August 1, 1967

To the Graduate Council:

I am submitting herewith a thesis written by Graham Shannon Smith, Jr. entitled "The Phytotoxicity of Selected Herbicides and Their Residual Effects in the Establishment of Emerald Zoysia." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

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THE PHYTOTOXICITY OF SELECTED HERBICIDES AND THEIR RESIDUAL EFFECTS IN THE ESTABLISHMENT OF EMERALD ZOYSIA

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Graham Shannon Smith, Jr.

August 1967

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude and appreciation to:

Dr. Lloyd M. Callahan for his assistance and guidance in conducting the research and for his interest and encouragement throughout the period of graduate study.

Dr. Frank F. Bell for his friendship and understanding during the course of the author's graduate and undergraduate studies, for his editing and suggestions to improve the thesis, and for serving on the author's graduate committee.

Dr. Henry A. Fribourg for his assistance in the statistical designs and analyses of data, his valuable comments and suggestions to improve the thesis, and for serving on the author's graduate committee.

Dr. Homer D. Swingle for serving on the author's graduate committee.

My wonderful wife, Cathy, for her encouragement, patience, love, and moral and financial assistance.

The University of Tennessee Agricultural Experiment Station for the financial aid of a graduate assistantship.

727240

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CHAPTER I

INTRODUCTION

Desirable herbicides for aiding the establishment of turfgrasses are those which provide a high level of weed control and are non-phytotoxic to the newly planted turfgrass.

Many researchers have reported on the foliage symptoms of herbicidal injury to established turfgrasses. Some workers have studied the effects of herbicides on newly seeded turfgrasses. However, very little work has been conducted to determine the effects of herbicides on vegetatively propagated turfgrasses at the time of their establishment.

Extensive research has shown that most of the more commonly used preemergence type herbicides will provide excellent weed control in established turfgrasses if applied properly and at the correct rate. However, many of these same herbicides have caused considerable turfgrass injury.

Prior to the use of a preemergence herbicide it is desirable to know the residual life of the chemical for its safe and efficient use. However, information concerning the residual activity of many of these herbicides is quite limited.

In the spring of 1965, a 2-year study was started at Knoxville, Tennessee to investigate (1) the effectiveness of several preemergence

type herbicides in controlling certain weeds, (2) the tolerance of newly plugged 'Emerald' zoysia (Zoysia japonica x Z. tenuifolia Willd. ex Trin.) to these herbicides, (3) the effects of fresh herbicide treatments and soil herbicide residues on the root regrowth of common Kentucky bluegrass (Poa pratensis L.) sod-plugs grown under greenhouse conditions, and (4) the rate of dissipation or depth of penetration of the herbicides which were applied to the zoysia plots in the field.

CHAPTER II

REVIEW OF LITERATURE

Many preemergence type herbicides are available which effectively control crabgrass (Digitaria Spp.) in a well established turfgrass sod. Research has shown that most of the more commonly used herbicides will give effective control of weeds for which they are recommended if directions for application are followed correctly. However, the more important factor to consider when using an herbicide on turfgrasses is the tolerance of the turfgrass to the chemical. Complete eradication of weeds is of little value if the chemical severely limits the growth of the turfgrass.

Under practical applications the loss of turfgrass sods caused by herbicides often is overlooked. The injury to the turfgrass usually is not observed for several weeks or months after the application. In these very frequent occurrences, the loss of the sod is all too often ascribed to other causes when it was actually the herbicide which directly or indirectly injured the turf. Most often the herbicide causes the turf to be weakened just enough so that it can be damaged easily or destroyed by diseases, insects, high temperatures, drouth, or other environmental stresses.

Despite the numerous reports that herbicides have injured turfgrass sods, few investigators have reported the specific cause

of the injury. The affects of various herbicides on root growth and/or shoot development of turfgrasses has not been determined fully. Furthermore, the soil residue level at which herbicides may remain phytotoxic have not been assayed effectively.

This review of available literature will generalize (1) the effectiveness of each herbicide used in this study in controlling crabgrass, (2) the phytotoxicity of a number of these herbicides on certain cool- and warm-season turfgrasses, and (3) the generally known residual activity of each herbicide.

I. HERBICIDAL CONTROL OF CRABGRASS

The herbicidal control of crabgrass has received extensive study during the past several years. Investigations throughout the United States have shown that practically all of the more commonly used preemergence crabgrass herbicides will give outstanding control if applied properly. Since the literature describing the effective weed control given by the commonly used herbicides is quite abundant, only a selected few of the research reports will be presented in this review.

Investigations throughout the country have shown that excellent (90 to 100 percent in most cases) control of crabgrass can be obtained using either DMPA at 15 to 20 pounds per acre, DCPA at 10

to 15 pounds per acre, or bandane at 20 to 60 pounds per acre (15, 17, 26, 34, 38).[1]

Bensulide at 10 to 20 pounds per acre and trifluralin at 1 to 4 pounds per acre have proved to be very effective preemergence crabgrass herbicides (14, 17, 27, 38).

Benefin, an analog of trifluralin, has received little investigation because it has not been available very long. Herron (24) reported that benefin at 1.5 pounds per acre and up to as high as 6 pounds per acre has given extremely good control of crabgrass for the entire season in Kentucky tests. In Pennsylvania, Duich, et al. (15) recorded 97 and 99 percent control of crabgrass using benefin at 2 and 4 pounds, respectively.

Few investigators have used simazine or atrazine for control of crabgrass in turfgrasses, but Klingman (26) reported that 2 pounds per acre of simazine provided 96 percent control of crabgrass for a three or four month period following application. After six months, simazine was still giving 80 to 82 percent control. In this same study, atrazine at 2 pounds gave 77 percent initial control and 65 percent control after six months. Lewis and Klingman (28) recorded 90 percent control of crabgrass following a simazine application of 3 pounds per acre. Atrazine, at the same rate, was less effective, giving 65 percent control. Simazine at 1 pound per acre has reportedly prevented goosegrass (Eleusine indica) germination (21).

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[1]Numbers in parenthesis refer to literature cited.

Herron (24) found that terbutol at 10 and 15 pounds per acre gave extremely good control of crabgrass for the growing season over a period of more than two years in Kentucky. Skogley and Jagschitz (38) obtained an average of 96 percent control of crabgrass for the years 1960 to 1964 using terbutol at 10 pounds per acre. At 15 pounds, terbutol gave 99 percent control for the same years average. In a New Jersey test (17) terbutol at 10 and 20 pounds gave only 44 and 83 percent control of crabgrass, respectively.

In a Rhode Island study (38) siduron at 9 pounds per acre provided 94 percent control of crabgrass. Under Kentucky (24) conditions, siduron at rates lower than 9 pounds did not give satisfactory control of crabgrass, but at 9 to 18 pounds extremely good crabgrass control was obtained for the entire growing season. Siduron at 8 pounds gave 99 percent control of crabgrass after 17 weeks and 92 percent control after 22 weeks in a test by Lewis and Gilbert (29), but the herbicide did not adequately control goosegrass. No reports of the effectiveness of sindone in controlling crabgrass were found in the literature.

II. HERBICIDAL PHYTOTOXICITY TO TURFGRASSES

The phytotoxicity of the more commonly used preemergence crabgrass herbicides to various turfgrasses has received considerably less study than their effectiveness in controlling weeds. Turfgrass injury has occurred numerous times, but the response of the turfgrass

to these herbicides has varied from year to year and from location to location. Consequently, much confusion exists as to the safety of the many herbicides to turfgrasses.

Reports of phytotoxicity are mainly on observations of foliage injury.

Bluegrasses

Mature sods of Kentucky bluegrass are reportedly tolerant to rates of granular DMPA at 15 to 20 pounds per acre (1, 15, 17, 19, 32, 34, 35, 39), DCPA at 6 to 12 pounds per acre (1, 11, 15, 16, 17, 19, 24, 31, 34, 36), bandane at 30 to 60 pounds per acre (15, 17, 34, 37), and siduron at 4 to 9 pounds per acre (24, 29).

Even though DMPA, DCPA, and bandane have been used extensively on bluegrass turf, Gaskin (23) has shown that all of these herbicides, as well as trifluralin, reduce the number and length of rhizomes of Kentucky bluegrass plants.

The use of trifluralin or sprays of DMPA, DCPA, or bensulide on bluegrass involves apparently some danger of herbicide phytotoxicity. Turf thinning and/or discoloration following trifluralin applications have been reported by a number of investigators (2, 4, 5, 14, 20, 23, 34, 36, 38). Duich, et al. (14) reported that DMPA and DCPA emulsions caused temporary discoloration of 'Merion' Kentucky bluegrass while the bensulide emulsion caused stunted growth and discoloration for seven weeks following treatments.

Herron (24) and Engel (17) applied terbutol and bensulide to bluegrass sods with no discernible foliage injury, but Engel and Callahan (18) discovered that soil residues of both of these herbicides reduced the root growth of Merion Kentucky bluegrass.

Trifluralin has been reported as being injurious to bluegrass sods, but benefin, the analog of trifluralin, has been applied safely to common Kentucky bluegrass (24) and 'Newport' Kentucky bluegrass (15).

The highly phytotoxic effect of simazine on Kentucky bluegrass was reported by Gallagher and Jack (22). Simazine at 4 pounds killed all of the treated grasses which included common and Merion Kentucky bluegrass and annual bluegrass (Poa annua L.). Fulwider and Engel (21) have observed the killing effect of simazine on Kentucky bluegrass also.

Fine-Leaved Fescues

Red fescue (Festuca rubra L.) has tolerated DMPA at 20 pounds (1, 2), DCPA at 7.5 pounds (1, 2), and bandane at 30 pounds (2), but Pennsylvania studies (15, 16) have demonstrated that both of these herbicides can injure this turfgrass. Skogley and Jagschitz (37) have recorded severe injury to red fescue following bandane treatments of 30 to 60 pounds per acre. Cornman, et al. (11) reported severe injury to red fescue following DMPA or DCPA applications, as did Mower and Cornman (32) using only DCPA.

Reduction of red fescue stands following treatments with trifluralin at 1.5 and 3 pounds per acre was reported by Ahrens, et al. (2).

Gallagher and Jack (22) reported a complete kill of a red fescue variety following treatments with simazine at 4 or 8 pounds per acre.

Bentgrasses

A number of workers have studied the effects of preemergence crabgrass herbicides applied to various bentgrass species and strains.

Bingham and Schmidt (5) applied DCPA at 10 pounds per acre, DMPA granular at 15 pounds per acre, and bensulide at 10 and 15 pounds per acre to colonial bentgrass (Agrostis tenuis Sibth.) with no resultant visible injury, however, the emulsifiable concentrate of DMPA caused severe injury. In contrast, Skogley and Jagschitz (38) and Duich, et al. (15) reported thinning or discoloration of bentgrass following DMPA at 15 pounds or DCPA at 11 pounds. Cornman, et al. (11) reported, in a New York study, that bensulide at 10 to 80 pounds per acre did not injure a strain of creeping bentgrass (Agrostis palustris Huds.), but DCPA at 12 pounds thinned the turf by 30 percent and DMPA at 15 pounds caused even greater injury.

Roberts and Brockshus (33) noticed that DCPA at 10 and 15 pounds and DMPA reduced turf uniformity when applied to putting greens of C-15, C-27, C-28, C-32, C-50, and C-54 bentgrass selections, but terbutol seemed safe on all the bentgrasses except C-15.

Complete kill of bentgrass following simazine applications was reported by Gallagher and Jack (22) and Bingham and Schmidt (5).

Bermudagrasses

Only a few investigators have studied the tolerance of various bermudagrass varieties to the many available preemergence herbicides.

Klingman (26) used simazine, atrazine, DCPA, and trifluralin on bermudagrass (Cynodon dactylon (L.) Pers.) with no observable injury. Bensulide has been used safely on common bermudagrass (12). A number of research reports by Burt (6, 7, 8, 9) revealed that under Florida conditions, trifluralin, siduron, benefin, bensulide, bandane, terbutol, and DCPA have been used on established sods of tifgreen bermudagrass with practically no injury. DMPA, simazine, and atrazine were only slightly injurious.

Duble and Holt (13), studying the effect of preemergence herbicides as they influence establishment of tifgreen bermudagrass, found that simazine and bensulide retarded the spread of newly planted sprigs. DMPA and DCPA did not discolor the sprigs. Trifluralin, DMPA, and DCPA restricted the growth of planted stolons, but bandane seemed quite safe. Furthermore, it has been demonstrated that newly sprigged tifgreen bermudagrass is retarded by siduron (29).

Zoysiagrasses

Klingman (26) stated that an established sod of 'Meyer' zoysia (Zoysia japonica Steud.) was treated with simazine, DMPA, and trifluralin with no subsequent injury from either treatment, however, bandane and atrazine caused slight injury. Burt (8) recorded no injury to Emerald zoysia following treatments with trifluralin, bensulide, bandane, DCPA, terbutol, and simazine in a 1963 Florida test. DMPA and atrazine caused only slight injury after seven days, with no injury observable after 28 days. Burt (6) has used siduron and benefin safely on Emerald zoysia, and Lewis and Lilly (29) were able to apply siduron to newly sprigged Meyer zoysia with no injury.

