropylamino)-*s*-triazine] applications.

Our objectives were to evaluate the effect of i) eight selected herbicides and ii) time interval from preplant treatment to planting on the establishment of weeping lovegrass, Plains bluestem, and bermudagrass from seed. The influence of four herbicides on stolon growth of bermudagrass established with sprigs was also investigated.

## MATERIALS AND METHODS

### Experiment I

A preliminary field study was conducted during 1983 at the Oklahoma Turfgrass Research Center, Stillwater, to evaluate the effect of selected herbicides on three warm-season grasses established from seed.

Twenty pure-seed units (seeds) of each species, bermudagrass, an experimental hybrid designated Guymon X 10978b, weeping lovegrass cv. common, and 'Plains' bluestem, were planted at a soil depth of approximately 0.3 cm in plastic pots 15.2 cm in diameter and 12 cm deep. Pots contained a 50:50 v/v sterile-nonsterile soil mix overlaying a sterile layer of Kirkland (Thermic, udertic Paleustoll) soil. The mixed sterile-nonsterile soil layer was 5 cm in depth above the sterile soil layer 3.5 cm deep in each pot. The non-sterile soil fraction, an inoculum source of soil microorganisms, was pulverized and sieved through a U.S. standard #35 0.5 mm screen to remove weed seed. All seeds were processed using a separator (blower) to obtain a uniform pure seed size (density).

Eight herbicide treatments, pronamide [3,5-dichloro(_N_1, 1-dimethyl-2-propynyl)benzamide] at 1.1 kg/ha, metribuzin at 0.7 kg/ha, atrazine at 1.3 kg/ha, oryzalin (3,5-dinitro-$\underline{N}^4$,$\underline{N}^4$-dipropylsulfanilamide) at 1.2 kg/ha, diuron at 2.7

kg/ha, terbutryn at 2.2 kg/ha, sulfometuron methyl [Methyl 2-(((((4,6-dimethyl-2-pyrimidinyl)amino)-carbonyl)amino) sulfonyl)benzoate] at 0.1 kg/ha and DCPA (dimethyl tetrachloroterephthalate) at 8.4 kg/ha were applied to the soil surface of randomly selected pots on 24 June, 1983, one day after planting. A hand-held, $CO_2$-pressurized sprayer calibrated to deliver 374 liter/ha at 193 kPa pressure through three 80015 spray tips was used to dispense treatments. One-hundred pots, ten per herbicide treatment (eight herbicides and two controls), were arranged by species in three 10 by 10 latin squares. One of the two controls in each latin square consisted of seeds planted in sterile soil only with the other planted in sterile-nonsterile soil mix. Pots in each latin square were inserted to a 10-cm depth on 46-cm centers in soil of the experimental field site. A border row of planted pots surrounded each of the three latin squares. Individual pots received 450 ml of irrigation water every 48 to 72 h depending on cloud cover and natural precipitation.

The evaluation of herbicide action was measured by number of emerged seedlings, tillers and/or stolons on 6 Aug., and shoot and root mass, 24 Oct., 1983. Following removal of plants from pots, shoots were harvested and roots (with crowns) rinsed to dislodge adhering soil. Both roots and shoots were dried at 38' C for 48 h prior to recording weights.

Experiment II

The field study was expanded in 1984 at two adjacent sites to determine the effect of preplant applications of the eight herbicides on the establishment of bermudagrass, weeping lovegrass, and Plains bluestem from seed planted two, 30, 62, and 368 days after treatment (DAT). The soil type at each location was a Norge (udic Paleustoll) loam. Prior to study, approximately 30 cm of topsoil was removed from the surface of one location and uniformly deposited over the other location. The purpose of this modification was to create greater soil variability between location 1 (topsoil) and location 2 (subsoil). Experimental sites were plowed and disked at depths of approximately 20 and 8 cm, respectively to prepare and smooth the seedbed. Methyl bromide was administered at a rate of 488 kg/ha to reduce weed competition.

Identical treatments at both locations were arranged in split-split plot designs with four replications. Preplant herbicide treatments were whole plots, and species and planting date treatments were sub-and sub-subplots respectively. Herbicides and rates in kg/ha were: atrazine, 0.7; DCPA, 4.2; diuron, 1.3; metribuzin, 0.3; oryzalin, 0.6; pronamide, 0.6; sulfometuron methyl, 0.05; and terbutryn, 1.1. A $CO_2$-pressurized sprayer was utilized to broadcast herbicide treatments in 364 liter/ha water over the soil surface of 46 by 122 cm whole plots on 9 July, 1984. Two, 30, 62, and 368 DAT, 25 seeds of bermudagrass, weeping lovegrass, and Plains bluestem were uniformly distributed within 4.1-cm diameter sub-subplots. Seeds were covered with approximately 1 cm untreated soil. The study received approximately 2 cm supplemental irrigation every 72 to 96 h. Seedling counts were recorded 24 to 28 days after seeding.

Experiment III

The effect of four herbicides on the development of bermudagrass stolons was also evaluated during 1984 at two sites near experiment II. The experimental areas were prepared as described previously for experiment II.

Four bermudagrass sprigs were established in the center of each 0.9 by 0.9 m plot and were allowed to attain a uniform length of approximately 10 cm. Prior to herbicide application, sprigs were covered with a plastic disk 15 cm in diameter. Atrazine, diuron, oryzalin, and sulfometuron methyl at one, two, and three times label or recommended rate were applied 13 July, 1984 in 468 liter/ha water carrier over the exposed surface of the soil encircling the plants. Experimental areas received approximately 2 cm of irrigation water every 48 to 72 h.

A randomized complete block design was employed with four replications per location. Plant response to herbicide was measured as total number of stolons per plot on 26 to 29 Aug., 1984. Three stolons were randomly selected from each plot for measurement of stolon, internode, and root length, number of nodes, rooted nodes, and roots per node.

Data from experiments I and III were subjected to analyses of variance for a latin square and randomized complete block design, respectively, and the Waller-Duncan K-ratio t-test at the 0.05 level (K ratio = 100). Data from both sites of experiment III were averaged when analysis indicated a non-significant herbicide by location interaction.

Data from experiment II were subjected to a split-split-plot design analysis. The least-significant-difference (LSD) test was performed to compare means of herbicide treatments, seeding dates, and species.

## RESULTS AND DISCUSSION

### Experiment I

Five of eight herbicide treatments reduced bermudagrass, weeping lovegrass, and Plains bluestem seedling and tiller number 43 days after application (Table 1). Oryzalin at 1.2 kg/ha, diuron at 2.7 kg/ha, sulfometuron methyl at 0.1 kg/ha, and DCPA at 8.4 kg/ha were extremely toxic to seedlings of all species. Similarly, Frizzell (6) observed reductions in number of Plains bluestem seedlings following preemergence atrazine applications of 3.36 kg/ha to an Easpur (Thermic, fluentic Haplustoll) loam soil.

Pronamide at 1.1 kg/ha, metribuzin at 0.7 kg/ha, atrazine at 1.3 kg/ha, and terbutryn at 2.2 kg/ha did not affect bermudagrass and weeping lovegrass shoot and root mass 122 days after treatment.

Pots containing sterile Kirkland silt loam soil receiving no herbicide (data not shown) displayed greater numbers of seedlings and tillers than those with an untreated 50:50 v/v sterile-nonsterile soil mix.

Experiment II

Analysis of variance for seedling count indicated highly significant effects of herbicides, species, seeding dates, and species by seeding date interaction at both experimental sites. Greater numbers of weeping lovegrass seedlings established when seeded two and 30 days after preplant herbicide treatment in comparison to the other species (Table 2). Plains bluestem produced seedlings equal in number to weeping lovegrass when seeds of the two species were planted 368 DAT. Lack of uniform seed germination and seedling emergence of bermudagrass may have contributed to relatively low seedling counts for this species. Fermanian et al. (5) observed similar results with this cultivar under field conditions. Guymon x 10978b bermudagrass exhibited poor germination and growth and, on two occasions, ranked lowest among common bermudagrass and three $F_1$ generation hybrids evaluated for density of cover.

Although a herbicide by species interaction for data from location 2 was highly significant, response trends to many herbicide treatments were similar among species at both sites (Tables 3 and 4). No seedlings developed when species were seeded two days after oryzalin and DCPA applications of

0.6 kg/ha and 4.2 kg/ha, respectively. Germination and establishment of all species following the 9 Sep. seeding date (62 DAT) was influenced by sub-optimum environmental conditions.

Within three of eight herbicide treatments at location 1, sub-subplots seeded 30 DAT yielded greater seedling counts than those planted 2 DAT. Similarly, an increase in seedling numbers occurred within untreated sub-subplots. Therefore, loss of pronamide, atrazine, and DCPA activity may not have been entirely responsible for differences in seedling counts for the two dates.

Typically, herbicide residues did not significantly influence germination and emergence of species seeded 368 DAT.

Experiment III

Atrazine at 1.3, 2.7, and 4.0 kg/ha, diuron at 2.7, 5.4, and 8.1 kg/ha, and sulfometuron methyl at 0.2 and 0.3 kg/ha reduced number and length of bermudagrass stolons (Table 5). Smith et al. (13) reported that atrazine at 4.48 and 8.96 kg/ha reduced carbohydrate levels in bermudagrass for up to six weeks following fall treatments. Similarly, a preemergence atrazine application of 2.24 kg/ha reduced survival and stolon initiation of centipedegrass [Eremochloa ophiuroides (Munro) Hack. 'common'] (1). Johnson (8) observed moderate injury to common bermudagrass following repeated treatments with a bromacil (5-bromo-3-sec-butyl-6-

methyluracil) plus diuron combination at 1.1 + 1.1 kg/ha. He found that early injury to established common bermudagrass following two applications of atrazine at 2.2 kg/ha was not permanent.

