ENVIRONMENTAL INFLUENCE ON POSTEMERGENCE CHEMICAL CONTROL OF CRABGRASS (*Digitaria* spp.) IN TURF

by

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(ABSTRACT)

The influence of environment on efficacy of postemergence herbicides was quantified. A three-fold approach included: first, use of field test sites to select an herbicide sensitive to environmental conditions; second, quantify herbicide responses to temperature, moisture, and morphological conditions; and third, conduct laboratory research to determine if differential uptake, translocation, or metabolism would account for these responses to the environment.

Section one of the research was designed to determine if field research can be used to detect herbicides sensitive to environmental influences. Herbicides compared were: imazaquin, BAS 514 and tridiphane to fenoxaprop-ethyl (the cool-season herbicide standard) for postemergence control of large crabgrass (*Digitaria sanguinalis*) in Kentucky bluegrass (*Poa pratensis*) and bermudagrass (*Cynodon dactylon*) turf. BAS 514 was significantly influenced by variable environment.

Section two of the research studied control of southern crabgrass (Digitaria ciliaris) by BAS 514 as influenced by morphological and physiological factors. BAS 514 efficacy was influenced by crabgrass growth stage, air temperature, and irrigation level. Flowering crabgrass plants were the most tolerant, while preemergence and true-leaf stages were the most sensitive. Plants held at soil moisture levels near saturation and 25° C were the most sensitive to BAS 514. BAS 514 was not effective against plants grown at low moisture levels and 15° or 35° C.

Section three of the research compared the uptake, distribution, and metabolism of ^{14}C BAS 514 in southern crabgrass and Kentucky bluegrass plants, a sensitive and non-sensitive species. Foliar applied BAS 514 was rapidly absorbed by both species. Uptake and partitioning was similar in both species from 0.5 to 32 h, but different at 128 h, with bluegrass more uniformly distributing the herbicide. Metabolism of BAS 514 was low with only 3% metabolism in both species. Uptake, distribution, and metabolism apparently are not involved in differential sensitivity to BAS 514.

Field research can be used to select an herbicide sensitive to environmental influences. Temperature and soil moisture influenced the herbicidal activity of BAS 514. Uptake, translocation and metabolism did not appear to influence selectivity of this herbicide.

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INTRODUCTION

Introduction.

Maintaining a fine quality turf requires the exclusion or control of weeds, diseases, and insects. One prevalent turf weed problem is caused by three common grass species, large crabgrass [Digitaria sanguinalis (L.) Scop.] (11, 14), smooth crabgrass [Digitaria ischaemum (Schreb. ex. Schweig.) Schreb. ex. Muhl.], and southern crabgrass [Digitaria ciliaris (Retz) Koel]. These short-day, annual weeds are reported to be a problem throughout the United States (14) and world wide (15). These plants are invader species, prolific seed producers, aggressive competitors, and serve as alternate hosts for several nematode species and diseases (14).

Turfgrass is considered by some agricultural chemical companies to be the third most valuable crop in the United States[1]. Discussions with members of the turf industry indicate that over $800 million dollars were spent on pesticides and fertilizers for turf in 1989. Herbicides accounted for approximately one quarter of the total dollars. Of the total amount spent on herbicides, it is estimated that 68% of the total was for preemergence grass herbicides.

[1] Personal communications with representatives of B.A.S.F., Monsanto, and American Cyanamid Companies.

Current practices to control crabgrass are based upon the use of preemergence herbicides. Generally, preemergence materials are very effective; but they must be applied prior to germination of crabgrass seeds, because they provide little or no control of emerged seedlings. Since crabgrass seeds can germinate over a four- to five-month period, repeated applications of herbicides that have short residual activity is required. Several factors can influence the consistency of preemergence herbicide activity: application technique, timing, temperature, soil moisture, light, and levels of weed seed in the soil.