III. HERBICIDE RESIDUAL ACTIVITY

The persistence of preemergence herbicides in the soil is one of the more important factors to consider when choosing a chemical to be used on turfgrasses. The residual life of the compound should be known so that ther herbicide can be used safely and efficiently, without the persistence of harmful residues. It may be desirable to have a herbicide which persists long enough to provide control of weeds for a full season, and in some cases a carry-over effect is advantageous. However, turfgrasses which are somewhat sensitive to such materials may be more seriously injured if the herbicide persists for long periods of time.

A review of the literature disclosed that the pattern of disappearance or rate of dissipation of many of the herbicides used in this study has not been determined fully.

The response of Merion Kentucky bluegrass to soil residues of preemergence herbicides was studied by Engel and Callahan (18), in a 1963 New Jersey experiment. Merion Kentucky bluegrass sod-plugs which were grown in soil collected eight months after herbicide applications showed a significant reduction in root growth when grown in soil collected from the 0 to 2-inch depth in plots treated with terbutol and bensulide. Plants grown in soil from the 2 to 4-inch depth of soil treated with these two herbicides showed no reduction in roct growth, thus indicating that terbutol and bensulide residues remained in the top 2 inches of the soil. Root development of sod-plugs grown in soil from both the 0 to 2-inch and 2 to 4-inch depth previously treated with DCPA, DMPA, and bandane showed no significant reduction of root growth. Top growth of samples grown in bandane, terbutol, or bensulide treated soil was reduced significantly.

In a similar residue study by Singh and Campbell (36) it was found that DMPA persisted in the top 2 inches of the soil in quantities which affected the germination of Kanota oats (Avena sativa L.), but not Kentucky bluegrass. Herbicides were applied in 1961 and 1962 and the soil to be used in the bioassay test was collected in 1963. Trifluralin was the only herbicide which persisted in the top

2 inches of the soil at a level which reduced bluegrass germination.

A number of workers have reported on the effects of preemergence herbicides on seedling emergence of turfgrasses planted at intervals following herbicide application. These experiements offer some idea as to the persistence of toxic quantities of herbicides.

Chamberlain, et al. (10) reported that germination of Kentucky bluegrass was decreased significantly in DMPA and DCPA treated plots when seeding was done earlier than 20 weeks after herbicide treatments.

Preemergence herbicides were applied to a sod at three rates for three years in an experiment conducted by Juska and Hanson (25). With few exceptions, the herbicides, including DCPA, DMPA, and trifluralin retarded the stand establishment and vigor of Merion Kentucky bluegrass and common Kentucky bluegrass which was seeded into the killed sod. In the greenhouse portion of the study, germination of the turfgrasses was reduced from treatments with DMPA, DCPA, and trifluralin when the two grasses were seeded 1, 41, and 93 days after herbicides were applied to the soil in which the grasses were to be seeded. In contrast, Lewis and Lilly (30) stated that they were able to make fall seedings of Merion Kentucky bluegrass safely in soil treated the three previous springs with DMPA, DCPA, trifluralin, atrazine, bandane, benefin, and simazine.

Skogley and Jagschitz (37) obtained a good stand of Kentucky bluegrass, red fescue, and colonial bentgrass when established on

seedbeds which had been treated with trifluralin, at 1 pound, and when seeding had been delayed for six weeks after herbicide treatment. At trifluralin rates exceeding 1 pound, a good stand failed to develop even when seeding was delayed for eight weeks. Alder and Bevington (3) found that bluegrass could be sown successfully 45 days after an application of trifluralin at 1.5 pounds per acre.

In a New York study, Cornman, et al. (11) found that when red fescue or Merion Kentucky bluegrass were seeded in plots treated six weeks earlier with bensulide at 20 pounds, the germination of the turfgrasses was reduced. Terbutol at 15 pounds stopped all germination of the bluegrass even when seeding was done six weeks after herbicide treatment. Bandane at 35 pounds also inhibited germination.

No report of the residual life of sindone or siduron was found in the literature.

CHAPTER III

MATERIALS AND PROCEDURES

The study reported here was designed to determine the effectiveness of several preemergence herbicides in controlling selected weeds, the effects of these chemicals on newly planted Emerald zoysia, and the effects of soil residues of these herbicides on the root growth of common Kentucky bluegrass.

The weed control and turf tolerance study was conducted in field plots. The herbicide residue study was performed under greenhouse conditions. Procedures followed for the tests conducted under field conditions and in the greenhouse will be discussed separately.

These experiments were conducted during 1965 and 1966 at the Main Experiment Station of the University of Tennessee at Knoxville, Tennessee.

Field Experiment

The field study was initiated on July 28, 1965. The herbicides, their formulation, and their rates of application in pounds of active ingredient per acre were: O-(2,4-dichlorophenyl) O-methyl isopropyl phosphoramidothioate (DMPA) granular at 10 and 20 pounds; dimethyl 2,3,5,6-tetrachloroterephthalate (DCPA) granular at 12 and 24 pounds; 2-chloro-4,6-bis (ethylamino)-s-triazine (simazine) wettable powder at 2 and 4 pounds; 2-chloro-4-ethylamino-6-isopropylamino-

s-triazine (atrazine) wettable powder at 2 and 4 pounds; 2,6-di-tert-butyl-p-tolyl-methylcarbamate (terbutol) granular at 10 and 20 pounds; N-(2-mercaptoethyl) benzenesulfonamide (bensulide) granular at 10 and 20 pounds; α, α, α-trifluoro-2,6-dinitro-N, N-dipropyl-p-toluidine (trifluralin) granular at 2 and 4 pounds; N-butyl-N-ethyl-alpha, alpha, alpha-trifluoro-2,6-dinitro-p-toluidine (benefin) granular at 2 and 4 pounds; 1-(2-methylcyclohexyl)-3-phenylurea (siduron) wettable powder at 12 and 24 pounds; an equal mixture of 1,1-dimethyl-4,6-diisopropyl-5-indanyl ethyl ketone and 1,1-dimethyl-4,6-diisopropyl-7-indanyl ethyl ketone (sindone) emulsifiable concentrate at 7 and 14 pounds; and polychlorodicyclopentadiene isomers (bandane) granular at 40 and 80 pounds. The rates of application for each herbicide were either the manufacturers' rate recommended or a low rate (1X) and double this rate (2X).

The field plots were established on an Emory clay loam soil. The soil had a pH value of 5.5, a cation exchange capacity of 9.2 milliequivalents per 100 grams, and contained 1.7 percent organic matter. The mechanical analysis showed that the soil contained 35 percent sand, 37 percent silt, and 28 percent clay by volume.

Treatments were arranged in a randomized complete block design, with three replications. The treatments included two rates of each of eleven herbicides and an untreated or check plot. The treated portion of each plot measured 3 x 18 feet in size with a 1-foot border between treatments, but with no borders between replications. The experimental

area measured 92 x 54 feet in size.

The planting bed was prepared in the following manner. As the area was plowed, 150 pounds of 6-12-12 grade fertilizer per acre were incorporated into the top 6 to 8 inches of the soil. The area was then thoroughly disked, smoothed, firmed, and smoothed again. Emerald zoysia sod-plugs, approximately 2-inches square, were planted on 12-inch centers and immediately firmed into the planting bed with a roller.

The newly plugged Emerald zoysia was irrigated twice a day for the first week following planting, then once a day for the second week. Thereafter the plugs were irrigated only when they showed symptoms of moisture stress.

Rainfall data was obtained from the experiment station in Knoxville (See Appendix).

All of the herbicide treatments were made on the day that the zoysia plugs were planted. Granular formulations were applied with a three-foot wide lawn spreader that was calibrated to deliver the desired quantity of each herbicide. The liquid formulations were applied with a hand-pump compression sprayer. In all cases of herbicide application, the rates were halved and the plots treated twice to assure a more uniform plot coverage.

The effective weed control of each herbicide was determined by a plant count method. Crabgrass and goosegrass plants were counted in an area 2 x 16 feet in size located in the center of each plot.

Crabgrass and goosegrass control data were collected on August 13 and September 22, 1965.

Evaluation of turf tolerance to each herbicide was made by counting the number of injured and dead plugs of Emerald zoysia in a portion of each treated and each untreated plot. An injured plug was one which appeared stunted, chlorotic, necrotic, or produced no stolon growth. Only the center two rows of plugs in each plot, totaling 36 plugs, were used in the turf injury ratings. Injury ratings were made on October 18, 1965 and on June 9 and December 12, 1966.

Greenhouse Experiment

A greenhouse study was initiated to determine the effects of fresh applications and of soil residues of preemergence herbicides on the regrowth of mature common Kentucky bluegrass sod-plugs. The fresh herbicide applications and rates tested were the same as those used in the field study.

The field plot soil residue samples used in the greenhouse study were collected on June 1, 1966, 10 months following the treatment date in the field. Twelve soil cores were collected from each plot using a Hoffer soil core device. Each soil sample was cut into 2-inch sections. Only the sections representing the 0 to 2- and 2 to 4-inch depths of the soil were retained for use in the greenhouse.

The amount of rainfall during the interval between herbicide application and the collection of the soil samples was 29 inches.

An estimated 25 inches of irrigation were applied during this time interval. Thus, an approximate total of 54 inches of water reached the plots.

The experimental design used was a split-plot arrangement of treatments in a randomized complete block. The main plot treatments were: (1) common Kentucky bluegrass grown in the 0 to 2-inch soil residue samples, (2) common Kentucky bluegrass grown in the 2 to 4-inch soil residue samples, and (3) common Kentucky bluegrass grown in soil freshly treated with each herbicide. The split-plot treatments were the eleven herbicides at two rates each and the untreated sample. All treatments were replicated three times along the greenhouse bench.

The greenhouse temperatures ranged from 64° to 78°F. during the night and 81° to 92°F. during the day. A few days the temperature in the greenhouse reached 95°F.

Common Kentucky bluegrass sod-plugs, 4 inches in diameter, were cut back to 1-inch in depth and mounted in one-quart cans on top of soil either treated with fresh herbicides or a residue sample from the field plots. All of the one-quart containers were first filled with 900 grams (3 inches in depth) of washed, white sand. A 250 gram layer (1 inch in depth) of soil was placed on top of the sand. The soil layer was either a residue sample, a freshly treated sample, or was untreated. All of the soil receiving fresh herbicide treatments was of the same type as that in the field plots. Each soil sample was air-dried and passed through a $\frac{1}{4}$-inch mesh screen before being used.

In treating the soil with the fresh herbicide applications, the granular materials were mixed with 25 grams of soil and evenly applied to the soil surface of each container. The liquids were applied in 25 ml. of tap water.

After the preparation of the test containers was completed, they were randomized on the greenhouse bench and the sod-plugs allowed to grow for 25 days.

Each container received 25 ml. of a complete nutrient solution and 25 ml. of tap water every other day, and 50 ml. of tap water each day that the nutrient solution was not applied.

The replications were conducted separately and spaced at five day intervals to allow enough time for the container dismantling process. At the completion, the containers were soaked in water for one day, after which the soil and sand were washed from the roots of the plugs under low water pressure. This procedure removed the soil back to the original 1-inch of sod-plug depth.

On September 9 and 10, 1966, all of the bluegrass sod-plugs were photographed to show root and shoot development in relation to each herbicide treatment. The roots of each sod-plug were then excised to determine the root weight produced by regrowth during the 25-day test period. In cases where no roots had grown below the original 1-inch sod-plug depth, the root regrowth was considered to be zero. Dry root weights were determined by weight loss during ashing. The excised roots were first oven-dried at 158°F. overnight,

then weighed. The roots were then ashed for $1\frac{1}{2}$ hours at 1,256°F. and weighed again. The weight loss during ashing was recorded as the root regrowth, as milligrams of dry weight, for each sample grown for 25 days.

CHAPTER IV

RESULTS AND DISCUSSION

The discussion of results obtained in the field study and the greenhouse study will be presented separately. The field study will be divided into a section dealing with the weed control obtained and a section describing the zoysia injury following herbicide treatments. The discussion of the greenhouse test is divided into a section describing the effects of fresh herbicide application on common Kentucky bluegrass and another section discussing the effects of the herbicide residues, including their apparent depth of penetration in the soil.

I. HERBICIDAL AID TO ESTABLISHING EMERALD ZOYSIA

The use of herbicides to aid the establishment of an Emerald zoysia turf was studied in the field. The major objective was to determine the effects of the herbicides on the growth and development of the newly plugged zoysia. The herbicidal control of crabgrass and goosegrass was also investigated, but was of less importance.

Since the herbicides were applied to a newly prepared planting bed preemergence to weed germination, the rate of establishment of the zoysia was expected to be enhanced in plots treated with chemicals which combined effective weed control with non-phytotoxicity

to the turfgrass.