Oryzalin exhibited no effect on bermudagrass stolon internode length while restricting root growth. Dancy and Coble (2) observed root inhibition throughout the growing season on 'Tifton 44' and 'Coastal' bermudagrass following preemergence oryzalin applications of 0.84 and 1.68 kg/ha to sprigs. Similarly, the herbicide caused little reduction in stolon growth.

Data analysis of bermudagrass stolon number from locations 1 and 2 indicated a significant herbicide by location interaction. Inconsistency of stolon production following the 0.1 kg/ha sulfometuron methyl treatment was partially responsible for the interaction.

Diuron, sulfometuron methyl, and atrazine reduced number of nodes per stolon by 32 to 81 percent. This reduction was attributed to decreased stolon length.

Fewer root numbers per node were observed for six of 12 herbicide treatments. Sulfometuron methyl at 0.2 and 0.3 kg/ha, diuron at 5.4 and 8.1 kg/ha, oryzalin at 3.7 kg/ha, and atrazine at 4.0 kg/ha reduced root counts by 27 to 68 percent. Johnson and Burns (10) report that root weight of 'Tifway' bermudagrass was reduced following an atrazine treatment after the turf had started to break dormancy.

Oryzalin had no effect on number of rooted nodes per stolon. Typically, bermudagrass response to oryzalin was expressed as root growth inhibition.

Results indicate that phytotoxicity of selected herbicides on weeping lovegrass, Plains bluestem, and bermudagrass established from seed was influenced by herbicide treatment, species, and time interval from treatment to planting. Response of bermudagrass stolons to atrazine, diuron, oryzalin, and sulfometuron methyl varied with herbicide and application rate.

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Table 1. Effect of eight preemergence herbicide treatments on seedling emergence, tiller number, and weight of shoot and root dry matter of three warm-season grass species.

| Treatment | Rate | Weeping lovegrass | | | | Plains bluestem | | | | Bermudagrass | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Days after treatment | | | | | | | | | | | |
| | | 43 | | 122 | | 43 | | 122 | | 43 | | 122 | |
| | | Seedling number | Tiller number | Shoot mass | Root mass | Seedling number | Tiller number | Shoot mass | Root mass | Seedling number | Tiller number | Shoot mass | Root mass |
| | kg/ha | | | Dm(g) | Dm(g) | | | Dm(g) | Dm(g) | | | Dm(g) | Dm(g) |
| Untreated Check | 0.0 | 6.7 a[+] | 17.6 a | 3.4 a | 2.6 a | 7.3 a | 24.8 a | 3.1 bc | 2.3 bc | 2.5 a | 5.0 a | 3.2 a | 1.3 a |
| Pronamide | 1.1 | 3.1 bc | 8.7 b | 3.2 a | 2.4 a | 1.2 cd | 5.2 c | 2.0 bc | 1.3 bc | 2.2 a | 6.1 a | 1.9 a | 1.4 a |
| Metribuzin | 0.7 | 4.7 b | 11.8 b | 2.7 a | 2.4 a | 1.4 c | 3.6 cd | 3.1 bc | 1.5 bc | 2.1 a | 4.2 a | 2.2 a | 1.6 a |
| Atrazine | 1.3 | 3.2 bc | 8.5 b | 3.8 a | 3.1 a | 3.3 b | 10.0 b | 8.4 a | 4.2 a | 1.5 a | 1.6 b | 1.2 a | 0.6 a |
| Terbutryn | 2.2 | 1.5 cd | 3.0 c | 3.9 a | 2.6 a | 0.1 cd | 0.1 d | 0.3 c | 0.2 c | 0.1 b | 0.2 c | 0.1 a | 0.1 a |
| Oryzalin | 1.2 | 0.0 d | 0.0 c | --- | --- | 0.0 d | 0.0 d | --- | --- | 0.0 b | 0.0 c | --- | --- |
| Diuron | 2.7 | 0.0 d | 0.0 c | --- | --- | 0.0 d | 0.0 d | --- | --- | 0.0 b | 0.0 c | --- | --- |
| Sulfometuron methyl | 0.1 | 0.0 d | 0.0 c | --- | --- | 0.0 d | 0.0 d | --- | --- | 0.0 b | 0.0 c | --- | --- |
| DCPA | 8.4 | 0.0 d | 0.0 c | --- | --- | 0.0 d | 0.0 d | 1.0 c | 0.5 c | 0.0 b | 0.0 c | --- | --- |

[+]Means followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test (K ratio = 100).

Table 2. Mean emerged seedling counts for planting dates averaged over nine herbicide treatments for three species at two locations, Experiment II.

| | Location | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | | | 2 | | | |
| | Days after treatment (Planting date) | | | | | | | |
| Species | 2 | 30 | 62 | 368 | 2 | 30 | 62 | 368 |
| | ---seedling count--- | | | | | | | |
| Weeping lovegrass | 3.0+ | 4.3 | 4.6 | 5.3 | 2.3 | 3.7 | 2.9 | 4.6 |
| Plains bluestem | 0.5 | 3.6 | 1.6 | 5.3 | 0.6 | 1.8 | 2.5 | 4.4 |
| Bermudagrass | 0.6 | 1.0 | 0.0 | 2.7 | 0.3 | 0.2 | 0.1 | 2.3 |

| | Location 1 | Location 2 |
|---|---|---|
| +LSD (0.05) between species within planting date by location | 1.02 | 0.79 |
| LSD (0.05) between planting dates within species by location | 1.05 | 0.79 |

Table 3. Mean effects of nine preplant herbicide treatments and four planting dates on emerged seedling counts averaged over species, location 1, Experiment II.

| Planting date | Atrazine | Terbutryn | Pronamide | Metribuzin | Sulometuron methyl | Diuron | Oryzalin | DCPA | Untreated Check |
|---|---|---|---|---|---|---|---|---|---|
| | Rate (kg/ha) | | | | | | | | |
| Days after treatment | 0.7 | 1.1 | 0.6 | 0.3 | 0.05 | 1.3 | 0.6 | 4.2 | 0.0 |
| | seedling count | | | | | | | | |
| 2 | 2.6[+] | 2.0 | 1.7 | 1.4 | 1.0 | 0.8 | 0.0 | 0.0 | 2.8 |
| 30 | 5.3 | 2.8 | 3.8 | 2.0 | 2.7 | 1.9 | 1.7 | 2.1 | 4.8 |
| 62 | 2.8 | 3.3 | 2.0 | 2.6 | 1.9 | 1.8 | 0.8 | 1.4 | 2.2 |
| 368 | 4.3 | 5.0 | 3.9 | 4.8 | 4.4 | 4.2 | 4.8 | 3.3 | 4.8 |

[+]LSD (0.05) between planting dates within herbicide treatment = 1.81
LSD (0.05) between herbicide treatments within planting date = 1.78

Table 4. Mean effects of nine preplant herbicide treatments on emerged seedling counts of three species and two planting dates, location 2, Experiment II.

| Species | Planting date | Atrazine | Terbutryn | Pronamide | Metribuzin | Sulometuron methyl | Diuron | Oryzalin | DCPA | Untreated Check |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after treatment | Rate (kg/ha) | | | | | | | | |
| | | 0.7 | 1.1 | 0.6 | 0.3 | 0.05 | 1.3 | 0.6 | 4.2 | 0.0 |
| | | seedling count | | | | | | | | |
| Weeping | 2 | 3.5 | 3.0 | 2.8 | 1.8 | 3.8 | 3.3 | 0.0 | 0.0 | 2.5 |
| lovegrass | 30 | 3.5 | 6.0 | 5.0 | 3.5 | 6.0 | 5.3 | 0.0 | 0.0 | 4.3 |
| Plains | 2 | 2.5 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.8 |
| bluestem | 30 | 6.3 | 2.8 | 1.0 | 0.8 | 1.3 | 0.0 | 0.5 | 1.3 | 2.5 |
| Bermudagrass | 2 | 0.3 | 0.5 | 0.8 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 1.0 |
| | 30 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 |

LSD (0.05) between planting dates within herbicide treatment = 2.41
LSD (0.05) between herbicide treatments within planting date = 2.45

Table 5. Mean effects of twelve herbicide treatments on bermudagrass stolon and root growth, locations 1 and 2, Experiment II.

| Treatment | Rate | Stolon number Location 1 | Stolon number Location 2 | Stolon length+ | Internode length+ | Root length+ | Nodes per stolon+ | Rooted nodes per stolon+ | Root number per node+ |
|---|---|---|---|---|---|---|---|---|---|
| | kg/ha | | | cm | cm | cm | | | |
| Atrazine | 1.3 | 18 b-e++ | 15 b-e | 86 bcd | 3.5 abc | 3.5 ab | 26 bcd | 12 a-d | 5.4 ab |
| Atrazine | 2.7 | 17 cde | 9 ef | 68 cde | 3.0 cd | 4.0 a | 21 bcd | 9 cde | 5.2 ab |
| Atrazine | 4.0 | 12 def | 11 def | 56 ef | 2.8 de | 3.1 b | 17 def | 9 cde | 4.5 b |
| Diuron | 2.7 | 16 c-f | 12 c-f | 66 de | 3.4 abc | 3.6 ab | 17 def | 10 bcd | 5.5 ab |
| Diuron | 5.4 | 8 ef | 7 ef | 29 g | 3.5 abc | 1.8 c | 7 g | 3 f | 2.0 c |
| Diuron | 8.1 | 6 f | 5 f | 24 g | 3.1 bcd | 1.7 c | 8 fg | 4 ef | 2.7 c |
| Oryzalin | 1.2 | 32 a | 18 a-d | 90 bc | 3.7 a | 1.5 cd | 26 bc | 14 abc | 5.6 ab |
| Oryzalin | 2.5 | 22 abc | 21 ab | 99 ab | 3.6 ab | 0.8 d | 27 b | 15 ab | 5.3 ab |
| Oryzalin | 3.7 | 21 bcd | 22 ab | 93 b | 3.5 abc | 0.8 d | 29 ab | 16 a | 4.8 b |
| Sulfometuron methyl | 0.1 | 9 ef | 20 abc | 54 ef | 2.3 ef | 1.4 cd | 21 bcd | 14 abc | 5.4 ab |
| Sulfometuron methyl | 0.2 | 11 ef | 12 c-f | 26 g | 2.0 fg | 0.9 cd | 10 efg | 8 def | 4.6 b |
| Sulfometuron methyl | 0.3 | 22 bcd | 11 def | 35 fg | 1.8 g | 0.9 cd | 17 cde | 12 abcd | 4.8 b |
| Untreated Check | 0.0 | 27 ab | 25 a | 118 a | 3.5 abc | 3.7 ab | 38 a | 16 a | 6.2 a |

+ Data from both locations were averaged when analysis of variance indicated no significant (0.05) herbicide by location interaction.