The most widely recommended preemergence crabgrass herbicides include benefin [N-butyl-N-ethyl-2,6-dinitro-4-(trifluoromethyl)benzenamine], bensulide [O,O-bis(1-methylethyl)-S-[2-phenylsulfonyl)amino]ethyl] phosphoro-dithioate], oryzalin [4-dipropylamino)-3,5-dinitro benzene-sulfanomide], oxadiazon [3-[2,4-dichloro-5-(1-methyl-ethoxy)-phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one], pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitro-benzenamine], and trifluralin [2,6-dinitro-N,N-dipropy-4-(trifluororomethyl)benzenamine]. These preemergence herbicides are poorly translocated, have little foliar uptake, and are active only on germinating seeds or seedlings (38). The majority of these compounds interfere with cellulose microfibril formation and orientation, reducing cell division and cell wall biosynthesis.

The organic arsenical herbicides are registered for postemergence large crabgrass control but, can injure warm-season turf and requirement multiple applications (6). Fenoxaprop-ethyl is the only postemergence herbicide presently registered for large crabgrass control in cool- and warm-season turf (6).

Herbicides that could effectively control crabgrass plants postemergence would allow increased flexibility in a turf weed control program and reduce the prophylactic use of herbicides. Postemergence crabgrass herbicides have the potential to reduce herbicide usage and lessen the potential environmental complications. They would not be applied in a prophylactic manner, could be used to treat only the problem areas, have lower soil activity, do not move as readily in the soil, and are generally applied at lower rates per acre than preemergence herbicides.

Many researchers have published articles concerning the influence of the plant environment on herbicidal efficacy. While it is generally accepted that herbicides behave differently in various environments, there is presently no accepted method for testing the differential responses. This research addresses one method of comparing variability of location response using four postemergence grass herbicides for control of large crabgrass, a common weed in turf.

Literature review.

From 1980 to 1989, over 25 articles concerning environmental effects on herbicide efficacy have been published by Weed Science. The conditions evaluated were plant water relations, growth stage, rainfall, temperature, relative humidity, time of day of application, and light level and quality. Based on the literature, responses observed in the field, and equipment available, it is proposed that the two most appropriate environmental factors to investigate are air temperature and leaf water potential as related to soil moisture.

Plants respond to environmental stress in a number of ways. Some stresses lead directly to plant death. Other stresses injure the plant, leading to reduced plant growth, but not directly cause death (23). For example, very low or high temperatures can lead to rupturing of the plasmalemma and loss of cellular integrity (resulting in death), while chilling temperatures can reduce or inhibit plant processes, but not fatally (23). Moderate levels of drought stress do not cause immediate plant death and have been linked to a number of plant responses (24).

Chilling injury can occur at moderate temperatures: as high as 15° C for flowering rice (Oryza sativa L.) (1). Chilling injury can occur due to metabolic disturbances, alterations to membrane permeability, and enzyme energy of activation (26), and inactivation of membrane-bound enzymes

(26). Membrane bound enzymes may be influenced by changes in membrane permeability or fluidity and hydrophobic bonding between lipids and the enzyme. Free-radical formation has also been shown with a number of species and has the potential of releasing cellular contents.

High temperature stress has been attributed to heat-induced drought injury, starvation, inhibition of biosynthetic pathways, and protein breakdown (23). All of these factors are influenced by the duration of exposure to these temperatures. Heat-induced drought stress has been shown in bentgrass that was desiccated under prolonged heat stress (21).

Plant starvation occurs above the temperature compensation point, when respiration is greater than photosynthesis. Starvation is due to a combination of factors such as reduced photosynthesis, altered translocation of photoassimilates, photo-oxidation of chloroplasts, reduced activity of RuBP carboxylase, and reduction in ADP and ATP. Chlorophyll accumulation was retarded in watermelon (Calocynthis citrullus) seedlings after exposure to 35-45° C for 4-24 h in darkness (23). Reductions in protein concentrations have been attributed to an increase in protein turnover or a reduction in synthesis. Tobacco leaves subjected to 50° C temperatures displayed normal yellowing (aging) of affected tissue which was reversible with the addition of kinetin (16). Lipid and β glucan synthesis in

bean plants (Phaseolus vulgaris L.) was inhibited by dipping in water at 47° C for 2 minutes. Leaf growth was inhibited at 12 h, recovering by 24 h. The heat shock produced a severe inhibition of synthesis of β-1,4-glucosyl glycosidic linkages and stimulated β-1,3-linkage synthesis (23). Membrane peroxidation especially of unsaturated fatty acids, has also been implicated in high temperature stress.