Weed Control

Excellent preemergence control of crabgrass and goosegrass was obtained with all herbicides at the rates of application for the entire growing season following treatments. Observations at the first rating date, August 13, 1965, 16 days after treatments, showed that practically all of the herbicides had provided greater than 95 percent control of crabgrass and goosegrass. The exception was siduron at 12 and 24-pounds per acre which provided only 88 percent control (Table I). Simazine at 2 and 4-pounds gave 100 percent control, the highest control recorded at the first rating date. The plant count of crabgrass and goosegrass in all plots at the first rating date is shown in Table XII, Appendix.

Crabgrass and goosegrass control 56 days after the herbicides were applied was equally as effective at the second rating date, September 22, 1965, as they were at the first rating date (Table I). The control ranged from 93 to 99 percent. Plant counts at the second rating date are shown in Table XIII, Appendix.

The excellent weed control obtained with a number of the herbicides used in this study agreed closely with data reported by other researchers (15, 17, 24, 26, 38).

TABLE I

PERCENT CONTROL OF CRABGRASS AND GOOSEGRASS BASED ON PLANT COUNTS IN PLOTS OF EMERALD ZOYSIA FOLLOWING HERBICIDE APPLICATIONS ON JULY 28, 1965, KNOXVILLE. AVERAGE OF THREE REPLICATIONS

Herbicide	Rate Pounds/Acre	Percent Control Aug. 13, 1965	Percent Control Sept. 22, 1965
Simazine	4	100	99
Simazine	2	100	98
Benefin	4	99	99
Sindone	7	99	99
Trifluralin	4	99	99
Trifluralin	2	99	98
Bensulide	20	99	99
Atrazine	4	99	99
DCPA	12	99	97
Benefin	2	99	98
Sindone	14	99	99
Terbutol	10	99	98
Bensulide	10	99	98
DMPA	20	99	98
Bandane	80	99	98
DMPA	10	98	97
Terbutol	20	98	98
Bandane	40	98	96
Atrazine	2	97	99
DCPA	24	95	97
Siduron	24	88	97
Siduron	12	88	93
Check	--	0	0

Emerald Zoysia Injury

The herbicide treatments were divided into four arbitrary categories on the basis of the kind and extent of injury they caused to the Emerald zoysia. The initial injury observed on October 14, 1965, the residual and/or delayed injury recorded on June 9, 1966, and the final plot ground coverage by the zoysia on December 12, 1966, were considered in the placement of each treatment into one of the four categories. The phytotoxicity of the herbicides under field conditions was distinguished as: (1) treatments causing none to slight injury, (2) treatments causing slight to moderate injury, (3) treatments causing moderate to severe injury, and (4) treatments causing highly severe injury.

The herbicides which caused none to slight injury to the Emerald zoysia were siduron and DMPA (Table II). Siduron at 12-pounds per acre caused no observable foliage injury thus allowing the Emerald zoysia to cover the ground without inhibition of growth by the herbicide. This can be seen by comparing the 93 percent ground cover in the plot receving the 12 pounds of siduron with the 88 percent ground cover in the untreated plot. Siduron at 24 pounds caused only a very slight injury of 7.4 percent. This was the only treatment which had a final zoysia ground cover of 100 percent. The zoysia plugs in the siduron-treated plots appeared to be the most vigorous and rapidly spreading of all the plugs in the test (Figure 1).

DMPA caused slightly more initial injury than siduron, but 93 and 95 percent zoysia ground cover was obtained under 10 and 20-pound

TABLE II

HERBICIDE TREATMENTS,
APPLIED JULY 28, 1965, CAUSING NONE TO VERY SLIGHT INJURY
TO NEWLY PLUGGED EMERALD ZOYSIA AT KNOXVILLE

Herbicide	Rate Pounds/acre	Percent Injury Oct. 14, 1965	Percent Injury June 9, 1966	Percent Zoysia Ground Cover Dec. 12, 1966
Siduron	12	0.0	0.0	93.0
Siduron	24	0.0	7.4	100.0
DMPA	10	0.9	2.7	93.0
DMPA	20	3.7	7.4	95.0
Check	--	0.0	0.0	88.0

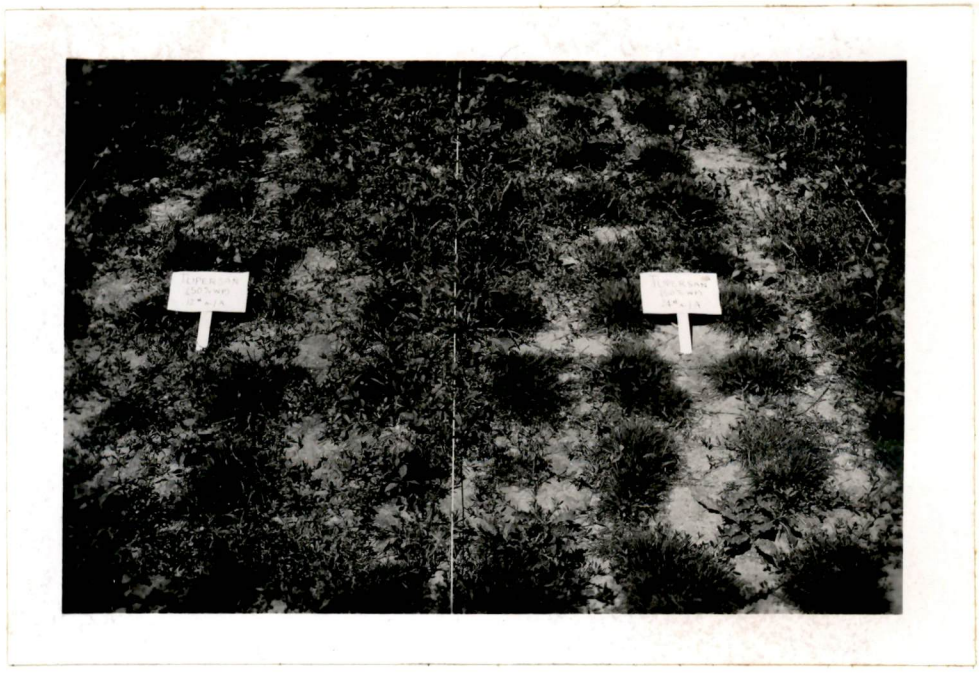

FIGURE 1

GROWTH OF PLUGS OF EMERALD ZOYSIA IN FIELD PLOTS
10 MONTHS FOLLOWING TREATMENT WITH SIDURON (TUPERSAN)

per acre rates, respectively. The zoysia cover in the DMPA-treated plots exceeded the cover obtained in the untreated plots (Table II, p. 26). The healthy appearance of the zoysia plugs and their rapid stolon spread following the DMPA treatments was comparable to the results with siduron treatments (Figure 2).

Most of the herbicide treatments appeared to cause only slight to moderate injury to the Emerald zoysia (Table III). The treatments which fell within this category were both rates of benefin, atrazine, and DCPA, and the low rate of sindone, bandane, simazine, and trifluralin. A number of the herbicide treatments in this category caused little initial injury, but moderate delayed injury occurred. However, the zoysia recovered sufficiently to cover nearly as much of the ground in these plots as it did in the untreated plots.

Atrazine and simazine, both at 2-pounds per acre, caused 2.8 and 3.7 percent initial injury and 11.1 and 10.1 percent residual injury, respectively. However, the final zoysia ground cover of 92 and 93 percent, respectively, exceeded that of the untreated plots (Table III). Although atrazine at 4 pounds initially caused 21.3 percent injury the zoysia recovered sufficiently to cover 90 percent of the treated plot.

DCPA at 12-pounds per acre caused 14.8 percent initial injury and 23.1 percent residual injury (Table III). Under the 24-pound rate the zoysia showed a severe delayed injury of 53.7 percent. The zoysia in the 12 and 24-pound DCPA-treated plots did not cover as



FIGURE 2

GROWTH OF PLUGS OF EMERALD ZOYSIA IN FIELD PLOTS
10 MONTHS FOLLOWING TREATMENT WITH DMPA (ZYTRON)

TABLE III

HERBICIDE TREATMENTS,
APPLIED JULY 28, 1965, CAUSING SLIGHT TO MODERATE INJURY
TO NEWLY PLUGGED EMERALD ZOYSIA AT KNOXVILLE

Herbicide	Rate Pounds/acre	Percent Injury Oct. 14, 1965	Percent Injury June 9, 1966	Percent Zoysia Ground Cover Dec. 12, 1966
Benefin	2	0.9	15.7	85.0
Sindone	7	0.9	29.6	86.0
Bandane	40	2.8	23.1	81.6
Atrazine	2	2.8	11.1	92.0
Simazine	2	3.7	10.1	93.0
Trifluralin	2	8.3	33.3	88.0
DCPA	12	14.8	23.1	83.0
DCPA	24	18.5	53.7	86.0
Benefin	4	20.3	32.4	88.0
Atrazine	4	21.3	17.5	90.0
Check	--	0.0	0.0	88.0

rapidly as was observed in the untreated plots.

Benefin at 2-pounds per acre caused only slight zoysia injury while at 4-pounds it caused moderate injury. The zoysia ground cover in the benefin plots treated with 4 pounds equalled the cover in the untreated plots but under the 2-pound rate the cover was less than in the untreated plot (Table III, p. 30). Although the zoysia showed a rather moderately severe delayed injury following trifluralin at 2 pounds, the turfgrass recovered and the final plot coverage equalled that of the untreated plot (Table III, p. 30). Trifluralin appeared to be more phytotoxic than benefin.

Although only moderate residual injury was noticed in the plots receiving sindone at 7-pounds per acre and bandane at 40 pounds per acre, the final zoysia ground cover was not as great as the coverage in the untreated plots (Table III, p. 30).

The herbicide treatments which caused moderate to severe injury to the Emerald zoysia were the high rates of sindone, bandane, trifluralin, and simazine (Table IV). Of these herbicide treatments, sindone, bandane, and trifluralin greatly reduced the ground cover below that of the untreated plots. Although simazine caused a high initial injury of 58.3 percent, this was followed by a general turfgrass recovery which included a higher percentage of ground cover than that allowed by the other three treatments in this group. All four of these herbicides at the high rates caused marked inhibition of zoysia growth allowing ground coverage much less than that observed in the untreated plots.

TABLE IV

HERBICIDE TREATMENTS,
APPLIED JULY 28, 1965, CAUSING MODERATE TO SEVERE INJURY
TO NEWLY PLUGGED EMERALD ZOYSIA AT KNOXVILLE

Herbicide	Rate Pounds/Acre	Percent Injury Oct. 14, 1965	Percent Injury June 9, 1966	Percent Zoysia Ground Cover Dec. 12, 1966
Sindone	14	5.6	38.8	76.0
Bandane	80	14.8	37.9	73.0
Trifluralin	4	29.6	59.2	70.0
Simazine	4	58.3	36.1	80.0
Check	--	0.0	0.0	88.0

Herbicides causing highly severe injury to the Emerald zoysia were bensulide and terbutol (Table V). The severe injury caused by these two herbicides prevented the zoysia from recovering sufficiently to approach the ground cover obtained in the untreated plots.

Bensulide was by far the most phytotoxic herbicide to the Emerald zoysia in these tests (Table V). The highest initial and residual injury was observed in the bensulide treated plots. At 10-pounds per acre, 64.8 percent initial and residual injury occureed. The 20-pound rate caused 70.4 percent initial and 75.9 percent residual injury. The loss of a large number of zoysia plugs accompanied this high percent of injury. The eventual zoysia ground coverage in the plot treated with 20 pounds of bensulide was only 26.0 percent, and these plugs were chlorotic and severely stunted (Figure 3).

Although terbutol caused only slight initial injury, the delayed phytotoxicity was severe to highly severe (Table V). The delayed injury at 10 and 20-pounds per acre was 47.2 and 66.6 percent, respectively. The zoysia plugs in these plots were extremely stunted and very little stolon growth occurred (Figure 4).