++Means followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test (K ratio = 100).

# PART II

# ESTABLISHMENT OF PLAINS BLUESTEM WITH SELECTED PREEMERGENCE HERBICIDES AND ADSORBENTS

## ABSTRACT

'Plains' bluestem [Bothriochloa ischaemum var. ischaemum (L.) Keng.] is a quickly established, warm-season grass used for soil stabilization and erosion control throughout the southern Great Plains. Successful establishment of this species is often limited by annual grass and broadleaf weed competition. Preemergence herbicides with selectivity between all ischaemum ecotypes comprising the cultivar Plains and closely related weed species may be unavailable. Investigations were conducted to evaluate the phytotoxic effect of eight selected herbicides on establishment of Plains bluestem from seed and herbicide inactivation by activated carbon, bentonite, and activated sewage sludge. Effectiveness of the three materials in adsorbing pronamide [3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide] and oryzalin (3,5-dinitro-$N^4$, $N^4$-dipropylsulfanilamide) from aqueous solution was also investigated. Terbutryn [2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine] at 2.2 kg/ha, oryzalin at 1.2 kg/ha, diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] at 2.7 kg/ha, and sulfometuron methyl [Methyl 2-(((((4,6-dimethyl-2-pyrimidinyl)amino)-carbonyl)amino) sulfonyl)benzoate] at 0.1 kg/ha were extremely toxic to germinating seed and emerging seedlings. No reduction in shoot or root mass occurred 122 days following an atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] application of 1.3 kg/ha. Activated carbon at 2013 and 4026 kg/ha reduced phytotoxicity of all preemergence herbicides. In germination trials, optimum inactivation of oryzalin and pronamide occurred at carbon: herbicide ratios of between 89 to 111:1 and 83 to 100:1, respectively. Bentonite and sludge did not effectively neutralize oryzalin and pronamide concentrations in aqueous solution. The results indicate that use of activated carbon as a herbicide adsorbent applied to the soil surface above the seed zone may protect emerging Plains bluestem seedlings and prevent a shift in ecotype composition due to selective tolerance to a preemergence herbicide.

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*Additional Index Words*: Activated Carbon, Activated Sewage Sludge, Atrazine, Bentonite, *Bothriochloa ischaemum* var. *ischaemum*, DCPA, Diuron, Metribuzin, Oryzalin, Pronamide, Sulfometuron, Terbutryn.

## INTRODUCTION

'Plains' bluestem [*Bothriochloa ischaemum* var. *ischaemum* (L.) Keng.] is a quickly established, warm-season perennial grass well adapted to the southern plains region of the United States. This Old World bluestem cultivar is a composite of thirty morphologically similar selections of introduced plant materials from Afghanistan, India, Iraq, Pakistan, Turkey, and the U.S.S.R. (1). Low fertility and maintenance requirements make it an attractive species for soil stabilization and erosion control (10). Successful establishment of Plains bluestem from seed is often limited by weed competition (19). Preemergence applications of several s-triazine herbicides including atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] have shown potential for selective control of annual grasses and broadleaf weeds in establishing perennial warm-season grasses (13,14). However, use of atrazine during establishment of Plains bluestem has produced results varying from no apparent stand reduction to significant injury (2,8). These findings suggest that the composition of apomitic accessions comprising a cultivar such as Plains bluestem and segregating populations of sexually reproduced cultivars may be changed by selective tolerance to a preemergence herbicide. This raises serious questions regarding preemergence herbicide use during the early stages of seed increase of an improved cultivar without protection to emerging seedlings.

Adsorption of herbicides to clay minerals and organic matter may reduce their availability to plants. Substituted urea, s-triazine, and phenylcarbamate herbicides were adsorbed to a greater extent on H-montmorillonite compared to Na-montmorillonite of near neutral pH (3). Decreasing montmorillonite pH to cause protonation of atrazine increased adsorption (22). Organic cations were adsorbed by bentonite and kaolinite clays up to their cation exchange capacities (21). The amount of simazine [2-chloro-4,6-

bis(ethylamino)-*s*-triazine] required to reduce fresh weight of oats (*Avena sativa* L., 'Kanota') by fifty percent was positively correlated with soil organic matter content (18). Increasing soil organic matter by a given percentage generally required greater quantities of herbicide if equal biological toxicity was expected at both organic matter levels (20). Carboxyl, hydroxyl, and methyl groups which may interact with organic compounds are present in activated sewage sludge and carbon (21).

Activated carbon has been used to inactivate herbicides broadcast preemergence over crop seeds. A 130 kg/ha carbon application in a 2.5-cm band on the soil surface directly above Italian ryegrass (*Lolium multiflorum* Lam.) seeds provided adequate protection from diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] on a clay loam soil (5). Metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one] toxicity to winter wheat (*Triticum aestivum* L. 'McDermid') was neutralized by activated carbon at 84, 167, and 336 kg/ha applied in 5-cm bands over the seeded row (16). In Oregon, atrazine required greater amounts of activated carbon for protection of Kentucky bluegrass (*Poa pratensis* L. 'Merion') in comparison to diuron (12). Pronamide [3,5-dichloro(*N*-1,1-dimethyl-2-propynyl)benzamide] toxicity to perennial ryegrass (*Lolium perenne* L. 'Medalist II') was greatly reduced by activated carbon (15). Activated carbon at 200 kg/ha banded with seed inactivated preemergence DCPA (dimethyl tetrachloroterephthalate) applications of 6 and 12 kg/ha on two Australian native grasses (9).

Our objectives were to evaluate i) the effects of selected herbicides on establishment of Plains bluestem from seed, and ii) herbicide inactivation by activated carbon, bentonite, and activated sewage sludge above the seed zone. Adsorption of oryzalin (3,5-dinitro-$\underline{N}^4$,$\underline{N}^4$-dipropylsulfanilamide) and pronamide from aqueous solution by the three adsorbents was also investigated.

## MATERIALS AND METHODS

Prior to experimentation, 'Plains' bluestem seed was processed by hand, with the aid of a rub-board, to remove subtending appendages. A separator (blower) was used to obtain pure seed (caryopses) of uniform size. In addition, the caryopses were inspected visually under magnification (3X) to insure that perfect (undamaged) caryopses were used.

### Experiment I

A preliminary field study to evaluate phytotoxicity of several preemergence herbicides on Plains bluestem established from seed was conducted at the Oklahoma Turfgrass Research Center, Stillwater. Herbicide treatments (Table 1) were applied out-of-doors to plastic pots containing a sterile/nonsterile soil mixture and Plains bluestem seed.

Plastic pots 15.2 cm in diameter and 12 cm deep were filled with 8.5 cm of a 50:50 v/v sterile/nonsterile soil mixture overlaying 5 cm of sterile Kirkland (Thermic, udertic Paleustoll) silt loam soil. An electric sterilizer set at 93° C for 24 h was used to obtain sterile soil. The non-sterile soil, which served as an inoculum source for normal soil microorganisms, was pulverized and sieved through a U.S. standard # 35 0.5 mm sieve to remove weed seed.

On 24 June, 1983, twenty bluestem seeds per pot were placed on the soil surface and covered with 0.3 cm sterile soil. Herbicide treatments were applied immediately in 374 liter/ha water using a hand-held, $CO_2$-pressurized sprayer with three 80015 spray tips and 193 kPa pressure. One hundred pots, ten pots per preemergence herbicide treatment (eight herbicide treatments and two controls), were arranged in a 10 by 10 latin square. Each pot was inserted to a 10 cm depth in soil of the experimental field site. Pots received 450 ml supplemental water every 48 to 72 h depending on environmental conditions and evaporative water loss.

Herbicide phytotoxicity was evaluated by number of seedlings emerged and tillers 43 days after treatment (DAT), and shoot and root mass per pot, 122 DAT. Shoots were harvested by hand and roots (with crowns) were rinsed to remove adhering soil. Shoot and root mass measurements were recorded immediately following drying at 60° C for 48 h.

Experiment II

Samples of activated sewage sludge (Milorganite[1], Milwalkee Sewerage Corp., Milwalkee, WI.), activated carbon

(Gro-Safe[1], ICI Americas Inc., Wilmington, DL.), and bentonite (Aquagel[1], NL Baroid-NL Industries, Inc., New York, NY.) were tested for effectiveness in adsorbing oryzalin and pronamide from aqueous solution.

Quantities of sludge, bentonite, and carbon were shaken with 100 ml of either 135 mg/liter oryzalin or 120 mg/liter pronamide for 24 h on an Eberbach[1] platform shaker at 2 hz. Herbicide concentrations and range of adsorbent quantities (Table 2) were selected based on preliminary investigation and review of literature (7,18,22).