Plant responses to drought include growth inhibition, stomatal closure, and decreased intercellular space (17, 24). Drought stress can lead to reduced turgor pressure and cell enlargement. Cell elongation appears to be more sensitive to drought stress than photosynthesis (7). Drought stress, through its control of stomatal closure, has been shown to reduce photosynthesis and respiration in tomato, but in loblolly pine seedlings drought stress reduces photosynthesis while increasing respiration (8). In herbaceous species, a reduction in available water leads to a reduction in intercellular space and area of contact between cells, affecting the normal flow of gases within the leaf. Sunflower leaves have shown a 50% decrease in intercellular space in response to water deficiency (25).

Current work on the interaction of air temperature and herbicides has suggested that, within the physiological range, temperatures will produce effects within a biologically expected range (9, 12, 13, 19, 20, 28, 29, 30, 31, 33, 34, 36, 37, 39, 40). This means that for every 10° C increase in

temperature, physiological processes will increase 2.0 to 2.25 times. Both glyphosate and chlorsulfuron are influenced by air temperature for efficacy of grass control (9, 20).

Plant water potential serves as an accurate and easily obtained measurement of the water balance in a plant. From 1980 to 1989, at least nine different articles have been written on the subject of herbicide action as influenced by plant water relations (2, 3, 10, 19, 20, 22, 28, 31, 34). Work with wild oat (Avena fatua L.) (3), quackgrass (Agropyrons repens (L.) Beauv.) (3, 20), yellow foxtail [Setaria lutescens (Weigel) Hubb.] (10), littleseed canarygrass (Phalaris minor Retz.) (10), and barnyardgrass (Echinochloa crus-galli (L.) Beauv.) (10), have all demonstrated increased herbicidal activity with higher soil moisture levels. In general, these articles demonstrate that the activity of an herbicide is influenced by the water available to the plant.

Stage of growth of a plant can also have a strong influence on its sensitivity to an herbicide. Research with several herbicides for control of barnyardgrass (2) and fluazifop-butyl for control of quackgrass (19) indicates that younger plant growth stages are more sensitive to herbicides than are older plants.

Rainfall can directly influence soil moisture as well as affect how much herbicide is left on plant leaves. Six recent articles have suggested that rainwater can wash off herbicides

before they have been adequately taken up by the plant (4, 12, 13, 27, 30, 31).

The influence of relative humidity on efficacy of postemergence herbicides has been examined by several researchers. In general, their results suggest a positive correlation between increasing relative humidity and herbicide efficacy (13, 30, 31, 33, 39, 40).

Retzinger and Nalewaja (32) examined the influence of time of day on difenzoquat control of wild oat. Using field and growth chamber results, their research indicated a time of day and temperature optimum for difenzoquat activity.

Research on herbicide response to light suggests a positive correlation between light levels and herbicide response. Some of the research indicates that the overall herbicide efficacy was influenced (36, 37). Other research suggests that translocation was influenced while uptake was not (19).

The four herbicides evaluated in this research were: fenoxaprop-ethyl, (+/-)-2-[4-[(6-chloro-2-benzoxazolyl) oxy]phenoxy]propanoic acid; imazaquin, 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-4-oxo-1H-imidazol-2yl]-3-quinolinecarboxylic acid; BAS 514, 3,7-dichloro-8-quinolinecarboxylic acid; and tridiphane, 2-(3,5-dichlorophenyl)-2-(2,2,2-trichloroethyl)oxirane. No reports have been published concerning their response to environmental factors. The mode of action of BAS 514 has not been reported.