II. THE RESPONSE OF COMMON KENTUCKY BLUEGRASS TO FRESH TREATMENTS AND SOIL RESIDUES OF PREEMERGENCE HERBICIDES

In the greenhouse experiment, common Kentucky bluegrass was grown in soil collected from the 0 to 2- and 2 to 4-inch depths of field plots treated 10 months prior to sampling with selected preemergence herbicides. By using common Kentucky bluegrass as an

TABLE V

HERBICIDE TREATMENTS,
APPLIED JULY 28, 1965, CAUSING HIGHLY SEVERE INJURY
TO NEWLY PLUGGED EMERALD ZOYSIA AT KNOXVILLE

Herbicide	Rate Pounds/Acre	Percent Injury Oct. 14, 1965	Percent Injury June 9, 1966	Percent Zoysia Ground Cover Dec. 12, 1966
Bensulide	20	70.4	75.9	26.0
Bensulide	10	64.8	64.8	43.0
Terbutol	20	16.3	66.6	56.0
Terbutol	10	5.6	47.2	68.0
Check	--	0.0	0.0	88.0

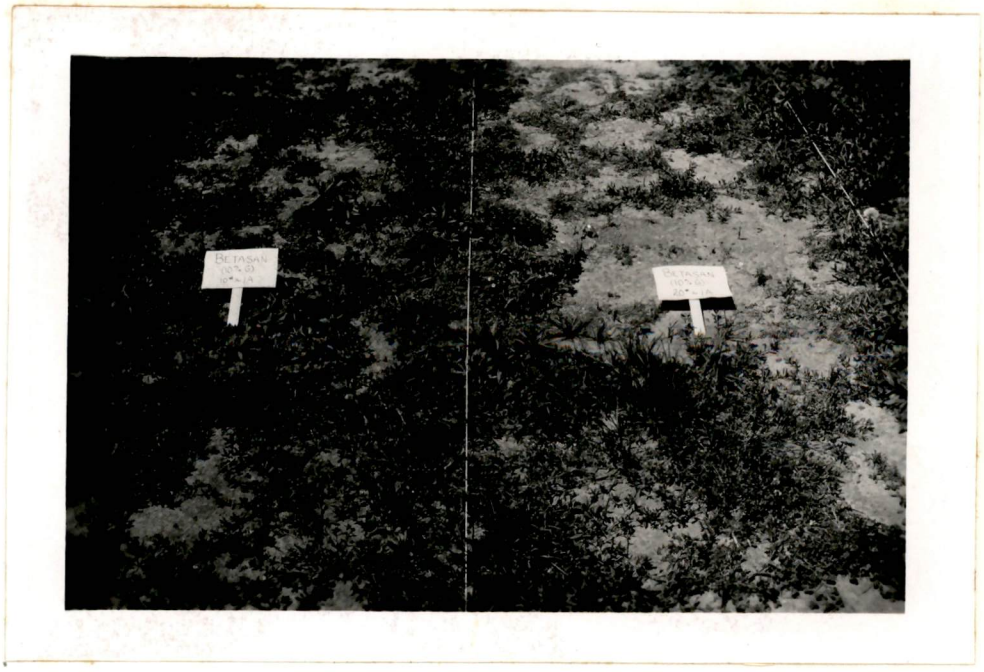

FIGURE 3

GROWTH OF PLUGS OF EMERALD ZOYSIA IN FIELD PLOTS
10 MONTHS FOLLOWING TREATMENT WITH BENSULIDE (BETASAN)

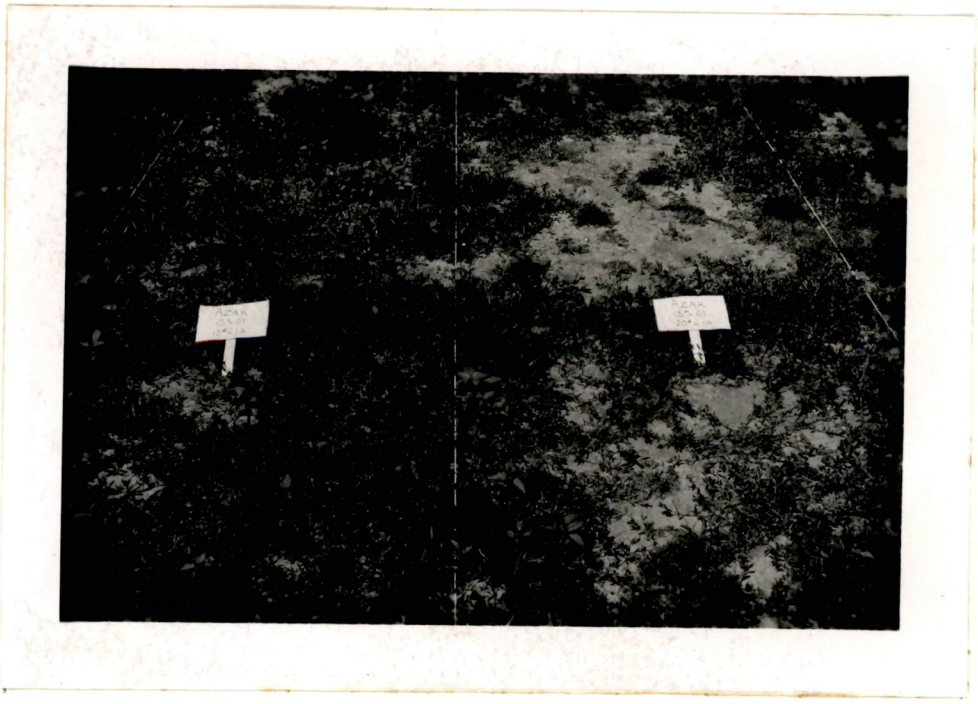

FIGURE 4

GROWTH OF PLUGS OF EMERALD ZOYSIA IN FIELD PLOTS
10 MONTHS FOLLOWING TREATMENT WITH TERBUTOL (AZAK)

indicator plant, an estimate of the residual phytotoxicity and the apparent depth of penetration of each herbicide could be determined. Common Kentucky bluegrass was grown also in soil treated with fresh applications of each herbicide to determine if, in fact, the chemicals were phytotoxic to the indicator plant.

The phytotoxicity of the fresh herbicide treatments will be discussed separately from the effects of the herbicide residues.

Phytotoxicity of Fresh Herbicide Treatments

Each of the fresh herbicide treatments caused a highly significant reduction in root regrowth of common Kentucky bluegrass sod-plugs as compared to the untreated or check sample (Table VI) (Figures 5, 6, and 7).

The least injurious of the fresh materials tested was siduron, which at the low rate caused a reduction of only 64 milligrams of root dry weight (Table VI.)

Most of the test herbicides caused moderate to severe injury to the root growth of the common Kentucky bluegrass sod-plugs (Table VI). These herbicides, at their respective high rates, listed by increasing phytotoxicity to root regrowth, were: benefin, bandane, DMPA, bensulide, sindone, trifluralin, terbutol, and DCPA.

The most phytotosic herbicides tested were simazine and atrazine (Table VI). At their low rate, both chemicals inhibited all root regrowth of the common Kentucky bluegrass, while at the high rate the sod-plugs were killed (Figures 5 and 6).

All of the low and high rates of the fresh herbicide treatments caused greater reductions in root regrowth than their

TABLE VI

THE EFFECTS OF FRESH APPLICATIONS OF SELECTED PREEMERGENCE HERBICIDES ON ROOT DRY WEIGHTS OF COMMON KENTUCKY BLUEGRASS SOD-PLUGS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS, KNOXVILLE. AVERAGE OF THREE REPLICATIONS

Herbicide	Rate Pounds/acre	Root Dry Weights[a] (mg./60 cu. in. of Soil)
Check	--	185
Sidruon	12	121
Bensulide	10	95
Siduron	24	89
Bandane	40	85
Benefin	2	81
Sindone	7	78
DMPA	10	75
Terbutol	10	70
Benefin	4	69
Bandane	80	67
DCPA	12	63
Trifluralin	2	58
DMPA	20	57
Bensulide	20	54
Sindone	14	50
Trifluralin	4	42
Terbutol	20	31
DCPA	24	31
Atrazine	4	0
Atrazine	2	0
Simazine	4	0
Simazine	2	0

[a]Averages scored by the same line do not differ significantly at the 0.01 level of probability according to Duncan's Multiple Range Test.

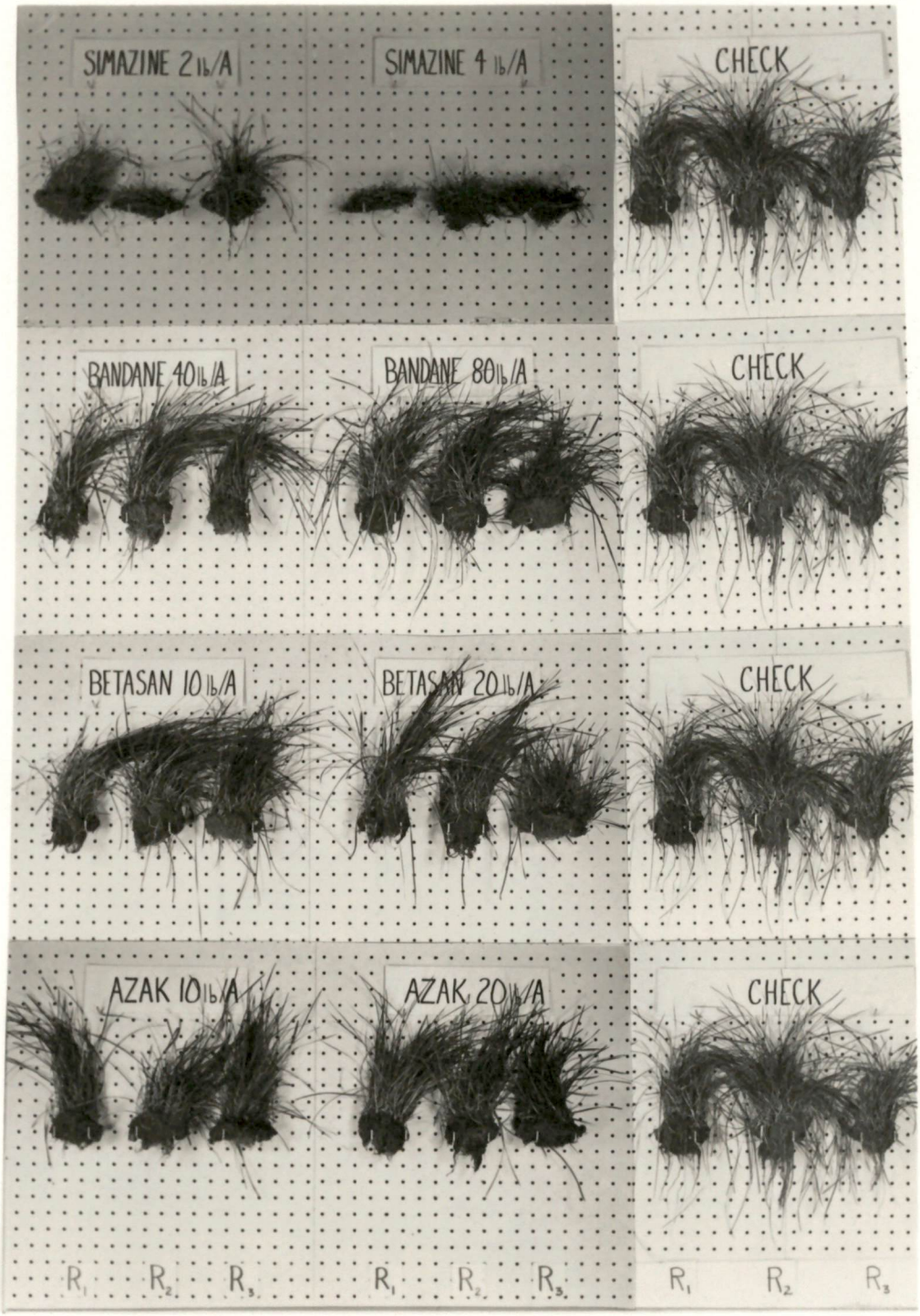

FIGURE 5

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED WITH FRESH APPLICATIONS OF SIMAZINE, BANDANE, BENSULIDE (BETASAN), AND TERBUTOL (AZAK)