A series of six germination tests, comprising two herbicides, oryzalin and pronamide, and three adsorbents, charcoal, bentonite, and sludge were conducted in a germinator/growth chamber set for 8 h light at 30° C and 16 h darkness at 20° C. Each germination test consisted of one herbicide and a range of quantities of one adsorbent. Plastic boxes 7.3 by 7.3 by 2.9 cm with lids served as germination containers. Substrate consisted of two thicknesses of 2-ply paper towel cut to equal size and drawn at random for each box. Five ml of previously shaken, herbicide-adsorbent mixture were added to the first layer of paper substrate within each box. Fifty Plains bluestem seeds were placed on a second layer of substrate which covered the herbicide-

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[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by Oklahoma State University, and does not imply its approval to the exclusion of other products that may also be suitable.

adsorbent mixture. Six replications (boxes) were used throughout all tests with one replication per germinator tray level in a randomized complete block design. Each test was evaluated at the end of five days incubation. Caryopses with radicle and/or coleoptile penetrating the seed coat constituted a germinated seed. Adsorbent effectiveness was measured by coleoptile and radicle length of six randomly-selected seedlings per box.

Experiment III

A field study was conducted during 1983 to evaluate the effectiveness of activated sewage sludge, activated carbon, and bentonite in protecting 'Plains' bluestem seedlings from preemergence herbicides. Soil of the experimental area was a Kirkland silt loam. The site was plowed and disked at depths of 20 and 8 cm respectively, to prepare and smooth the seedbed. Methyl bromide was administered at 488 kg/ha to reduce weed competition.

The experiment was designed as a split-plot with herbicide treatment as whole plots and adsorbent treatment as subplots with four replications. Ten, 10.2-cm dia. subplots were randomized and spaced in a row on 20.3-cm centers within each 0.3 by 2.1 m whole plot. In order to hold adsorbent(s) in place, a circular plastic form 10.2 cm in dia. and 10.2 cm wide was inserted to a soil depth of 2.5 cm enclosing nine of ten subplots. Two subplots (one with and the other without a plastic form bordering the perimeter) were included as standards.

On 2 Aug., 1983, twenty-five Plains bluestem seeds were broadcast on the soil surface within a 20.3 $cm^2$ area in the center of each subplot. Seeds were covered with approximately 0.3 cm sterilized soil. Sludge and bentonite at 13450, 40350, and 80700 kg/ha each were manually broadcast on the soil surface above the seed zone within subplots. Carbon treatments equivalent to 2013 and 4026 kg/ha were sprayed in 50 ml water carrier per subplot.

Herbicide treatments were applied 4 Aug., 1983, using a hand-held, $CO_2$-pressurized sprayer calibrated to deliver 468 liter/ha through an 80015 spray tip at 193 kPa pressure (Table 1). In addition, a soil stabilizer (Soil Gard[1], Walsh Chemical Corp., Philadelphia, PA) broadcast at 646 liter/ha in 33060 liter/ha water and an untreated check served as standards. The study received approximately 2 cm supplemental irrigation every 48 to 72 h.

Adsorbent effectiveness was measured by number of emerged seedlings recorded 1 Sep. and shoot mass 3 Nov., 1983. Shoots were harvested and prepared as previously described.

Data from experiment I were subjected to analyses of variance for a latin square and the Waller-Duncan K-ratio t-test at the 0.05 level (K ratio = 100). A stepwise regression procedure was used in experiment II to construct regression lines fitted to data from the herbicide-adsorbent treatments by germination test. Data from three treatments within each germination test from experiment II were also subjected to the Waller-Duncan, K-ratio t-test at the 0.05 level (K ratio = 100). Following a split-plot design analysis of data from experiment III, a least-significant-difference (LSD) test was performed to compare means of herbicide and adsorbent treatments.

## RESULTS AND DISCUSSION

### Experiment I

Data analyses for emerged seedling and tiller counts, and root and shoot mass revealed significant differences among herbicide treatments. All herbicides reduced Plains bluestem seedling and tiller numbers 43 DAT (Table 3). Terbutryn at 2.2 kg/ha, oryzalin at 1.2 kg/ha, diuron at 2.7 kg/ha, and sulfometuron methyl at 0.1 kg/ha were extremely toxic to germinating seeds and emerging seedlings. Similarly, Hagon (9) reported that diuron at 4 kg/ha and DCPA at 6 kg/ha reduced the number of emerged seedlings of Australian native grasses.

Pronamide, metribuzin, and DCPA applications of 1.1, 0.7, and 8.4 kg/ha respectively, suppressed root growth. Atrazine at 1.3 kg/ha did not affect shoot or root mass 122 DAT. The reduced number of emerged seedlings and production of shoot and root mass equivalent to the untreated check suggests variability of bluestem ecotypes within the species or selective tolerance to atrazine. Similarly, Bahler et al. (2) reported a fifty percent reduction in Plains bluestem stand following a preemergence atrazine application of 2.2 kg/ha on a loamy-sand soil with 0.4 percent organic matter, whereas an equivalent rate of atrazine on a silty-clay-loam soil with 3.1 percent organic matter caused no stand reduction. Frizzell (8) observed improved selectivity with atrazine during establishment of Plains bluestem on a Brewer (Thermic, pachic Argiustoll) silty clay loam soil in comparison to an Easpur (Thermic, fluentic Haplustoll) loam. He reported that seedling establishment of Old World bluestems with _s_-triazine herbicides can be significantly affected by cultivar.

Greater numbers of emerged seedlings and tillers and increased root mass occurred in pots containing untreated, sterile soil than those with an untreated 50:50 v/v sterile/nonsterile soil layer (data not shown). These results suggest that apparently undamaged caryopses are easily infested by soil pathogens in nonsterile soil which may influence seedling emergence and growth.

Experiment II

Germination studies indicated significant differences among adsorbent treatments and controls for Plains bluestem coleoptile and radicle length (Table 4). Presence of activated carbon, bentonite, and activated sewage sludge within germination boxes reduced radicle length after five days incubation. Effect of the three adsorbents on coleoptile length was variable. Carbon at 35900 mg/liter increased coleoptile growth in comparison to the untreated check. Difference in number of seeds to germinate was not significant among treatments. Sharples (17) demonstrated that lettuce (Latuca sativa L.) seed coatings with a carbon layer adjacent to the seed promoted faster, more uniform seedling emergence than did coatings containing other materials.

Initially, bluestem radicle and coleoptile length increased with increasing quantities of activated carbon in combination with oryzalin or pronamide. Fitted polynomials were used to express the relationship between adsorbent quantity and coleoptile and radicle length for each adsorbent and herbicide (Fig. 1 and 2).

Seedling protection from oryzalin and pronamide provided by bentonite and sludge was inadequate for concentration ranges selected. Similarly, Coffey and Warren (7) determined that activated carbon was far superior to bentonite clay and finely-ground muck soil in adsorbing six of eight herbicides evaluated. In Florida, pronamide toxicity to perennial ryegrass (cv. 'Medalist II') was greatly reduced with activated carbon (15). The investigators reported that sludge did not inactivate pronamide and that it interfered with adsorbing ability of carbon.

According to regression analyses, activated carbon requirement for production of maximum bluestem coleoptile length in combination with 135 mg/liter oryzalin and 120 mg/liter pronamide ranged from 12000 to 15000 mg/liter and 10000 to 12000 mg/liter, respectively. Carbon requirement for optimum radicle elongation was greater. Similarly, charcoal deactivated a 0.3 ppmw atrazine residue when present at concentrations of 30 to 50 ppmw in the soil (11).

Experiment III

Analyses of variance for number of emerged bluestem seedlings and shoot mass indicated highly significant effects of herbicides, adsorbents, and herbicide by adsorbent interaction. Typically, activated carbon reduced biological activity of the eight herbicides (Table 5). However, charcoal treatment did not provide adequate protection of bluestem from sulfometuron methyl at 0.1 kg/ha. Bovey and Miller (4) report that the degree of herbicide inactivation by activated carbon depended on herbicide type, dosage, plant species, and quantity of carbon applied. Similarly, activated carbon did not effectively adsorb highly soluble organic pesticides including diquat [6,7-dihydrodipyrido-(1, 2-a:2',1'-c)-pyrazidiinium dibromide], paraquat (1,1-dimethyl-4,4-bipyridinium dichloride), and the methyl arsenates (6,7,21).

Activated sewage sludge treatments were toxic to bluestem seed and emerging seedlings; consequently, herbicide inactivation by this material could not be measured. Presence of sludge on the soil surface above the seed zone may have physically obstructed bluestem seedling emergence and growth. In addition, quantities of nitrogen within 13450, 40350, and 80700 kg/ha sludge may have been detrimental to germinating bluestem seed and seedlings. Bentonite was ineffective in reducing phytotoxicity of the eight preemergence herbicides.

Incorporation of an untreated check and soil stabilizer as whole plot treatments within the split-plot field design contributed to the highly significant herbicide by adsorbent interaction observed for seedling number and shoot mass. Generally, emerged seedlings established in all subplots within these two whole plot treatments while bluestem establishment was restricted to subplots containing activated carbon for several herbicide treatments.

Number of emerged seedlings was highly correlated (correlation coefficient = 0.74) with production of shoot mass.

Activated carbon treatments of 2013 and 4026 kg/ha to soil receiving no herbicide was not harmful to bluestem. An increase in shoot mass occurred when soil stabilizer (Soil Gard[1]) was applied over carbon. A stabilizer could be used in conjunction with charcoal banding on moderately sloping soils.

On the basis of these data, use of activated carbon as a herbicide adsorbent applied to the soil surface above the seed zone reduced atrazine, DCPA, diuron, metribuzin, oryzalin, pronamide, and terbutryn phytoactivity on Plains bluestem. Results suggest that banding activated carbon above the seed zone may maintain cultivar integrity by preventing shifts in apomitic accession composition that may occur due to selective tolerance to certain preemergence herbicides.