Fenoxaprop-ethyl interferes with lipid synthesis (38). Imazaquin inhibits the acetohydroxy acid synthase enzyme that controls the production of valine, leucine and isoleucine (38). Tridiphane, when applied alone, acts as a meristematic inhibitor (38).

OBJECTIVES

The overall objectives of this dissertation research were three fold. First, to design a series of experiments to select an environmentally sensitive herbicide for postemergence selective control of crabgrass in turfgrass. Second, to test the selected herbicide to quantify its herbicidal efficacy for crabgrass control under different plant growth stages, air temperatures, and irrigation levels. Third, to determine the role of uptake and movement in selectivity of this herbicide. This was accomplished by comparing the uptake, translocation, and metabolism of BAS 514 in sensitive and non-sensitive plant species.

Influence of variable environments.

The first objective of this section of the dissertation was to determine if field data could be used to select an herbicide that was significantly influenced by variable environments. The second objective was to compare fenoxaprop-ethyl (the herbicide standard) to BAS 514, imazaquin, and tridiphane for turf safety and control of large crabgrass.

Turf was selected as an experimental situation because of its uniformity of leaf area, root volume, water use, and potential for competition. Large crabgrass is a short-day, annual weed indigenous to Virginia (11, 14) and a problem throughout the United States (14) and the world (15). Because Virginia is a state with a wide diversity of environmental, topographic, and soil conditions, most herbicides do not provide consistent, season-long control of large crabgrass throughout the state[2].

Influence of growth stage, temperature, and moisture.

While many herbicides are available for the preemergence control of crabgrass species in turf, the availability of postemergence herbicides is limited. One promising new herbicide for the postemergence control of crabgrass species is BAS 514 (18). BAS 514 has been shown to control barnyardgrass in rice (5, 27).

Several articles have been written concerning the influence of morphological and environmental factors on herbicidal efficacy. BAS 514 has never been adequately evaluted for its response to plant growth stage, air temperature, and irrigation level on the control of southern crabgrass plants. Kentucky bluegrass was included in the growth stage research to evaluate the safety of the herbicide

[2] Personal communication, Dr. S. W. Bingham.

for control of southern crabgrass in turf.

Uptake, translocation, and metabolism studies.

Previous sections have described the ability of BAS 514 to selectively control grass weeds in a grass crop, barnyardgrass in rice (27), and crabgrass in Kentucky bluegrass turf. The objectives of this portion of the research were to determine the influence that differential uptake, translocation and metabolism have in determining the selectivity of BAS 514 for control of crabgrass in Kentucky bluegrass turf.

Experiments were designed to compare the uptake and translocation of BAS 514 in southern crabgrass and Kentucky bluegrass from 0 to 128 h after application. Percent uptake, partitioning into each plant part and exudation from the roots were determined. Additional work was conducted to look at the level of metabolism of BAS 514 by both species at 128 h. This time was determined to allow maximum uptake and translocation of the herbicide.

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CHAPTER I

SELECTION OF HERBICIDES WITH EFFICACIES SENSITIVE TO VARIABLE ENVIRONMENTS

ABSTRACT. This research was designed to determine if field research can be used to detect herbicides sensitive to the physical and biological factors at a site that affect plant growth. In addition, it was designed to compare three herbicides: imazaquin, BAS 514 and tridiphane to fenoxaprop-ethyl for postemergence control of large crabgrass in Kentucky bluegrass and bermudagrass turf. BAS 514 efficacy was significantly influenced by variable environments. BAS 514 appeared equal to fenoxaprop-ethyl in terms of turf quality, phytotoxicity to the turf, large crabgrass control ratings, and large crabgrass standcounts as a second measure of control. Imazaquin reduced turf quality and was phytotoxic to both turf types, and did not adequately control large crabgrass. Tridiphane also caused low quality turf and did not control the large crabgrass.