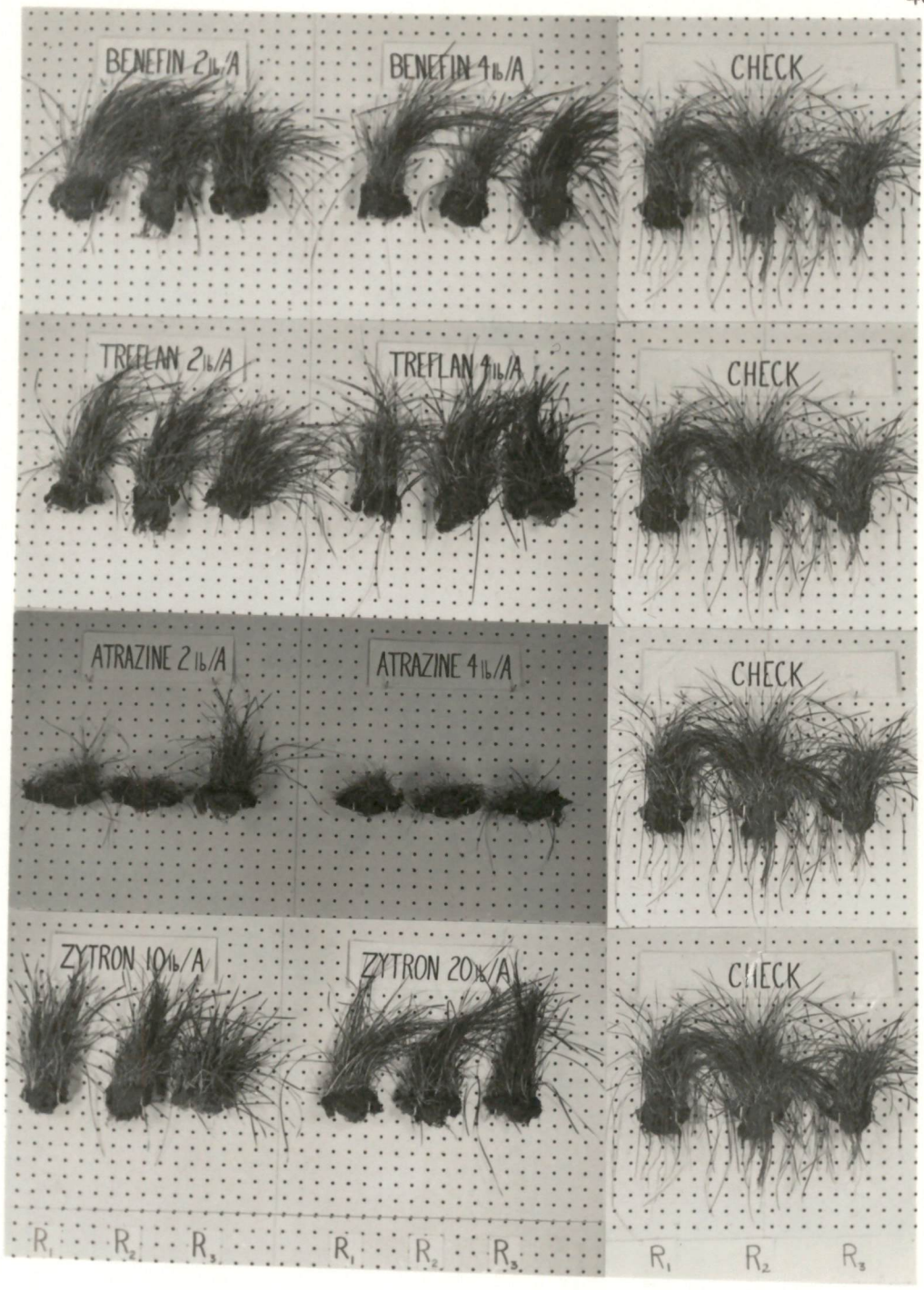

FIGURE 6

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED WITH FRESH APPLICATIONS OF BENEFIN, TRIFLURALIN (TREFLAN), ATRAZINE, AND DMPA (ZYTRON)

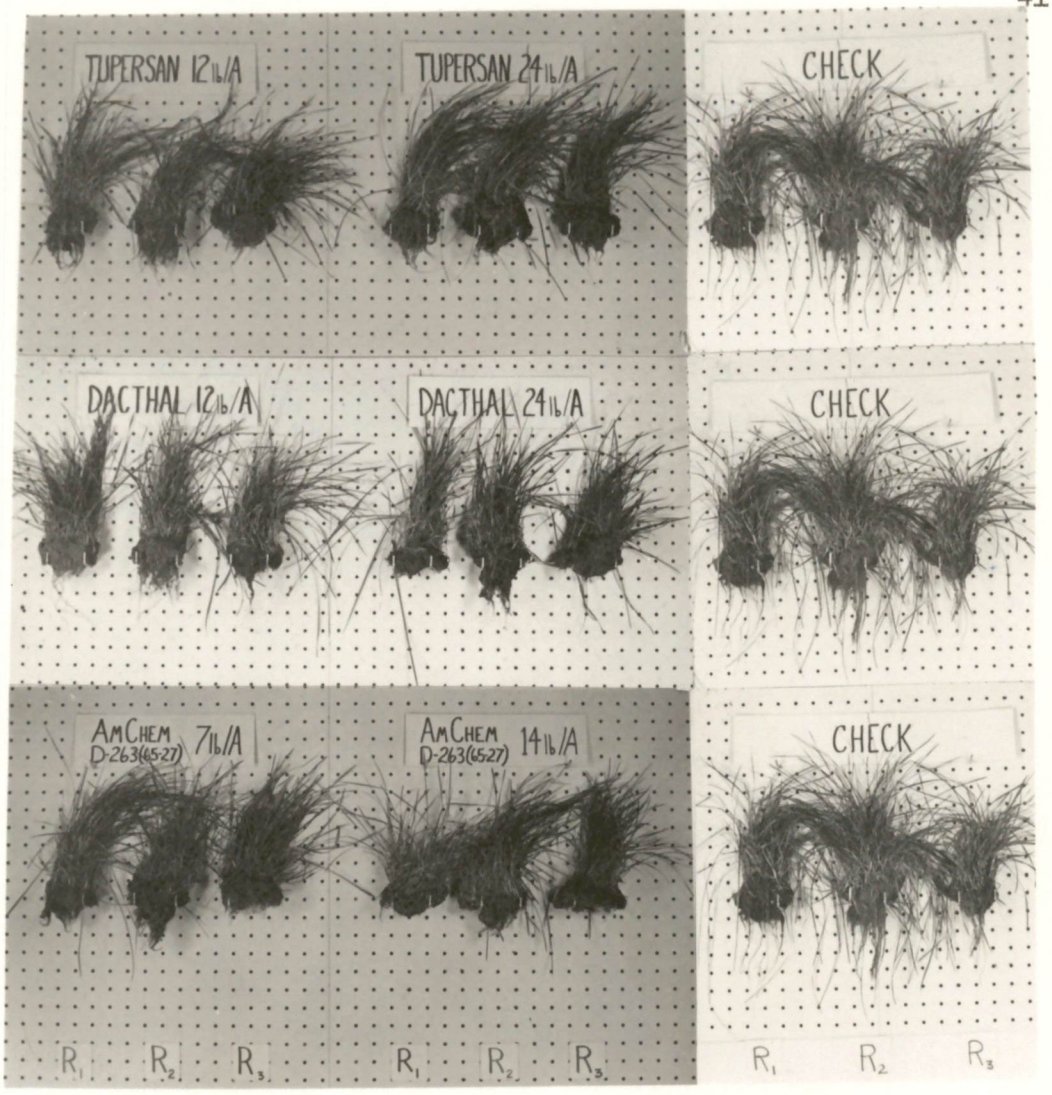

FIGURE 7

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED WITH FRESH APPLICATIONS OF SIDURON (TUPERSAN), DCPA (DACTHAL), AND SINDONE (AMCHEM D-263 (65-27))

corresponding herbicide residue samples (Table VII).

Phytotoxicity of Herbicide Residues

Sod-plugs of common Kentucky bluegrass were grown in soil collected from the 0 to 2- and 2 to 4-inch soil depths of field plots treated 10 months prior to sampling with various herbicides. This technique provided an estimate of the residual phytotoxicity of the selected herbicides and the soil depth at which they persisted in highest concentration. The higher rate of application of each herbicide tested was considered to be the better criterion in determining at what soil depth each chemical persisted in greatest quantities. The larger the amount of herbicide applied the easier the depth of persistence could be determined.

Both rates of each herbicide for both the 0 to 2- and 2 to 4-inch soil residue samples caused a highly significant reduction in root regrowth of common Kentucky bluegrass as compared to the untreated sample (Tables VIII, IX, X, and XI) (Figures 8, 9, 10, 11, 12, and 13). The exception was atrazine at 2-pounds per acre in the 0 to 2-inch residue sample (Table VIII). However, atrazine did cause a reduction of 44 milligrams in dry root weight below that of the untreated sample.

Herbicides which caused the greatest reduction in root growth of common Kentucky bluegrass in the 0 to 2-inch soil level were both rates of terbutol, bensulide, bandane, simazine, and sindone

TABLE VII

THE EFFECTS OF FRESH HERBICIDE APPLICATIONS AND HERBICIDE SOIL RESIDUES ON ROOT DRY WEIGHTS OF COMMON KENTUCKY BLUEGRASS SOD-PLUGS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS, KNOXVILLE. AVERAGE OF THREE REPLICATIONS

Herbicide	Rate Pounds/Acre	Root Dry Wt. (mg./60 cu. in. of Soil)[a] Soil Depth of Residue 0 to 2-in.	2 to 4-in.	Fresh Herbicide
DMPA	10	153 a	107 b	75 b
	20	115 a	62 b	57 b
DCPA	12	144 a	152 a	63 b
	24	132 a	146 a	31 b
Simazine	2	123 a	147 a	0 b
	4	90 a	127 a	0 b
Atrazine	2	186 a	101 b	0 c
	4	126 a	84 a	0 b
Terbutol	10	117 a	90 ab	70 b
	20	44 a	72 a	31 a
Bensulide	10	95 a	118 a	95 a
	20	66 a	90 a	54 a
Trifluralin	2	151 a	100 b	58 b
	4	135 a	89 b	42 c
Benefin	2	152 a	140 a	81 b
	4	133 a	93 ab	69 b
Siduron	12	155 a	129 a	121 a
	24	129 a	123 a	89 a
Sindone	7	140 a	117 ab	78 b
	14	91 ab	100 a	50 b
Bandane	40	136 a	123 ab	85 b
	80	70 b	147 a	67 b
Check	--	230 a	192 a	185 b

[a]Averages followed by the same letter within rows do not differ significantly at the 0.01 level of probability according to Duncan's Multiple Range Test.

TABLE VIII

THE EFFECTS OF LOW RATES OF PREEMERGENCE HERBICIDES FROM THE 0 TO 2-INCH DEPTH OF FIELD PLOTS ON ROOT DRY WEIGHTS OF COMMON KENTUCKY BLUEGRASS SOD-PLUGS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED 10 MONTHS PRIOR TO SAMPLING, KNOXVILLE. AVERAGE OF THREE REPLICATIONS.

Herbicide	Rate Pounds/acre	Root Dry Weights[a] (mg./60 cu. in. of Soil)
Check	--	230
Atrazine	2	186
Siduron	12	155
DMPA	10	153
Benefin	2	152
Trifluralin	2	151
DCPA	12	144
Sindone	7	140
Bandane	40	136
Simazine	2	123
Terbutol	10	117
Bensulide	10	95

[a]Averages scored by the same line do not differ significantly at the 0.01 level of probability according to Duncan's Multiple Range Test.

TABLE IX

THE EFFECTS OF HIGH RATES OF PREEMERGENCE HERBICIDES FROM THE 0 TO 2-INCH DEPTH OF FIELD PLOTS ON ROOT DRY WEIGHTS OF COMMON KENTUCKY BLUEGRASS SOD-PLUGS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED 10 MONTHS PRIOR TO SAMPLING, KNOXVILLE. AVERAGE OF THREE REPLICATIONS.

Herbicide	Rate Pounds/Acre	Root Dry Weights[a] (mg./60 cu. in. of Soil)
Check	--	230
Trifluralin	4	135
Benefin	4	133
DCPA	24	132
Siduron	24	129
Atrazine	4	126
DMPA	20	115
Sindone	14	91
Simazine	4	90
Bandane	80	70
Bensulide	20	66
Terbutol	20	44

[a]Averages scored by the same line do not differ significantly at the 0.01 level of probability according to Duncan's Multiple Range Test.

TABLE X

THE EFFECTS OF LOW RATES OF PREEMERGENCE HERBICIDES FROM THE 2 TO 4-INCH DEPTH OF FIELD PLOTS ON ROOT DRY WEIGHTS OF COMMON KENTUCKY BLUEGRASS SOD-PLUGS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED 10 MONTHS PRIOR TO SAMPLING, KNOXVILLE. AVERAGE OF THREE REPLICATIONS.

Herbicide	Rate Pounds/Acre	Root Dry Weights[a] (mg./60 cu. in. of Soil)
Check	--	192
DCPA	12	152
Simazine	2	147
Benefin	2	140
Siduron	12	129
Bandane	40	123
Bensulide	10	118
Sindone	7	117
DMPA	10	107
Atrazine	2	101
Trifluralin	2	100
Terbutol	10	90

[a]Averages scored by the same line do not differ significantly at the 0.01 level of probability according to Duncan's Multiple Range Test.

TABLE XI

THE EFFECTS OF HIGH RATES OF PREEMERGENCE HERBICIDES FROM THE 2 TO 4-INCH DEPTH OF FIELD PLOTS ON ROOT DRY WEIGHTS OF COMMON KENTUCKY BLUEGRASS SOD-PLUGS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL TREATED 10 MONTHS PRIOR TO SAMPLING KNOXVILLE. AVERAGE OF THREE REPLICATIONS.

Herbicide	Rate Pounds/Acre	Root Dry Weights[a] (mg./60 cu. in. of Soil)
Check	--	192
Bandane	80	147
DCPA	24	146
Simazine	4	127
Siduron	24	123
Sindone	14	100
Benefin	4	93
Bensulide	20	90
Trifluralin	4	89
Atrazine	4	84
Terbutol	20	72
DMPA	20	62

[a]Averages scored by the same line do not differ significantly at the 0.01 level of probability according to Duncan's Multiple Range Test.