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Table 1. Herbicides, chemical names, formulations, and rates used to determine phytotoxicity to Plains bluestem.

| Herbicide | Chemical Name | Formulation+ | Application rate |
|---|---|---|---|
| | | | kg/ha |
| Atrazine | 2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine | 80 WP | 1.3 |
| DCPA | dimethyl tetrachloroterephthalate | 75 WP | 8.4 |
| Diuron | 3-(3,4-dichlorophenyl)-1,1-dimethylurea | 80 WP | 2.7 |
| Metribuzin | 4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one | 75 DF | 0.7 |
| Oryzalin | 3,5-dinitro-$N^4$,$N^4$-dipropylsulfanilamide | 75 WP | 1.2 |
| Pronamide | 3,5-dichloro(*N*-1,1-dimethyl-2-propynyl)benzamide | 50 WP | 1.1 |
| Sulfometuron methyl | Methyl 2-(((((4,6-dimethyl-2-pyrimidinyl) amino)-carbonyl)amino) sulfonyl)benzoate | 75 DF | 0.1 |
| Terbutryn | 2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine | 80 WP | 2.2 |

+WP-wettable powder; DF-dry flowable.

Table 2. Herbicide and adsorbent combinations evaluated, Experiment II.

| | Germination test | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | | 4 | 5 | 6 |
| | Oryzalin | | | | Pronamide | | | |
| Treatment | | Carbon | Bentonite | Sludge | | Carbon | Bentonite | Sludge |
| | mg/liter | | | | | | | |
| 1 | 135 | 600 | 600 | 600 | 120 | 600 | 2990 | 600 |
| 2 | 135 | 1200 | 1790 | 2990 | 120 | 1200 | 5980 | 2990 |
| 3 | 135 | 1800 | 2990 | 5980 | 120 | 1800 | 8970 | 5980 |
| 4 | 135 | 2390 | 5980 | 11970 | 120 | 2390 | 17950 | 11960 |
| 5 | 135 | 2990 | 11960 | 29910 | 120 | 2990 | 35890 | 29910 |
| 6 | 135 | 5980 | 17950 | 59830 | 120 | 5980 | 59820 | 59820 |
| 7 | 135 | 8970 | 35890 | 89730 | 120 | 8970 | 71790 | 89730 |
| 8 | 135 | 11970 | 59820 | 119650 | 120 | 11970 | 89730 | 119650 |
| 9 | 135 | 17950 | 89740 | 239300 | 120 | 17950 | 107690 | 239300 |
| 10 | 135 | 35900 | 119650 | 358950 | 120 | 35890 | 119650 | 358950 |
| 11 | 0 | 600 | 600 | 600 | 0 | 600 | 2990 | 600 |
| 12 | 0 | 35900 | 119650 | 358950 | 0 | 35890 | 119650 | 358950 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 135 | 0 | 0 | 0 | 120 | 0 | 0 | 0 |
| 15 | 67 | 0 | 0 | 0 | 60 | 0 | 0 | 0 |
| 16 | 17 | 0 | 0 | 0 | 15 | 0 | 0 | 0 |

Table 3. Effect of eight herbicide treatments on seedling count, tiller number, and weight of shoot and root dry matter of Plains bluestem, Experiment I.

| | | Days after treatment | | | |
|---|---|---|---|---|---|
| | | 43 | | 122 | |
| Treatment | Rate kg/ha | Seedling+ count | Tiller+ count | Shoot+ mass DM(g) | Root+ mass DM(g) |
| Check | 0.0 | 5.0 a | 18.3 a | 3.5 ab | 2.6 a |
| Pronamide | 1.1 | 0.6 c | 3.2 bc | 1.1 ab | 0.8 b |
| Metribuzin | 0.7 | 0.6 c | 1.8 bc | 0.3 b | 0.3 b |
| Atrazine | 1.3 | 2.0 b | 5.7 b | 5.4 a | 2.3 a |
| Terbutryn | 2.2 | 0.0 c | 0.0 c | --- | --- |
| Oryzalin | 1.2 | 0.0 c | 0.0 c | --- | --- |
| Diuron | 2.7 | 0.0 c | 0.0 c | --- | --- |
| Sulfometuron methyl | 0.1 | 0.0 c | 0.0 c | --- | --- |
| DCPA | 8.4 | 0.1 c | 0.5 c | 0.6 b | 0.3 b |

+Means followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test (K-ratio = 100).

Table 4. Effect of activated carbon, bentonite, and sludge on Plains bluestem coleoptile and radicle length after five days in the germinator, Experiment II.

| Germination test | Adsorbent | Concentration+ | Coleoptile length++ | Radicle length++ |
|---|---|---|---|---|
| | | mg/liter | | |
| 1 | Untreated check | 0 | 27 b | 18 a |
| | Carbon | 600 | 28 b | 13 b |
| | Carbon | 35900 | 31 a | 11 b |
| 2 | Untreated check | 0 | 29 a | 19 a |
| | Bentonite | 600 | 27 b | 2.9 c |
| | Bentonite | 119650 | 23 c | 3.8 b |
| 3 | Untreated check | 0 | 28 a | 5.3 a |
| | Sludge | 600 | 29 a | 4.1 b |
| | Sludge | 358950 | 23 b | 1.6 c |

+Five ml of adsorbent-distilled water mixture was dispensed per 7.3 by 7.3 by 2.9 cm germination box.

++Means within germination tests followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test (K-ratio = 100).

Table 5. Weight of Plains bluestem shoot dry matter in one hundred herbicide/adsorbent combinations, Experiment III.

| | | Adsorbent (kg/ha) | | | | | | | | Untreated Check 1++ | Untreated Check 2++ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Charcoal | | Bentonite | | | Sludge | | | | |
| Herbicide | Rate | 2013 | 4026 | 13450 | 40350 | 80700 | 13450 | 40350 | 80700 | | |
| | kg ai/ha | Shoot mass (g) | | | | | | | | | |
| Untreated check | 0.0 | 16 | 13 | 20 | 7.1 | 9.8 | 0.9 | 0.0 | 0.5 | 1.6 | 17 |
| Atrazine | 1.3 | 17 | 12 | 2.1 | 1.5 | 1.5 | 3.5 | 0.0 | 0.0 | 0.1 | 0.3 |
| DCPA | 8.4 | 24 | 16 | 0.0 | 0.0 | 0.1 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| Diuron | 2.7 | 23 | 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Metribuzin | 0.7 | 21 | 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Oryzalin | 1.2 | 12 | 20 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pronamide | 1.1 | 19 | 19 | 1.9 | 0.5 | 3.3 | 3.3 | 2.4 | 0.0 | 0.0 | 0.0 |
| Sulfometuron methyl | 0.1 | 0.3 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Terbutryn | 2.2 | 13 | 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Soil Gard[1] | 262+ | 35 | 31 | 18 | 15 | 11 | 6.8 | 0.7 | 0.0 | 4.3 | 38 |

LSD (0.05) for comparisons between herbicide treatments within an adsorbent treatment = 9.48
LSD (0.05) for comparisons between adsorbent treatments within a herbicide treatment = 8.85

+Soil Gard application rate: 262 liter/ha

++Untreated check 2: a 10.2 cm dia. plastic form (10.2 cm wide) inserted to a soil depth of 2.5 cm encircled the subplot; untreated check 1: no plastic form encircled the subplot.

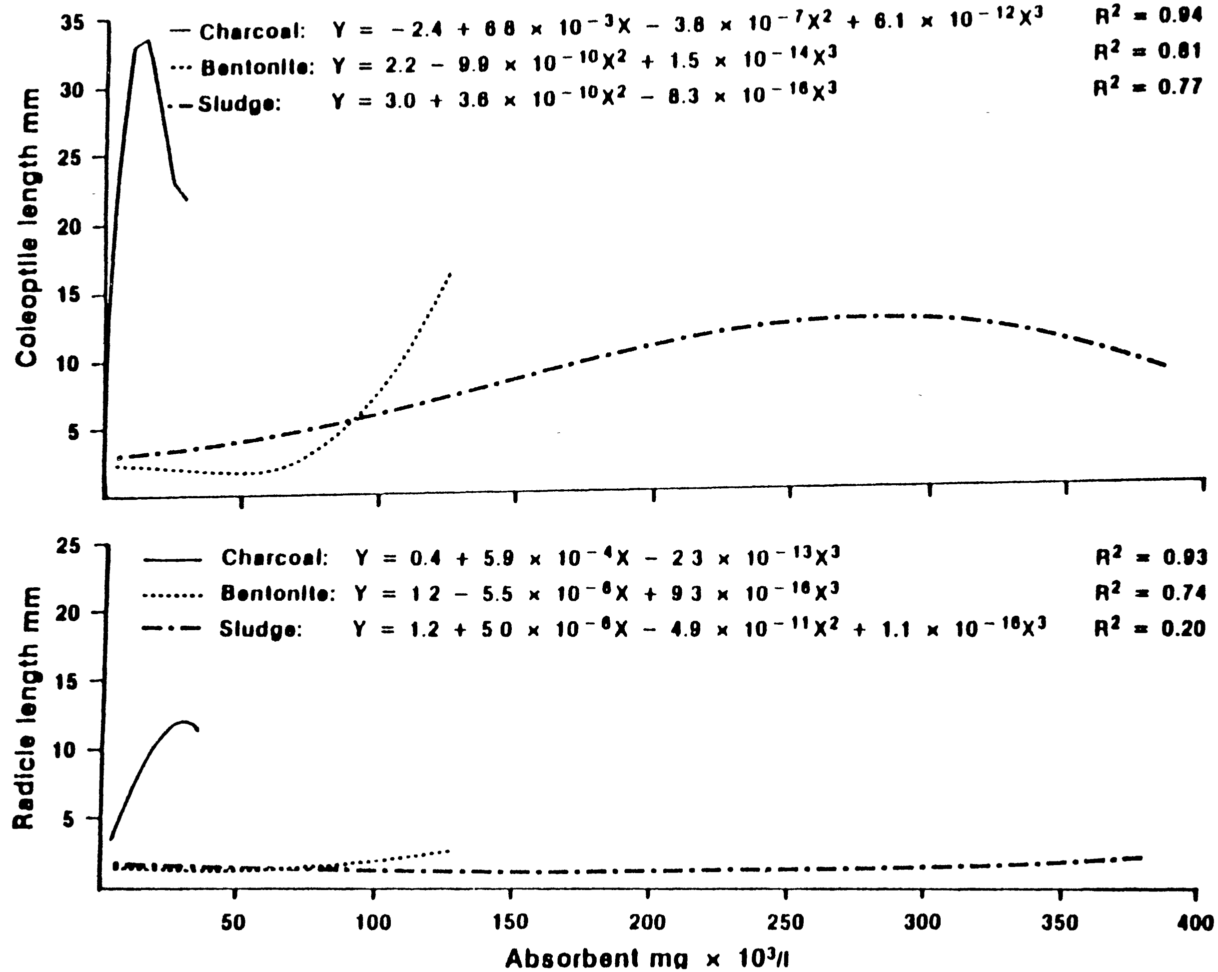


Figure 1. Relationship between Plains bluestem seedling coleoptile and radicle length and quantity of activated charcoal, bentonite, and activated sewage sludge in 135 mg/liter oryzalin, Experiment II.