Nomenclature: fenoxaprop-ethyl, (+/-)-2-[4-[(6-chloro-2-benzoxazolyl) oxy]phenoxy]propanoic acid; imazaquin, 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-4-oxo-1H-imidazol-2yl]-3-quinolinecarboxylic acid; BAS 514, 3,7-dichloro-8-quinolinecarboxylic acid; tridiphane, 2-(3,5-dichlorophenyl)-2-(2,2,2-trichloroethyl)oxirane; bermudagrass, Cynodon

dactylon (L.) Pers. #[1] CYNDA; large crabgrass, Digitaria sanguinalis (L.) Scop. # DIGSA; Kentucky bluegrass, Poa pratensis L. # POAPR. Additional index words. Environmental effects, crabgrass control, BAS 090, X-77.

INTRODUCTION

For use in this research, environmental variables refers to all environmental factors of a physical and biological nature that have an influence on plant growth and development. Many researchers have published articles concerning the influence of the plant environment on herbicidal efficacy. Factors such as temperature (7, 10, 14), plant water status (1, 5, 10, 17), relative humidity (7, 15, 16, 20), and light level (10, 18, 19) have all been shown to influence herbicide efficacy. While it is generally accepted that herbicides behave differently in various environments, there is presently no accepted method of testing the differential responses.

This research addresses one method of comparing variability of herbicide efficacy in response to variable environments using four postemergence grass herbicides for control of large crabgrass [Digitaria sanguinalis (L.) Scop.], a common weed in turf. Turf was selected as an experimental

[1]Letters following this symbol are a WSSA-appproved computer code from Composite List of Weeds. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

situation because of its uniformity of leaf area, root volume, water use, and potential for competition. Large crabgrass is a short-day, annual weed indigenous to Virginia (6, 8) and a problem throughout the United States 87) and the world (9). Because Virginia is a state with a wide diversity of environmental, topographic, and soil conditions, most herbicides do not provide consistent season-long control of large crabgrass throughout the state (2).

Current practices to control crabgrass utilize preemergence herbicides. Generally, preemergence materials are very effective, but they must be applied prior to germination of crabgrass seeds. They are most effective when weeds germinate in one or two flushes, but they provide no control of emerged seedlings. Since crabgrass seeds can germinate over a four- to five-month period, herbicides that have short residual activity must be applied repeatedly.

The organic arsenical herbicides have long been registered for postemergence large crabgrass control, but their potential for turf injury and requirement for multiple applications make them less desirable for turf work. Fenoxaprop-ethyl is presently the only postemergence herbicide registered for large crabgrass control in cool-season turf that does not exhibit the limitations of the organic arsenicals. Additional herbicides that could effectively control crabgrass plants as postemergence treatments without the limitations of the organic arsenicals would allow

increased flexibility in a turf-weed control program.

The first objective of this research was to determine if field data could be used to select an herbicide that was significantly influenced by variable environments. The second objective was to compare fenoxaprop-ethyl to three herbicides for turf safety and control of large crabgrass. Four sites were used; two were warm-season and two were transition zone sites. An herbicide that performs well under a variety of environmental conditions would be desirable for crabgrass control in a state like Virginia. Alternately, if an herbicide exhibited good crabgrass control in some sites but not others it may be necessary to study the compound further, so that its usage may be optimized.

MATERIALS AND METHODS

Environmental variables encompasses factors that contribute to plant growth that include competition between crop and weed species, ambient temperature, elevation, available water, and soil factors such as soil type, percentage organic matter, and pH. Field sites were selected to provide variations in such factors. Experiments were conducted at transition-zone and warm-season sites in 1987 and 1988 (Table 1.1). The transition-zone sites were at Blacksburg, VA. The warm-season sites were at Baskerville, VA, in 1987 and Kenbridge, VA, in 1988. Site KB87, the