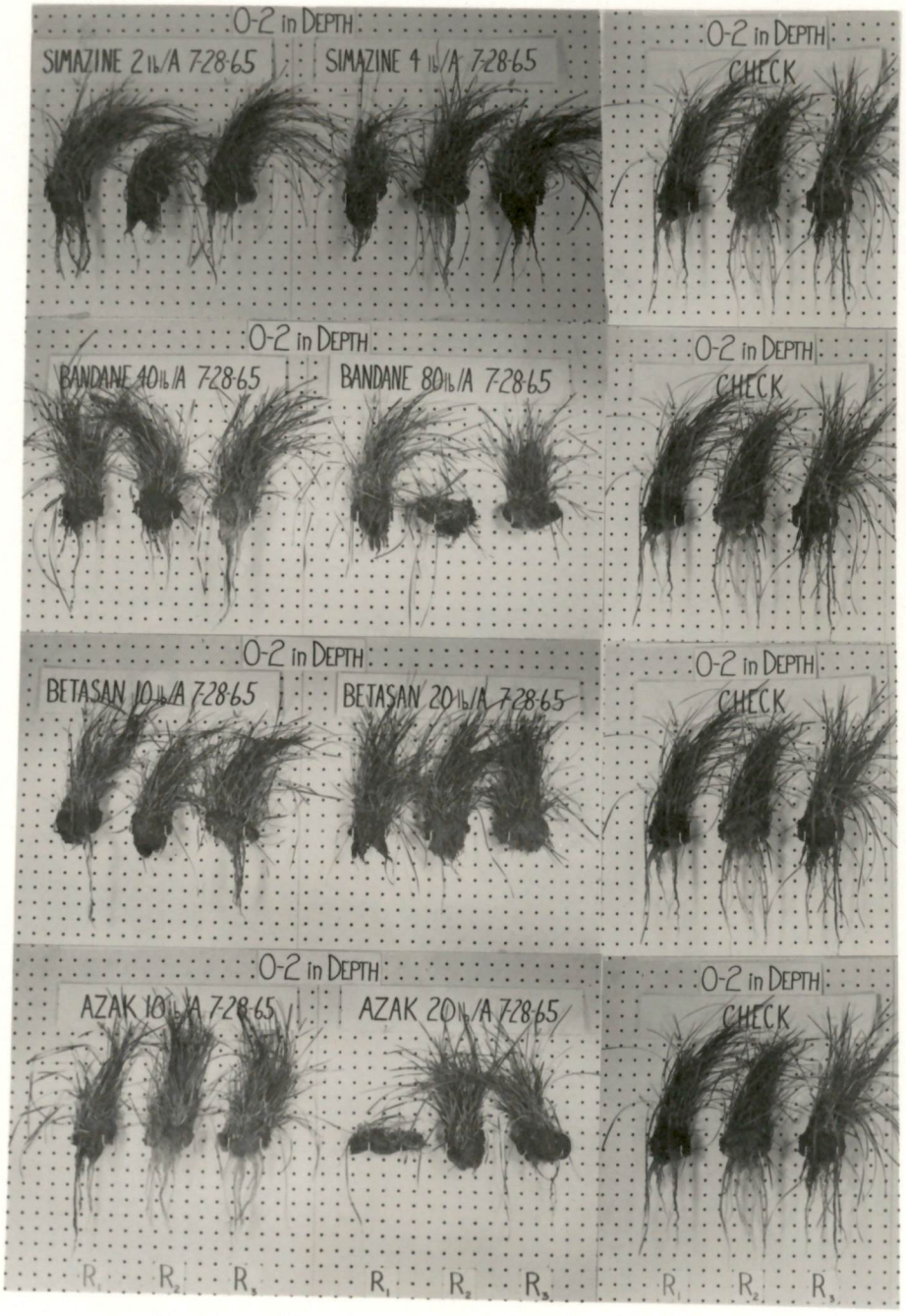

FIGURE 8

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL COLLECTED FROM THE 0 TO 2-INCH DEPTH OF FIELD PLOTS TREATED 10 MONTHS EARLIER WITH SIMAZINE, BANDANE, BENSULIDE (BETASAN), AND TERBUTOL (AZAK)

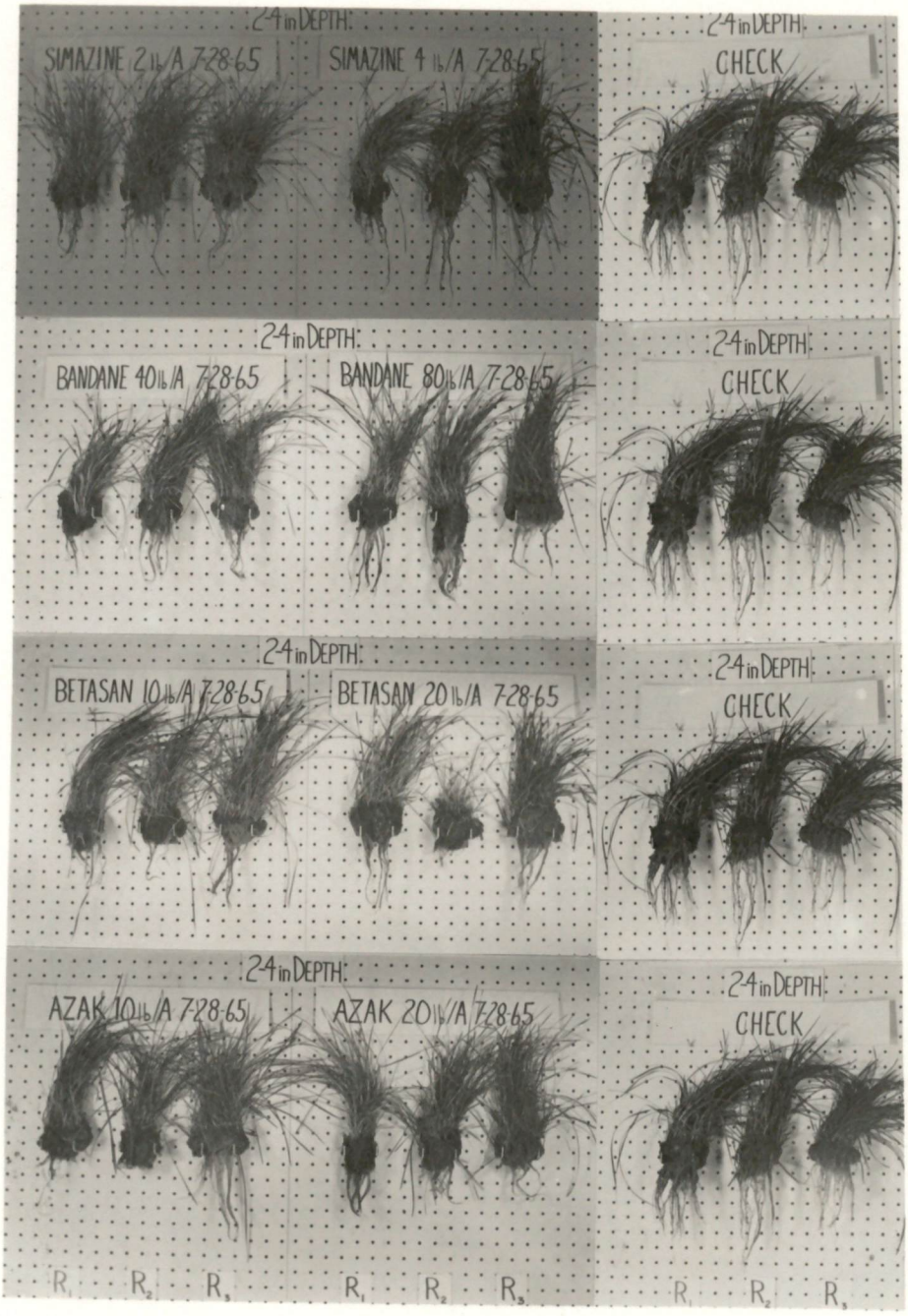

FIGURE 9

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL COLLECTED FROM THE 2 TO 4-INCH DEPTH OF FIELD PLOTS TREATED 10 MONTHS EARLIER WITH SIMAZINE, BANDANE, BENSULIDE (BETASAN), AND TERBUTOL (AZAK)

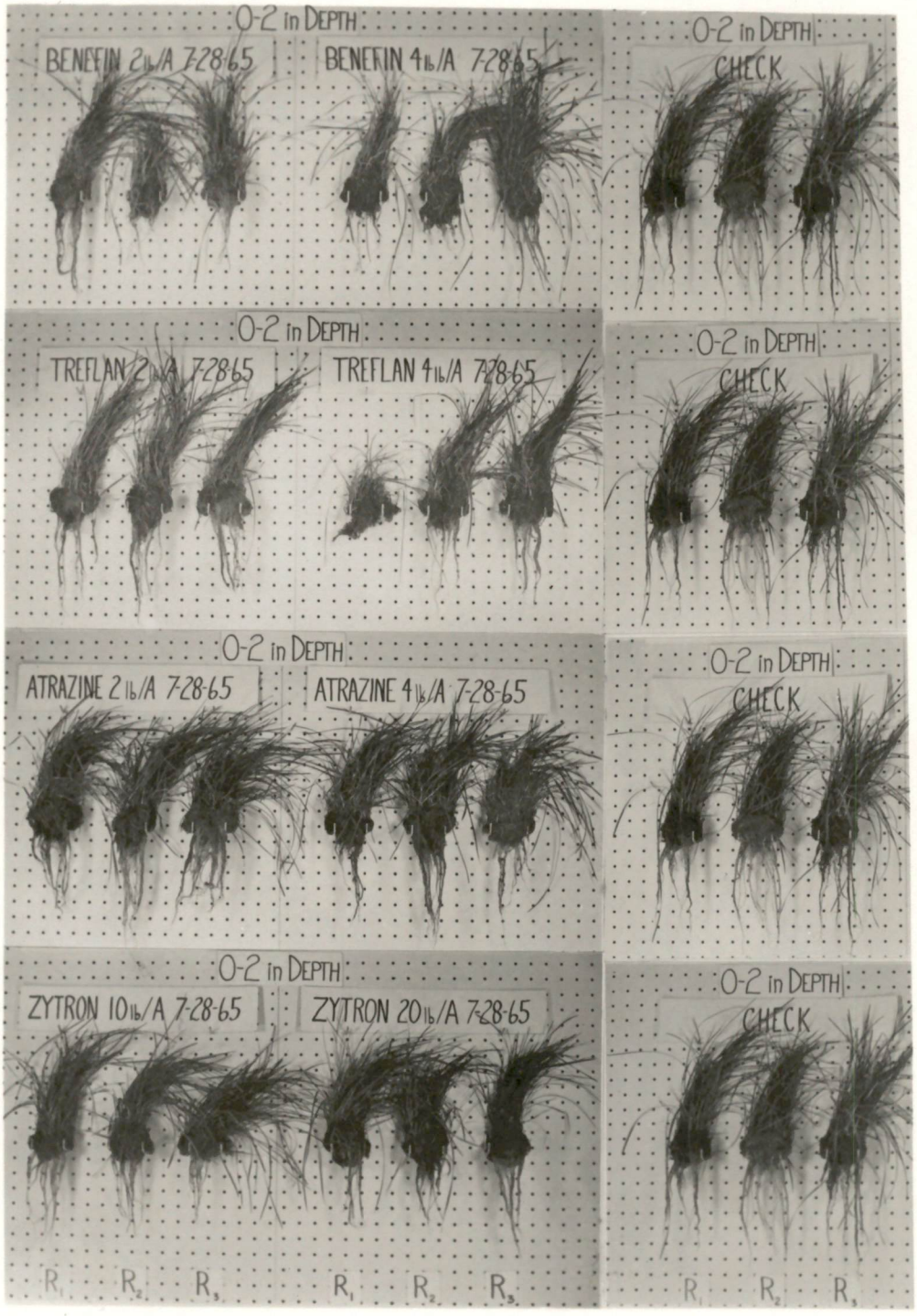

FIGURE 10

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL COLLECTED FROM THE 0 TO 2-INCH DEPTH OF FIELD PLOTS TREATED 10 MONTHS EARLIER WITH BENEFIN, TRIFLURALIN (TREFLAN), ATRAZINE, AND DMPA (ZYTRON)