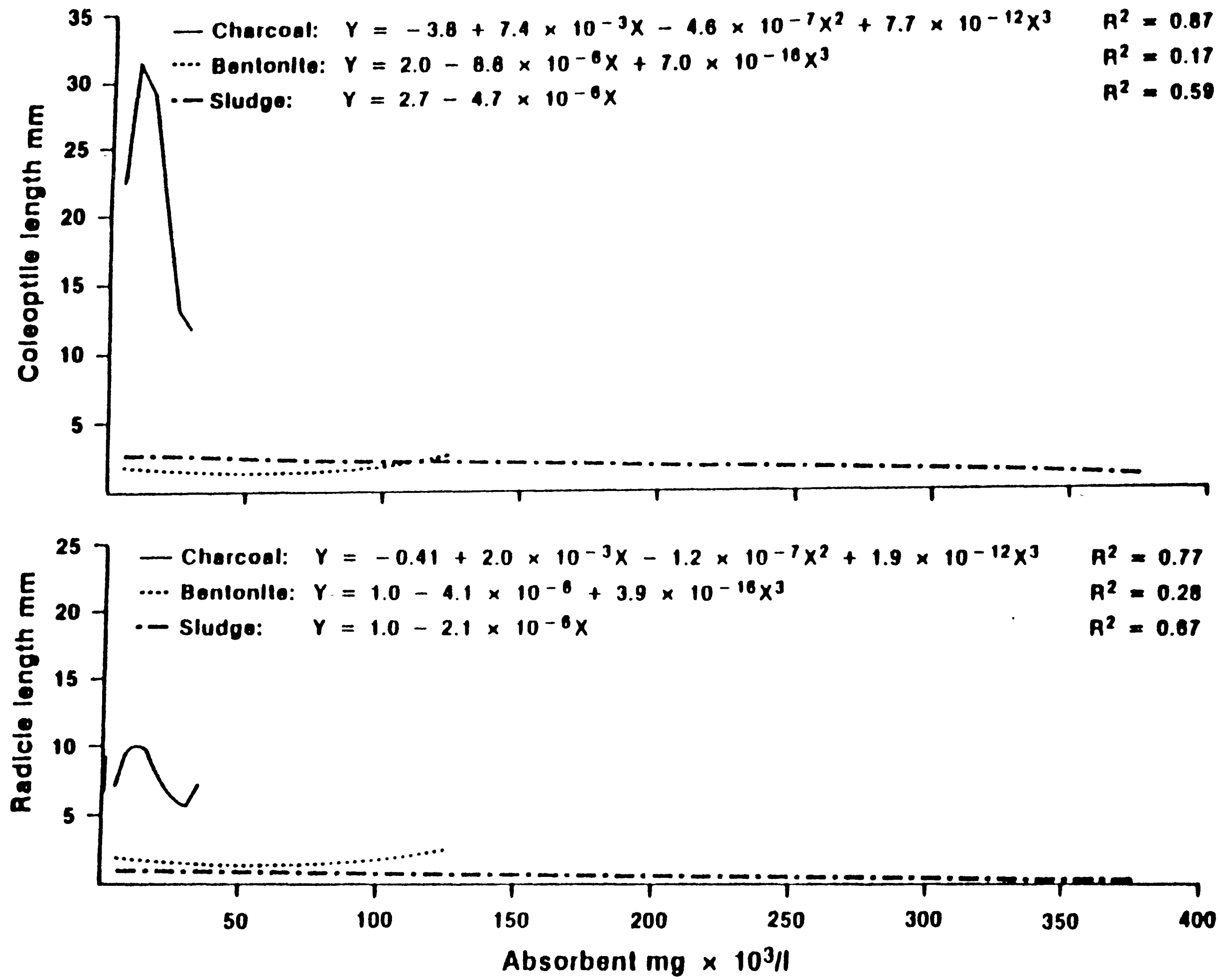


Figure 2. Relationship between Plains bluestem seedling coleoptile and radicle length and quantity of activated charcoal, bentonite, and activated sewage sludge in 120 mg/liter pronamide, Experiment II.

# PART III

# WEEPING LOVEGRASS AND BERMUDAGRASS ESTABLISHMENT WITH SELECTED PREEMERGENCE HERBICIDES AND ACTIVATED CARBON

ABSTRACT

The effectiveness of activated carbon in protecting weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees. 'Common'] and bermudagrass [*Cynodon dactylon* (L.) Pers., hybrid 'Guymon x 10978b'] seedlings from selected preemergence herbicides was investigated under field conditions at two locations. Generally, an increase in diameter of an activated carbon circle on the soil surface directly above the seed zone improved protection of weeping lovegrass and bermudagrass from preemergence herbicides. Activated carbon at 1120 kg/ha within an 82 $cm^2$ circle on the surface of a Norge (udic Paleustoll) loam subsoil above bermudagrass seeds provided adequate protection from seven of eight herbicides. Sulfometuron methyl [Methyl 2-(((((4,6-dimethyl-2-pyrimidinyl)amino)-carbonyl)amino)sulfonyl)benzoate], metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one], and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] at 0.1, 0.7, and 1.3 kg/ha respectively, reduced root growth of weeping lovegrass and bermudagrass establishing within carbon at both experimental sites. Activated carbon applied at 1120 kg/ha within a 5 $cm^2$ circular area on the soil surface above weeping lovegrass and bermudagrass seed inactivated a preemergence pronamide [3,5-dichloro(*N*-1, 1-dimethyl-2-propynyl)benzamide] application of 1.1 kg/ha.

A 5.1-cm carbon band on the surface of Norge topsoil above the seeded row protected emerging bermudagrass seedlings from pronamide, diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], and terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methyl-thio)-*s*-triazine] at 1.1, 2.7, and 2.2 kg/ha, respectively. Bermudagrass shoot mass above seeded rows 91 cm wide was greater in contrast to rows spaced 41 cm apart. Pronamide at 1.1 kg/ha and diuron at 2.7 kg/ha applied preemergence in conjunction with activated carbon did not affect bermudagrass ground cover 49 days after treatment. Bermudagrass establishment varied with row spacing and preemergence herbicide applications on Norge topsoil and subsoil with slopes of 1, 5, 6, and 8 percent.

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*Additional Index Words*: Atrazine, Carbon Band, *Cynodon dactylon*, DCPA, Diuron, *Eragrostis curvula*, Metribuzin, Oryzalin, Pronamide, Row Width, Slope, Sulfometuron, Terbutryn.

## INTRODUCTION

Weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees.] and bermudagrass [*Cynodon dactylon* (L.) Pers.] are warm-season perennial grasses well adapted to the southern region of the United States. Low fertility and maintenance requirements make these species attractive for soil stabilization and erosion control (7,9). Use of selective preemergence herbicides at seeding may enhance establishment and maintain quality of establishing species by reducing competition from annual grasses and broadleaf weeds (6,12). However, preemergence herbicides with selectivity between these and closely-related weed species may be unavailable.

Activated carbon banded over seeded rows may promote preemergence herbicide selectivity. When activated carbon was applied at 168 kg/ha in a band 2.5 cm wide over the seeded row, 'Linn' perennial ryegrass (*Lolium perenne* L.), 'Merion' Kentucky bluegrass (*Poa pratensis* L.), and chewings fescue (*Festuca rubra* var. *commutata* Gaud.) developed satisfactory stands on soils treated with 2.8 kg/ha diuron [3-(3, 4-dichlorophenyl)-1,1-dimethylurea] applied before emergence (10).

When a 2.5-cm activated carbon band was applied to the soil surface over rows seeded to white clover (*Trifolium repens* L.), carbon:herbicide ratios required for protection from 0.5 kg/ha diuron and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] were 50:1 and 100:1, respectively (14). In Minnesota, diuron and metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one] appeared to be adequately adsorbed by activated carbon to be of value for establishing Kentucky bluegrass, timothy (*Phleum pratense* L.), red clover (*Trifolium pratense* L.), and birdsfoot trefoil (*Lotus corniculatus* L.) (1). Activated carbon at 83 and 167 kg/ha applied within a band, 9 cm wide by 15 cm in length, on the surface of a sandy loam soil over hills of cotton (*Gossypium hirsutum* L. 'Stoneville

213') provided adequate protection from preemergence applications of diuron at 1.78 and 3.55 kg/ha (5).

Soil type and carbon band width influence crop protection from preemergence herbicides afforded by activated carbon. An activated carbon band 3 cm in width on the soil surface above seed rows of cucumber (Cucumis sativus L.) and tomato [Lycopersicon esculentum (L.) Mill.] provided excellent protection against diuron on a clay soil (2). The carbon band did not prevent diuron toxicity to seedlings emerging from sandy loam soil. At least three times more carbon was required for protection of Italian ryegrass (Lolium multiflorum Lam.) seedlings from diuron on a sandy loam in contrast to a clay loam soil (4). Less activated carbon was required for the same degree of protection as band width was increased from 0.8 to 2.5 cm.