transition-zone site in 1987, was an established Kentucky bluegrass turf on a Groseclose loam (clayey, mixed, mesic typic Hapludalfs) with a pH of 5.1 and an organic matter content of 3.1%. Site KB88, the transition zone site in 1988, was an established Kentucky bluegrass turf on a Groseclose loam with a pH of 5.0 and an organic matter content of 2.5%. Sites B87 and B88, the warm-season sites, were in established bermudagrass turf. The 1987 site at Baskerville was underlain by an Appling sandy loam (clayey, koaolinitic, thermic typic Hapludult) with a pH of 6.7 and an organic matter content of 1.9%. Site B88, the 1988 warm-season site at Kenbridge, was also underlain by an Appling sandy loam with a pH of 6.2 and an organic matter content of 2.1%. Rainfall was below the 10-year average for both sites in 1987. Efficacy of crabgrass control by fenoxaprop-ethyl has shown sensitivity to drought stress (3).

Treatments of the Kentucky bluegrass sites, KB87 and KB88, were on 18 July 1987 and 14 July 1988, respectively. Treatments of the bermudagrass sites, B87 and B88, were on 19 June 1987 and 23 June 1988, respectively. Treatments were applied to 1.8 by 1.8 m plots using a randomized complete block design with four replications. The treatments were applied with a CO_2 backpack sprayer with a pressure of 210 kPa, using 8003VS flat fan nozzle tips[2] to apply 280 L/ha.

[2]Spraying Systems Co., North Ave., Wheaton, IL 60187.

Large crabgrass at all sites was treated in the two- to five-true leaf stage of development. Herbicide rates were selected to cover the range of use rates for turf and consisted of fenoxaprop-ethyl at 0.14 and 0.28 kg ai/ha, imazaquin at 0.28 and 0.56 kg ai/ha with 0.25% v/v X-77[3] surfactant, BAS 514 at 0.56 and 1.12 kg ai/ha with 0.6% v/v BAS 090[4] surfactant, and tridiphane at 1.12 and 2.24 kg ai/ha.

Visual ratings were taken at 2 and 6 weeks after herbicide treatment for turf quality, turf phytotoxicity, and large crabgrass control. Turf quality was rated on a 1 to 9 scale, where 6 and above is considered acceptable quality. Turf phytotoxicity was rated on a 0 to 10 scale, where 0 is no injury and 10 is complete loss of the desireable turf species. Large crabgrass control was rated on a 0 to 100 scale, where 0 is no control and 100 is complete control of the weed. Large crabgrass plants were counted in a 1.25- by 1.25-m area in the center of the treated plots at 6-weeks after herbicide treatment.

Data from each site were analyzed separately since the sample variances between the two sites and the 2 years were significantly different (4). Data from all visual observations were transformed using an arcsine transformation

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[3] Chevron Chem. Co., San Francisco, CA 94119. Alkylaryl-polyoxyethylene glycols, free fatty acids, and isopropanols are the major functioning agents.

[4] Undisclosed chemistry, B.A.S.F. Corp., 100 Cherry Hill Rd., Parsippany, NJ 07054

(21) before analysis, but means were transformed back for presentation. Data for the high and low rates of individual herbicides were combined and compared to high and low rates of fenoxaprop-ethyl using orthogonal contrasts at the 0.05 level (11). Fenoxaprop-ethyl was used as the standard of comparison because it is the most effective registered herbicide on cool-season turf for large crabgrass control. Fenoxaprop-ethyl's safety and efficacy is evidenced by its sales volume to the turf industry.

One of the research objectives was to determine differences in variability due to site quality. After testing for normality of population variances, the data were subjected to a multiple range test for comparison of variances. Comparisons of the variability between sites for each herbicide over all concentrations were performed using multiple comparisons between the log-transformed variances following the methods of Levy (12, 13).

RESULTS AND DISCUSSION

Kentucky bluegrass sites. At site KB87, the turf quality at 2 weeks demonstrated that all herbicide treatments had a positive effect on turf appearance and that the three new chemicals were equal to fenoxaprop-ethyl in this regard (Table 1.2). At 6 weeks, imazaquin-treated and the control plots had lower quality than fenoxaprop-ethyl. At site KB88, turf

quality ratings taken at 2 and 6 weeks showed that only fenoxaprop-ethyl and BAS 514 had improved turf quality.