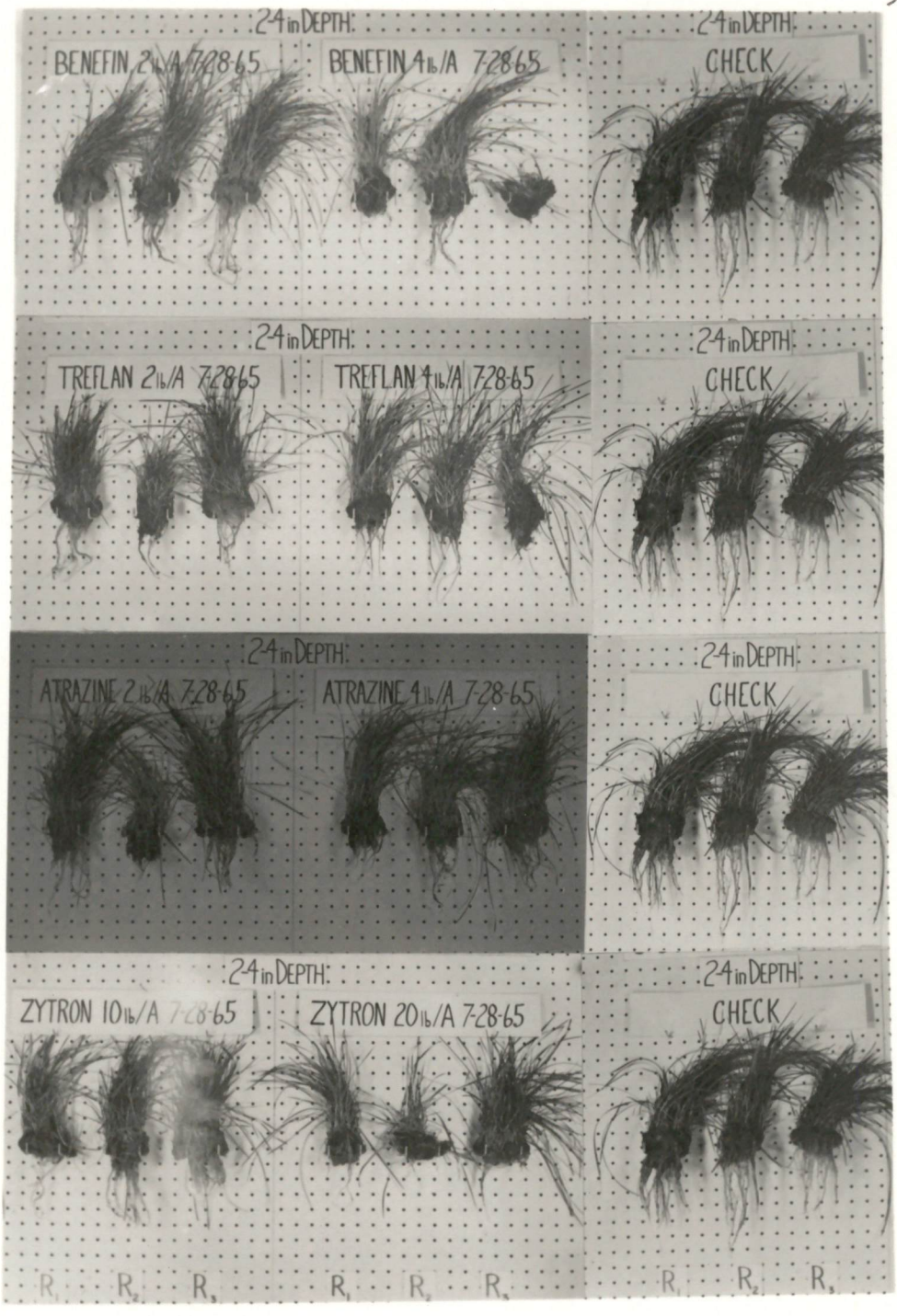

FIGURE 11

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL COLLECTED FROM THE 2 TO 4-INCH DEPTH OF FIELD PLOTS TREATED 10 MONTHS EARLIER WITH BENEFIN, TRIFLURALIN (TREFLAN), ATRAZINE, AND DMPA (ZYTRON)

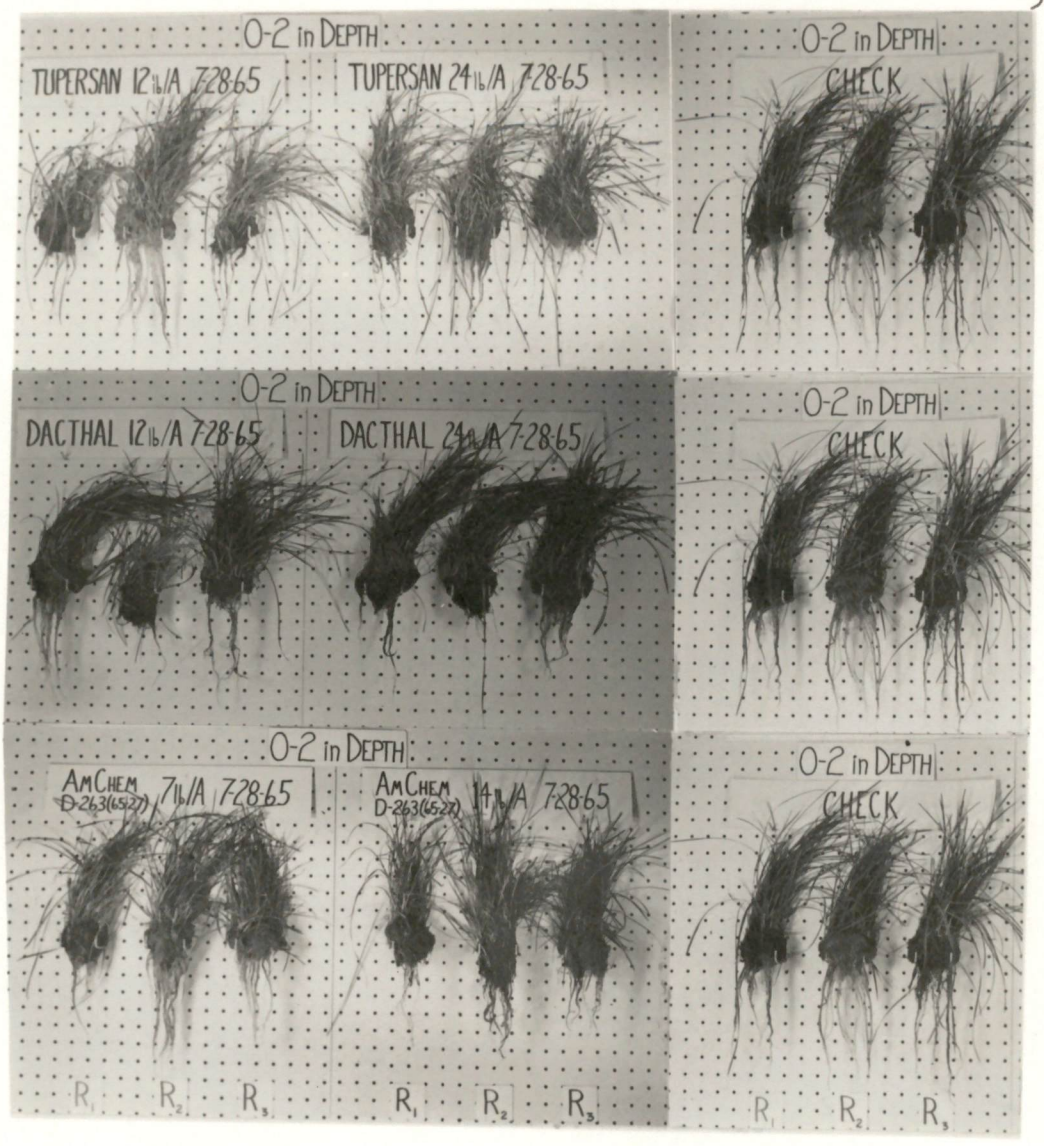

FIGURE 12

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL COLLECTED FROM THE 0 TO 2-INCH DEPTH OF FIELD PLOTS TREATED 10 MONTHS EARLIER WITH SIDURON (TUPERSAN), DCPA (DACTHAL), AND SINDONE (AMCHEM D-263 (65-27))



FIGURE 13

ROOT GROWTH OF COMMON KENTUCKY BLUEGRASS GROWN FOR 25 DAYS UNDER GREENHOUSE CONDITIONS IN SOIL COLLECTED FROM THE 2 TO 4-INCH DEPTH OF FIELD PLOTS TREATED 10 MONTHS EARLIER WITH SIDURON (TUPERSAN), DCPA (DACTHAL), AND SINDONE (AMCHEM D-263 (65-27))

(Tables VIII, p. 44 and IX, p. 45). In the 2 to 4-inch soil level, the most phytotoxic herbicides were both rates of DMPA, terbutol, atrazine, and trifluralin (Tables X, p. 46 and XI, p.47).

DCPA, sindone, and siduron, at their high rates, were equally injurious throughout both soil levels (Tables IX, p. 45 and XI, p. 47). This indicates that these three herbicides tended to leach uniformly throughout the top 4 inches of the soil.

Those herbicides, at their respective low rates, which caused the greatest reduction in root growth of common Kentucky bluegrass sod-plugs, regardless of the soil level of their greatest persistence, were terbutol, bensulide, and sindone (Tables VIII, p.44 and X, p. 46). These same herbicides were also the most phytotoxic at their high rates when considering their effects at both soil depths (Tables IX, p. 45 and XI, p. 47).

The herbicide treatments which caused the least significant reduction in root regrowth of common Kentucky bluegrass, considering their effect at both depths, were the low rate of siduron, both rates of DCPA, and the low rate of benefin (Tables VIII, p. 44 , X, p. 46 , and XI, p. 47).

CHAPTER V

SUMMARY AND CONCLUSIONS

A study of the herbicidal aid in establishing an Emerald zoysia sod was initiated at Knoxville on the Main Experiment Station in the summer of 1965. The primary objective was to determine the tolerance of newly planted Emerald zoysia sod-plugs to several pre-emergence type herbicides. Also, the effectiveness of the chemicals in controlling selected weeds was investigated.

Results of the field study showed that all of the herbicides provided excellent preemergence control of crabgrass and goosegrass throughout the growing season following treatments. Almost complete elimination of annual weedy grasses from the turfgrass planting bed was achieved with all herbicides at both rates of application.

The injury to the Emerald zoysia following herbicide treatments varied from none to very severe.

In this test, the safest chemicals applied to the newly plugged zoysia were siduron and DMPA. These two herbicides caused either no observable injury or only slight injury, and thus greatly enhanced the establishment rate of the turfgrass. These two herbicides provided 93 to 100 percent ground cover by the end of the second growing season following treatments.

The most phytotoxic of the herbicides tested were bensulide and terbutol. Both caused highly severe injury to the Emerald zoysia. These two herbicides seriously retarded the growth of the zoysia and greatly inhibited ground cover.

Those herbicide treatments causing slight to moderate injury which allowed an equal or greater percent ground cover by the zoyia when compared to the cover in the untreated plots were atrazine at 2 and 4-pounds per acre, simazine at 2-pounds, benefin at 4-pounds, and trifluralin at 2-pounds. The zoysia in the plots treated with sindone at 7-pounds, bandane at 40 pounds, benefin at 2-pounds and DCPA at 12 and 24-pounds did not cover as great a percent of the ground as was observed in the untreated plots.

The high rates of sindone, bandane, trifluralin, and simazine were moderate to severely injurious to the Emerald zoysia. The zoysia did not attain as great a ground cover in these treated plots as it did in the untreated plots.

The results of the field study indicated that the tolerance of the newly planted turfgrass to various herbicides was the more important factor to consider when choosing a chemical to aid the establishment of the turfgrass. The use of herbicides which effectively eliminated weed competition, but which also greatly retarted the growth of the turfgrass was more detrimental to establishment rate than the actual competition from the weeds.

In the greenhouse study, common Kentucky bluegrass was grown in soil freshly treated with herbicides and in soil collected from the 0 to 2- and 2 to 4-inch depths of field plots treated 10 months prior to sampling with herbicides. By using common Kentucky bluegrass as an indicator plant, an estimate of the residual phytotoxicity and depth of penetration of each herbicide in the soil could be determined.

All of the fresh herbicide treatments reduced significantly the root regrowth of the common Kentucky bluegrass plants. The safest of the fresh materials tested was siduron. Atrazine and simazine were the most phytotoxic, killing the bluegrass plants at the high rates of application. The high rates of DCPA, terbutol, trifluralin, sindone, and bensulide were also highly injurious to root growth.

The root regrowth of common Kentucky bluegrass grown in the herbicide residue samples was significantly less for all treatments as compared to the root growth of sod-plugs in the untreated soil. The single exception was atrazine at its low rate in the 0 to 2-inch residue sample which caused a non-significant reduction in root growth.

Herbicides which tended to persist in the 0 to 2-inch soil level and were most phytotoxic to the regrowth of common Kentucky bluegrass roots were simazine, bandane, bensulide, and terbutol. Those herbicides which tended to leach into the 2 to 4-inch soil

level and cause the greatest reduction of root regrowth were benefin, trifluralin, atrazine, and DMPA. The herbicides which tended to leach uniformly throughout the 0 to 2- and 2 to 4-inch soil layers were sindone, siduron, and DCPA.

When considering the overall effect of the herbicides at both soil depths, the most phytotoxic chemicals were both rates of terbutol, bensulide, and sindone. It should be noted that terbutol and bensulide were the most injurious herbicides in the field study also.

The least phytotoxic residue samples were the low rate of siduron and benefin, and both rates of DCPA. Siduron was also the least injurious herbicide tested in the field.

Preemergence herbicide residues had sufficient influence on the regrowth of the turfgrass root system of common Kentucky bluegrass to justify further research into the residual activity of each chemical tested.

LITERATURE CITED

LITERATURE CITED

1. Ahrens, J. F., and A. R. Olson. 1961. Comparison of preemergence herbicides for the control of crabgrass. Proc. Northeastern Weed Control Conf. 15:276-279.