When activated carbon bands are used in conjunction with preemergence herbicides, greater weed control is expected as seeded row width increases due to a decrease in the proportion of the field covered with carbon (15). An increase in seeded row width coupled with a decrease in carbon requirement per hectare may improve cost-effectiveness of the carbon-banding technique.

The objectives of these studies were to evaluate i) the effectiveness of activated carbon applied within 5, 20, and 82 $cm^2$ circles on the soil surface above weeping lovegrass and bermudagrass seeds in reducing phytotoxicity of eight selected preemergence herbicides, and ii) the influence of seeded row width and carbon rate on establishment of bermudagrass with activated carbon bands and five herbicides applied preemergence on soils with varying slope.

## MATERIALS AND METHODS

### Experiment I

A field study was conducted in 1984 at the Oklahoma Turfgrass Research Center, Stillwater, to evaluate the effectiveness of activated carbon applied to the soil surface directly above seeds of weeping lovegrass (cv. 'Common') and bermudagrass (hybrid 'Guymon x 10978b') in reducing phytotoxicity of selected preemergence herbicides. Prior to investigation, the Norge (udic Paleustoll) loam soil was modified to create greater soil variation between two adjacent sites. Approximately 30 cm of topsoil was removed from the surface of location 2 and uniformly deposited on location 1. At the subsoil and topsoil sites, soils were plowed and disked at depths of approximately 20 and 8 cm respectively, to prepare and smooth the seedbed. Methyl bromide was administered at 488 kg/ha to reduce weed competition.

Identical treatments at both sites were arranged by species in a split-plot design with four replications. Preemergence herbicides were whole plots, and activated carbon within circles of varying diameter were subplots. Bermudagrass and weeping lovegrass seeds were planted 1 and 2 Aug. respectively, location 1, and 6 and 7 Aug., 1984 respectively, location 2. Twenty-five seeds of either weeping lovegrass or bermudagrass were planted at 0.5-cm depth within a 1.3 $cm^2$ area in the center of each subplot. Three subplots were randomized and spaced on 31-cm centers in a row within each 46 by 81 cm whole plot. Subplots consisted of activated carbon (Gro-Safe[1], ICI Americas, Inc., Wilmington, DL) at 1120 kg/ha within 2.5, 5.1, and 10.2 cm diameter circles on the soil surface above the seed zone. Immediately following planting, carbon was sprayed by hand in 30 ml water over the soil surface within each subplot.

Eight herbicide treatments, atrazine, at 1.3 kg/ha; DCPA (dimethyl tetrachloroterephthalate), at 8.4 kg/ha; diuron, at 2.7 kg/ha; metribuzin, at 0.7 kg/ha; oryzalin (3, 5-dinitro-$\underline{N}^4$,$\underline{N}^4$-dipropylsulfanilamide), at 1.2 kg/ha; pronamide [3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide], at 1.1 kg/ha; sulfometuron methyl [Methyl 2-(((((4,6-dimethyl-2-pyrimidinyl)amino)-carbonyl)amino)sulfonyl)benzoate] at 0.1 kg/ha and terbutryn [2-(tert-butylamino)-4-(ethylamino)-6-thylthio)-s-triazine] at 2.2 kg/ha were applied 24 to 48 h after planting using a $CO_2$-pressurized sprayer calibrated to deliver 468 liter/ha through an 80015 spray tip at 193 kPa pressure. Two untreated checks, one with carbon directly over the seed zone and one without carbon, were

[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by Oklahoma State University, and does not imply its approval to the exclusion of other products that may also be suitable.

included as standards. Each site received approximately 1 cm irrigation water every 24 to 48 h.

Effect of carbon circle diameter on herbicide toxicity was measured by emerged seedling number and weight of root mass recorded 45 and 75 days after treatment respectively, for each species. Roots (with crowns) were harvested by hand, rinsed to dislodge adhering soil, dried at 60' C for 48 h, and weighed.

## Experiment II

The effect of five preemergence herbicides, two rates of activated carbon, and two row widths on establishment of bermudagrass (hybrid °Guymon x 10978b°) from seed was evaluated during 1985 at two sites adjacent to experiment I. Experimental areas were prepared as described previously.

Treatments were arranged in a 6 by 2 by 2 (herbicide, row width, activated carbon rate) factorial design with four replications per site. Each of the four replicates was located on a different slope: approximately 1, 5, 6, and 8 percent. On 11-17 July, 1985, two hundred bermudagrass seeds were planted across slope at a soil depth of approximately 0.3 cm in each of two rows 61 cm in length, spaced 46 or 91 cm apart, within 61 by 122 cm plots. Activated carbon at 560 or 1120 kg/ha was broadcast immediately within a band 5.1 cm wide and 51 cm in length on the soil surface above the seeded row. Prior to carbon application, a 5.1 by 51 cm metal box was centered above the seeded row. Activated carbon was sprayed in 3047 liter/ha water using a hand-held,

$CO_2$-pressurized sprayer with one 8003E spray tip.

Twenty-four to 48 h after planting, five herbicide treatments, diuron at 2.7 kg/ha, oryzalin at 1.2 kg/ha, pronamide at 1.1 kg/ha, sulfometuron methyl at 0.1 kg/ha, and terbutryn at 2.2 kg/ha were applied as described for experiment I. An untreated check was included as a standard. Experimental sites received approximately 1.3 cm supplemental irrigation every 24 to 48 h.

Herbicide, carbon rate, and row width effects on bermudagrass establishment were evaluated by emerged seedling counts per row recorded 49 days after treatment. Bermudagrass stolons within a 30.5 by 30.5 cm quadrat centered between rows and randomly placed across slope were harvested for determination of bermudagrass ground cover 90 days after treatment. In addition, a plug 10.2 cm in diameter and 10.2 cm in soil depth was extracted from a randomly selected area over the row seeded furthest downslope. Following removal of shoots from the plug, roots (with crowns) were rinsed to dislodge adhering soil. All stolons and roots were dried at 38° C for 48 h, and weighed.

Data from experiments I and II were subjected to analyses of variance for a split-plot and factorial design, respectively, and the Waller-Duncan K-ratio t-test at the 0.05 level (K ratio = 100). When analyses indicated a significant herbicide by carbon circle diameter interaction for emerged seedling counts on Norge topsoil (location 1), the least-significant-difference test was used to compare herbicide by carbon diameter means. Although included in all analyses of data from experiment I, means for an untreated check with no carbon over the seeds are not shown. Data from both field sites of experiment II were averaged when analyses indicated no significant location interaction with the three factors, herbicide, activated carbon rate, and row width. An LSD test was used to compare interaction means.

## RESULTS AND DISCUSSION

### Experiment I

Analyses of variance for number of emerged weeping lovegrass and bermudagrass seedlings, and root mass indicated highly significant effects of herbicides at both locations.

On Norge subsoil (location 2) planted to weeping lovegrass, activated carbon provided excellent protection against diuron, DCPA, and pronamide at 2.7, 8.4, and 1.1 kg/ha, respectively (Table 1). Number of emerged weeping lovegrass seedlings and root mass production following preemergence applications of the three herbicides in conjunction with activated carbon was equivalent to the untreated check. However, all herbicides reduced root mass of weeping lovegrass established on Norge topsoil (location 1). Similarly, an activated carbon application of 130 kg/ha in a 2.5-cm band over annual ryegrass seeds in a clay loam soil provided adequate protection from 3.4 kg/ha diuron applied preemergence (4). On a sandy loam soil, the 130 kg/ha carbon rate was not adequate. Sulfometuron methyl, metribuzin, and atrazine at 0.1, 0.7, and 1.3 kg/ha respectively, reduced bermudagrass and weeping lovegrass root growth at both sites.

Although metribuzin at 0.7 kg/ha, oryzalin at 1.2 kg/ha, and sulfometuron methyl at 0.1 kg/ha significantly reduced the number of weeping lovegrass and bermudagrass seedlings emerging from the Norge subsoil, activated carbon applied at 1120 kg/ha protected seedlings of both species from 1.1 kg/ha pronamide. Meyers et al. (13) found that 122 kg/ha activated carbon was sufficient to protect 'Medalist II' perennial ryegrass seedlings from preemergence applications of pronamide at 1.1 kg/ha.

Activated carbon applied at 1120 kg/ha above seed in untreated soil increased weight of weeping lovegrass root mass at both locations, and bermudagrass seedling density on Norge subsoil in contrast to the untreated check with no carbon (data not shown). Bovey and Miller (3) observed increased bean (Phaseolus vulgaris L. var. Black Valentine) and cucumber fresh weight when 640 ppmw carbon was mixed in potted sand. Similarly, number of emerged tall fescue (Festuca arundinacea Schreb.), perennial ryegrass, and Kentucky bluegrass seedlings increased in response to 336 kg/ha activated carbon (8).

Weeping lovegrass seedlings emerging from the Norge subsoil were influenced by carbon circle diameter (Table 2).

Fewer weeping lovegrass seedlings emerged within carbon circles 2.5 cm in diameter on Norge subsoil, in contrast to 10.2-cm dia. circles. Consequently, 10.2-cm dia. circles yielded greater root mass at this location. Liptay and Marriage (11) reported that a 2-cm band containing 5 or 10 mg carbon/$cm^2$ on the soil surface over the seeded row furnished inadequate protection from preemergence metribuzin applications of 0.56 kg/ha for cauliflower (Brassica oleracea var. botrytis L.), whereas complete protection was obtained with a 10 by 10-cm carbon square.

Herbicide and carbon circle diameter means were significant for number of emerged seedlings of both species on Norge topsoil, as was the herbicide by carbon circle diameter interaction. Activated carbon at 1120 kg/ha within a circle 10.2 cm in diameter above bermudagrass seeds provided excellent protection from seven of eight herbicides applied preemergence at this location (Table 3). Protection of bermudagrass seedlings emerging from the Norge topsoil treated with pronamide at 1.1 kg/ha was consistent among carbon circles 2.5, 5.1, and 10.2 cm in diameter. Activated carbon at 1120 kg/ha did not inactivate 0.1 kg/ha sulfometuron methyl applied preemergence.