Turf phytotoxicity ratings taken at site KB87 revealed no phytoxicity problems with any of the treatments at the 2- or 6-week ratings (Table 1.2). At site KB88, the 2-week phytotoxicity rating suggested that imazaquin did cause some injury. By the 6-week rating, the turf had recovered and no differences were seen.

Control of large crabgrass at KB87 at 2 weeks suggested that the best control occurred with fenoxaprop-ethyl and BAS 514 (Table 1.3). The 6-week rating revealed that fenoxaprop-ethyl, BAS 514 or tridiphane provided equal control. The site KB88 ratings at 2 and 6 weeks showed that fenoxaprop-ethyl and BAS 514 afforded the highest level of large crabgrass control and were not different from each other.

Counts of large crabgrass at site KB87 and KB88 revealed that fenoxaprop-ethyl, BAS 514, and tridiphane were equivalent (Table 3). Imazaquin was not as effective at either site.

Bermudagrass sites. Site B87 had no differences in turf quality at 2 or 6 weeks after treatment (Table 1.4). At site B88, turf quality at 2 and 6 weeks suggested fenoxaprop-ethyl and BAS 514 provided the highest quality.

Turf phytotoxicity ratings taken at 2 weeks at site B87 revealed all herbicide treatments caused a moderate level of phytotoxicity, with the untreated control being safer than

fenoxaprop-ethyl (Table 1.4). The 6-week rating indicated no phytotoxicity from any treatment. The site B88 data again indicated a moderate level of turf phytotoxicity at the 2-week rating with imazaquin and the untreated control displaying lower injury than fenoxaprop-ethyl. The 6-week rating showed no injury present. This agrees with the 1987 data suggesting that 6 weeks were sufficient time for the bermudagrass to recover.

Control ratings of large crabgrass at site B87 at 2 weeks demonstrated relatively poor control from all treatments, with no difference between fenoxaprop-ethyl and untreated control or any other chemical (Table 1.5). The 6-week rating suggested that all treatments were different from fenoxaprop-ethyl, with imazaquin and BAS 514 giving better control of crabgrass while tridiphane gave less. At site B88, 2-week large crabgrass control data suggested that fenoxaprop-ethyl provided less control than BAS 514. The 6-week rating indicated that fenoxaprop-ethyl and BAS 514 provided the highest level of large crabgrass control.

Large crabgrass standcounts at site B87 indicated the lowest final populations followed treatment with fenoxaprop-ethyl, imazaquin, and BAS 514 (Table 1.5). The site B88 data show that all herbicide treatments were equally effective in controlling final populations.

Based on all the criteria tested: (turf quality, phytotoxicity, crabgrass control ratings and crabgrass

standcounts) the best treatments for the bluegrass and bermudagrass sites were fenoxaprop-ethyl and BAS 514.

Variable environments. The variability of the data presented suggested that location influenced both phytotoxicity and control of large crabgrass. This is reinforced by the fact that the variances for crabgrass control ratings were significantly different between the four experimental sites. Since it was therefore not appropriate to combine experiments and make comparisons across sites, one alternative method was to perform multiple comparisons of the variances of each treatment across sites (Table 1.6). By comparing variances, it was possible to determine which herbicide was most sensitive to site quality. No significant differences in variances between sites were seen with fenoxaprop-ethyl, imazaquin, or tridiphane; however, BAS 514 and the non-treated control had significant differences. This suggests that BAS 514 was more sensitive to site quality than the other herbicides and that field testing was able to detect this difference. Use of this type of analysis might be employed to select herbicides for controlled environment work to look at the influence that site has on herbicide efficacy.