2. _____, R. J. Lukens, and A. R. Olson. 1963. Single and repeated applications of preemergence crabgrass killers on turf. Proc. Northeastern Weed Control Conf. 17:483-484.

3. Alder, E. F., and R. B. Bevington. 1962. Diphendtrile, dipropalin, and trifluralin as pre-emergent turf herbicides. Proc. Northeastern Weed Control Conf. 16:505-510.

4. Ames, R. B., and C. R. Skogley. 1962. Pre- and post-emergence crabgrass control in lawn turf. Proc. Northeastern Weed Control Conf. 16:528-535.

5. Bingham, S. W., and R. E. Schmidt. 1964. Crabgrass control in turf. Proc. Southern Weed Conf. 17:113-122.

6. Burt, E. O. 1965. Summary of south Florida research. Tolerance of warm season turfgrasses to pre-emergence and post-emergence herbicides. Proc. Fla. Turf-grass Management Conf. 13:160-161.

7. _____. 1963. Tolerance of warm season turfgrasses to herbicides. Proc. Fla. Turf-grass Management Conf. 11:165.

8. _____. 1964. Tolerance of warm season turfgrasses to herbicides. Proc. Southern Weed Conf. 17:123-126.

9. _____. 1965. Warmseason turfgrasses and preemergence herbicides. Golf Course Reporter 33(3):54-56.

10. Chamberlain, H. E., J. L. Fults, and M. A. Ross. 1962. The effects of five preemergence herbicides on Kentucky bluegrass seeded at intervals after herbicide treatment. Res. Progress Report Western Weed Control Conf. p. 28-29.

11. Cornman, J. F., F. M. Madden, and N. J. Smith. 1964. Tolerance of established lawn grasses, putting greens, and turfgrass seeds to pre-emergence crabgrass control chemicals. Proc. Northeastern Weed Control Conf. 18:519-522.

12. Dewald, C. L., L. W. Fancher, and B. H. Lake. 1963. Betasan--A promising new herbicide for use on turf. Proc. Southern Weed Conf. 16:110-115.

13. Duble, R. L., and E. C. Holt. 1965. Preemergence herbicides as they influence bermudagrass establishment. Golf Course Reporter. 33(3):50-51.

14. Duich, J. M., B. R. Fleming, A. E. Dudeck, and C. J. Shoop. 1964. 1963 crabgrass control results in Pennsylvania. Proc. Northeastern Weed Control Conf. 18:507-510.

15. _____, G. J. Shoop, and B. R. Fleming. 1965. 1964 preemergence crabgrass control results. Golf Course Reporter. 33(3):58-64.

16. _____, B. R. Fleming, and A. E. Dudeck. 1961. The effect of pre-emergence chemicals on crabgrass and bluegrass, fescue, and bentgrass turf. Proc. Northeastern Weed Control Conf. 15:260-275.

17. Engel, R. E. 1963. Crabgrass control obtained on turf treated with several new and developmental preemergence herbicides. Proc. Northeastern Weed Control Conf. 17:490-492.

18. _____, and L. M. Callahan. 1967. Merion Kentucky bluegrass response to soil residue of preemergence herbicides. Weeds. 15:128-130.

19. _____, and W. F. Meggitt. 1960. A progress report of preemergence crabgrass control on lawn turf. Proc. Northeastern Weed Control Conf. 14:304-307.

20. _____, R. N. Cook, and R. D. Ilnicki. 1962. Crabgrass control in established turf with preemergence herbicides. Proc. Northeastern Weed Control Conf. 16:543-544.

21. Fulwider, J. R., and R. E. Engel. 1958. Pre-emergence control of goosegrass in turf areas. Proc. Northeastern Weed Control Conf. 12:138-139.

22. Gallagher, J. E., and C. C. Jack. 1958. Chickweed control test 1956-57. Proc. Northeastern Weed Control Conf. 12:151-153.

23. Gaskin, T. A. 1964. Effect of pre-emergence crabgrass herbicides on rhizome development in Kentucky bluegrass. Agron. J. 56:340-342.

24. Herron, J. W. 1965. Preemergence crabgrass control research in Kentucky bluegrass and bermudagrass. Golf Course Reporter. 33(3):20-22.

25. Juska, F. V., and A. A. Hanson. 1964. Effect of preemergence herbicides on seedling emergence of turfgrass species. Weeds. 12:97-101.

26. Klingman, G. C. 1962. Weed Control in zoysia, tall fescue and bermudagrass turf. Proc. Southern Weed Conf. 15:69-73.

27. Lewis, W. M. 1965. Preemergence crabgrass control with comparisons of spray and granular applications. Proc. Southern Weed Conf. 18:118-127.

28. _____, and G. C. Klingman. 1963. Three evaluation methods for taking weed control data in bermudagrass turf. Proc. Southern Weed Conf. 16:105-109.

29. _____, and W. B. Gilbert. 1966. The effect of siduron on crabgrass and goosegrass control and the establishment of five warm-season and three cool-season turfgrasses. Proc. Southern Weed Conf. 19:150-154.

30. _____, and J. P. Lilly. 1966. Retreatments of preemergence and postemergence crabgrass herbicides and their residual effects on the establishment of three turfgrasses. Proc. Southern Weed Conf. 19:161-167.

31. Limpel, L. E., P. H. Schuldt, and D. Lamont. 1960. Preemergence control of crabgrass and other weeds in turf by Dac-893. Proc. Northeastern Weed Control Conf. 14:299.

32. Mower, R. C., and J. F. Cornman. 1960. Pre-emergence and post-emergence crabgrass control. Proc. Northeastern Weed Control Conf. 14:271-277.

33. Roberts, E. C., and D. R. Brockshus. 1966. Kind and extend of injury to greens from preemergence herbicides. The Golf Supt. 34(5):13-18, 36.

34. _____, and J. J. Ptacek. 1962. Studies at Iowa State University. Preemergence crabgrass control. Golf Course Reporter. 30(3):18-26.

35. Santelman, P. W., and J. A. Meade. 1960. Preemergence crabgrass control in lawns. Proc. Northeastern Weed Control Conf. 14:288-291.

36. Singh, R. K. N., and R. W. Campbell. 1965. Herbicides on bluegrass. Weeds. 13:170-172.

37. Skogley, C. R., and J. A. Jagschitz. 1964. The effect of various preemergence crabgrass herbicides on turfgrass seeds and seedlings. Proc. Northeastern Weed Control Conf. 18:523-529.

38. _____, _____. 1965. Chemical crabgrass control in turfgrass. Golf Course Reporter. 33(3):14-16.

39. Wiltse, M. G. 1960. A new herbicide for turf - Zytron. Proc. Northeastern Weed Control Conf. 14:292-298.

APPENDIX

TABLE XII

PLANT COUNTS AND PERCENT CONTROL OF CRABGRASS AND GOOSEGRASS IN FIELD PLOTS OF EMERALD ZOYSIA 16 DAYS AFTER HERBICIDES WERE APPLIED ON JULY 28, 1965, KNOXVILLE

Herbicide	Rate Pounds/Acre	Plant Counts[a]		Percent Control
		Crabgrass	Goosegrass	
Simazine	4	0	0	100.0
Simazine	2	0	0	100.0
Benefin	4	0	1	99.9
Sindone	7	0	1	99.9
Trifluralin	4	0	3	99.5
Trifluralin	2	1	2	99.5
Bensulide	20	0	3	99.5
Atrazine	4	2	2	99.4
DCPA	12	1	3	99.4
Benefin	2	0	4	99.4
Sindone	14	0	5	99.3
Terbutol	10	1	4	99.3
Bensulide	10	0	5	99.3
DMPA	20	1	5	99.0
Bandane	80	0	6	99.0
DMPA	10	0	9	98.6
Terbutol	20	2	8	98.4
Bandane	40	0	12	98.0
Atrazine	2	9	7	97.4
DCPA	24	1	27	95.5
Siduron	24	0	71	88.6
Siduron	12	1	73	88.1
Check	--	73	548	0.0

[a]Plant Count is the total for three replications.

TABLE XIII

PLANT COUNT AND PERCENT CONTROL OF CRABGRASS AND GOOSEGRASS IN FIELD PLOTS OF EMERALD ZOYSIA 56 DAYS AFTER HERBICIDES WERE APPLIED ON JULY 28, 1965, KNOXVILLE

Herbicide	Rate Pounds/Acre	Plant Counts[a]		Percent Control
		Crabgrass	Goosegrass	
Trifluralin	4	0	2	99.7
Benefin	4	0	2	99.7
Bensulide	20	0	2	99.7
Atrazine	4	0	3	99.5
Simazine	4	0	3	99.5
Sindone	14	0	3	99.5
Sindone	7	0	3	99.5
Atrazine	2	2	3	99.3
Terbutol	20	1	6	98.8
Trifluralin	2	0	7	98.8
Benefin	2	0	7	98.8
DMPA	20	0	9	98.5
Terbutol	10	0	9	98.5
Simazine	2	0	10	98.3
Bandane	80	1	9	98.3
Bensulide	10	0	11	98.2
DMPA	10	0	15	97.5
DCPA	24	0	15	97.5
DCPA	12	0	16	97.3
Siduron	24	0	16	97.3
Bandane	40	0	24	96.0
Siduron	12	0	37	93.8
Check	--	18	580	0.0

[a]Plant count is the total for three replications.

TABLE XIV

PLUG COUNTS AND PERCENT INJURY IN FIELD PLOTS OF EMERALD ZOYSIA 78 DAYS AFTER HERBICIDES WERE APPLIED ON JULY 28, 1965, KNOXVILLE

Herbicide	Rate Pounds/Acre	Plug Count[a] Dead	Injured[b]	Healthy	Percent Injury[c]
Siduron	12	0	0	108	0.0
Siduron	24	0	0	108	0.0
DMPA	10	0	1	107	0.9
Benefin	2	0	1	107	0.9
Sindone	7	0	1	107	0.9
Simazine	2	0	3	105	2.8
Bandane	40	0	3	105	2.8
DMPA	20	0	4	104	3.7
Atrazine	2	0	4	104	3.7
Sindone	14	0	6	102	5.6
Terbutol	10	0	6	102	5.6
Trifluralin	2	0	9	99	8.3
DCPA	12	0	16	92	14.8
Bandane	80	1	15	92	14.8
Terbutol	20	0	18	90	16.3
DCPA	24	0	20	88	18.5
Benefin	4	6	16	86	20.3
Atrazine	4	4	19	85	21.3
Trifluralin	4	10	22	76	29.6
Simazine	4	7	56	45	58.3
Bensulide	10	14	56	38	64.8
Bensulide	20	22	54	32	70.4
Check	--	0	0	108	0.0

[a]Plug count is the total for three replications.

[b]Injured plugs were those plugs which were stunted, chlorotic, necrotic, or lacked stolon spread.

[c]Percent injury is based on both dead and injured plugs.

TABLE XV

PLUG COUNTS AND PERCENT INJURY IN FIELD PLOTS OF EMERALD ZOYSIA 10 MONTHS AFTER HERBICIDES WERE APPLIED ON JULY 28, 1965, KNOXVILLE

Herbicide	Rate Pounds/Acre	Plug Count[a]			Percent Injury[c]
		Dead	Injured[b]	Healthy	
Siduron	12	0	0	108	0.0
DMPA	10	0	3	105	2.7
Siduron	24	0	8	100	7.4
DMPA	20	0	8	100	7.4
Atrazine	2	1	10	97	10.1
Simazine	2	0	12	96	11.1
Benefin	2	0	17	91	15.7
Atrazine	4	4	15	89	17.5
Bandane	40	1	24	83	23.1
DCPA	12	1	24	83	23.1
Sindone	7	2	30	76	29.6
Benefin	4	6	29	73	32.4
Trifluralin	2	6	30	72	33.3
Simazine	4	7	32	69	36.1
Bandane	40	4	37	67	37.9
Sindone	14	2	40	66	38.8
Terbutol	10	2	49	57	47.2
DCPA	24	4	54	50	53.7
Trifluralin	4	15	49	44	59.2
Bensulide	10	15	55	38	64.8
Terbutol	20	11	61	36	66.6
Bensulide	20	23	59	26	75.9
Check	--	0	0	108	0.0

[a]Plug count is the total for three replication.

[b]Injured plugs were those plugs which were stunted, chlorotic, necrotic, or lacked stolon spread.

[c]Percent injury is based on both dead and injured plugs.

TABLE XVI

MONTHLY RAINFALL (INCHES) DATA FOR THE AGRICULTURAL EXPERIMENT STATION AT KNOXVILLE FOR AUGUST 1965 TO JUNE 1966

Month	Year	Total Monthly Precipitation (Inches)
August	1965	2.55
September	1965	3.24
October	1965	1.71
November	1965	2.18
December	1965	0.47
January	1966	3.71
February	1966	4.74
March	1966	2.09
April	1966	5.47
May	1966	3.42
Total		29.58