Experiment II

Number of emerged bermudagrass seedlings, weight of shoot and root mass within rows, and shoot mass (ground cover) between rows were affected by preemergence herbicide treatments. Activated carbon in a 5.1-cm band on the topsoil surface above the seeded row protected emerging bermudagrass seedlings from pronamide, diuron, and terbutryn at 1.1, 2.7, and 2.2 kg/ha, respectively (Table 4). All herbicides reduced bermudagrass seedling density on Norge subsoil, and weight of shoot and root mass at both experimental sites.

Pronamide at 1.1 kg/ha and diuron at 2.7 kg/ha did not significantly affect bermudagrass ground cover between rows 49 days after treatment. White clover with its stoloniferous growth habit has also demonstrated the ability to recover from reduced seedling populations during establishment with 2.5-cm carbon bands and preemergence diuron applications (14). Oryzalin and sulfometuron methyl at 1.2 and 0.1 kg/ha, respectively, caused severe reductions in bermudagrass shoot and root mass within rows.

Number of bermudagrass seedlings emerging from the Norge subsoil was affected by activated carbon rate and seeded row width by carbon rate interaction. Increasing rate of activated carbon from 560 to 1120 kg/ha did not influence seedling numbers within rows 46 cm in width. However, greater numbers of bermudagrass seedlings emerged in rows seeded 91 cm apart with activated carbon banded at 1120 kg/ha, in contrast to the 560 kg/ha carbon rate. Lee (10) reported that quantity of carbon required to protect several cool-season grasses from preemergence herbicides varied with species, herbicide, and rate of herbicide application.

Shoot mass of bermudagrass within rows spaced 91 cm apart was greater in contrast to rows 41 cm in width. Seedling density and root mass within rows increased with increasing row width. Generally, when activated carbon is banded above seeded rows, weed control improves as row width increases (15). However, bermudagrass at both experimental sites was established with minimal weed competition. The data suggest that environmental factor(s) in addition to improved weed control between rows may influence seedling establishment and growth of bermudagrass within rows of varied width.

Bermudagrass seedling density, weight of root and shoot mass within rows, and ground cover between rows varied significantly among replications with slopes of 1, 5, 6, and 8 percent on Norge topsoil and subsoil. An increase in soil water available for plant uptake on soils with one-percent slope may have contributed to this response.

Results of these experiments confirm the effectiveness of activated carbon in protecting grass species from many preemergence herbicides (4,8,10). Establishment of bermudagrass from seed with preemergence herbicides and activated carbon bands is influenced by carbon rate, herbicide, width of seeded row, and soil composition and slope.

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Table 1. Mean effect of eight preemergence herbicide treatments averaged over activated carbon circle diameter on emerged seedling count and weight of root dry matter of weeping lovegrass and bermudagrass on Norge topsoil and subsoil, Experiment I.

| | | Weeping lovegrass | | | Bermudagrass | | |
|---|---|---|---|---|---|---|---|
| | | Location | | | | | |
| | | Topsoil | Subsoil | | Topsoil | Subsoil | |
| Herbicide | Rate | Root[++] mass | Seedling[++] count | Root[++] mass | Root[++] mass | Seedling[++] count | Root[++] mass |
| | kg/ha | DM(g) | | DM(g) | DM(g) | | DM(g) |
| Untreated check[+] | 0.0 | 1.9 a[++] | 9.0 a | 0.48 a | 0.85 ab | 5.3 a | 1.1 a |
| Atrazine | 1.3 | 0.3 cd | 7.8 ab | 0.22 bc | 0.19 cd | 1.4 de | 0.0 d |
| DCPA | 8.4 | 0.8 bcd | 6.3 ab | 0.37 ab | 0.27 cd | 1.7 d | 0.3 cd |
| Diuron | 2.7 | 0.1 cd | 8.0 ab | 0.37 ab | 0.16 d | 1.7 d | 0.2 cd |
| Metribuzin | 0.7 | 0.1 d | 1.2 c | 0.05 cd | 0.01 d | 0.0 e | 0.0 d |
| Oryzalin | 1.2 | 0.6 bcd | 4.3 bc | 0.21 bcd | 0.66 abc | 2.5 cd | 0.5 cd |
| Pronamide | 1.1 | 1.1 b | 8.0 ab | 0.39 ab | 1.0 a | 4.4 ab | 1.0 ab |
| Sulfometuron methyl | 0.1 | 0.0 d | 0.5 c | 0.01 d | 0.07 d | 0.2 e | 0.0 d |
| Terbutryn | 2.2 | 0.9 b | 5.8 ab | 0.23 bc | 0.40 cd | 3.2 bc | 0.7 abc |

[+]Untreated check: subplots with activated carbon at 1120 kg/ha on the soil surface above the seed zone receiving no herbicide treatment.

[++]Means followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test (K-ratio = 100).

Table 2. Mean effect of activated carbon circle diameter averaged over preemergence herbicide treatment on emerged seedling count and weight of root dry matter of weeping lovegrass on Norge topsoil and subsoil, Experiment I.

| Carbon circle dia. | Location | | |
|---|---|---|---|
| | Topsoil | Subsoil | |
| | Root mass | Seedling count | Root mass |
| cm | DM(g) | | DM(g) |
| 10.2 | 0.79 a+ | 6.8 a | 0.35 a |
| 5.1 | 0.96 a | 5.8 ab | 0.25 ab |
| 2.5 | 0.31 b | 4.4 b | 0.16 b |

+Means followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test. (K-ratio = 100).

Table 3. Mean emerged bermudagrass and weeping lovegrass seedling counts for herbicides and carbon circle diameters on Norge topsoil, Experiment I.

| | | Bermudagrass | | | Weeping lovegrass | | |
|---|---|---|---|---|---|---|---|
| | | Carbon circle diameter (cm) | | | | | |
| Herbicide | Rate | 2.5 | 5.1 | 10.2 | 2.5 | 5.1 | 10.2 |
| | kg/ha | Seedling number | | | | | |
| Untreated check+ | 0.0 | 6.3 | 4.3 | 5.5 | 7.0 | 16 | 13 |
| Atrazine | 1.3 | 0.0 | 1.8 | 5.5 | 3.3 | 11 | 13 |
| DCPA | 8.4 | 0.0 | 2.0 | 4.0 | 1.0 | 12 | 8.3 |
| Diuron | 2.7 | 0.0 | 0.0 | 4.5 | 2.0 | 10 | 5.8 |
| Metribuzin | 0.7 | 0.0 | 0.0 | 0.8 | 0.0 | 1.8 | 4.5 |
| Oryzalin | 1.2 | 0.5 | 3.5 | 4.5 | 3.5 | 7.8 | 9.3 |
| Pronamide | 1.1 | 6.5 | 6.8 | 6.3 | 7.3 | 11 | 12 |
| Sulfometuron methyl | 0.1 | 0.0 | 1.0 | 3.5 | 0.0 | 1.0 | 1.0 |
| Terbutryn | 2.2 | 0.0 | 4.3 | 2.3 | 5.0 | 8.3 | 9.8 |
| LSD (0.05) for comparisons between herbicides within carbon circle and species | | | 3.46 | | | 4.81 | |
| LSD (0.05) for comparisons between carbon circles within herbicides and species | | | 3.02 | | | 4.29 | |

Table 4. Mean effect of five preemergence herbicide treatments averaged over activated carbon rate and row width on seedling emergence, and weight of shoot and root dry matter of bermudagrass on Norge topsoil and subsoil, Experiment II.

| Herbicide | Rate | Seedling number: Location Topsoil | Seedling number: Location Subsoil | Shoot mass+: Between rows | Shoot mass+: Within row | Root+ mass: Within row |
|---|---|---|---|---|---|---|
| | kg/ha | | | DM(g) | DM(g) | DM(g) |
| Untreated Check+ | 0.0 | 8.0 a++ | 5.3 a | 12 a | 5.9 a | 1.0 a |
| Pronamide | 1.1 | 7.6 a | 4.0 b | 9.4 ab | 4.1 b | 0.7 b |
| Diuron | 2.7 | 7.1 a | 4.2 b | 8.5 ab | 3.5 b | 0.5 b |
| Terbutryn | 2.2 | 6.9 a | 3.8 b | 7.1 b | 3.5 b | 0.6 b |
| Oryzalin | 1.2 | 5.0 b | 0.8 c | 4.9 b | 1.5 c | 0.2 c |
| Sulfometuron methyl | 0.1 | 1.0 c | 0.3 c | 0.1 c | 0.2 c | 0.0 c |

+Data from both locations were averaged when analysis of variance indicated no significant location interaction with the three factors, herbicide, carbon rate, and seeded row width.

++Means followed by the same letter are not significantly different according to the Waller-Duncan K-ratio t-test (K-ratio = 100).

## VITA

Thomas Joe Samples

Candidate for the Degree of

Doctor of Philosophy

Thesis: BERMUDAGRASS, PLAINS BLUESTEM, AND WEEPING LOVEGRASS ESTABLISHMENT WITH SELECTED PREEMERGENCE HERBICIDES AND ADSORBENTS

Major Field: Crop Science

Biographical:

Personal Data: Born in Cleveland, Ohio, August 16, 1950, the son of Mack and Constance Samples.

Education: Graduated from Mapleton High School, Polk, Ohio, in May, 1968; received Bachelor of Science in Agriculture degree from Ohio State University in December, 1972, with a major in Agronomy; received Master of Science degree in Agronomy from Oklahoma State University in July, 1981; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in December, 1985.

Professional Experience: Acquired agri-business experience (grain marketing, sales, fertilizer and pesticide application, and management) while employed by Franklin Landmark, Inc., from December, 1972, to July, 1978; employed as a graduate research assistant by the Department of Agronomy and the Department of Horticulture and Landscape Architecture while a graduate student from August, 1978, to November, 1985.