This research suggests that BAS 514 can provide efficacious control of crabgrass in turf. BAS 514 and fenoxaprop-ethyl were shown to be equal in terms of turf quality, phytotoxicity, crabgrass control ratings and number

of crabgrass plants. Since BAS 514 demonstrates sensitivity to site quality, it may be necessary to conduct further research on environmental influences, so that this herbicide may be used most effectively.

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Table 1.1. Site characteristics for test locations.

Location & Turf Type		Elev.	Temp.[a] Min	Temp.[a] Max	Soil Type	pH	OM
		(m)	---(°C)---				(%)
KB87	Blacksburg bluegrass	610	15.5	32.9	clayey loam	5.1	3.1
KB88	Blacksburg bluegrass	620	16.7	33.9	clayey loam	5.0	2.5
B87	Baskerville bermudagrass	76	18.3	33.9	sandy loam	6.7	1.9
B88	Kenbridge bermudagrass	137	15.5	36.7	sandy loam	6.2	2.1

[a]Average temperature for the duration of the experiment.

Table 1.2. Influence of four herbicides on turf quality and phytotoxicity at Kentucky bluegrass sites[a].

	Location			
	KB87		KB88	
	Weeks After Application			
Herbicide	2	6	2	6
	----- Turf Quality[b] (1-9) ------			
fenoxaprop	5.8[c]	5.8	6.5	7.4
imazaquin	5.6	4.5*	5.3*	5.5*
BAS 514	5.9	5.8	6.9	7.5
tridiphane	5.6	5.6	5.9*	6.3*
none	4.5*	4.3*	5.0*	5.0*
	----- Phytotoxicity[d] (0-10) ----			
fenoxaprop	0.0	0.6	0.1	0.4
imazaquin	0.3	1.6	1.9*	0.0
BAS 514	0.4	0.4	0.4	0.0
tridiphane	0.5	0.6	0.5	0.1
none	0.3	1.5	0.0	0.0

[a] Herbicide rates used (kg ai/ha) were: BAS 514 0.56 & 1.12, fenoxaprop-ethyl 0.14 & 0.28, imazaquin 0.28 & 0.56, and tridiphane 1.12 and 2.24.

[b] Turf quality is a 1 to 9 rating, where 6 and above are considered acceptable quality.

[c] Each number is the average for the high plus low concentration of each herbicide. Fenoxaprop-ethyl is contrasted with the other treatments at the .05 level. Asterisks within a column indicate significant difference from fenoxaprop-ethyl.

[d] Turf phytotoxicity is a 0 to 10 rating where 0 is no toxicity and 10 is complete loss of the turf.

Table 1.3. Influence of four herbicides on large crabgrass control and standcounts at Kentucky bluegrass sites[a].

	Location			
	KB87		KB88	
	Weeks After Application			
Herbicide	2	6	2	6
	---- Crabgrass control[b] (%) ----			
fenoxaprop	93[c]	86	98	91
imazaquin	46*	38*	30*	13*
BAS 514	65	83	100	87
tridiphane	58*	75	65*	50*
none	0*	5*	0*	0*
	-- Crabgrass standcounts (#/m^2) --			
fenoxaprop		1		1
imazaquin		6*		21*
BAS 514		2		3
tridiphane		5		9
none		20*		25*

[a] Herbicide rates used (kg ai/ha) were: BAS 514 0.56 & 1.12, fenoxaprop-ethyl 0.14 & 0.28, imazaquin 0.28 & 0.56, and tridiphane 1.12 and 2.24.

[b] Large crabgrass control is a 0 to 100 rating, where 0 is no control and 100 is complete control of the weed.

[c] Each number is the average for the high plus low concentration of each herbicide. Fenoxaprop-ethyl is contrasted with the other treatments at the .05 level. Asterisks within a column indicate significant difference from fenoxaprop-ethyl.

Table 1.4. Influence of four herbicides on turf quality and phytotoxicity at bermudagrass sites[a].

	Location			
	KB87		KB88	
	Weeks After Application			
Herbicide	2	6	2	6
	----- Turf Quality[b] (1-9) ------			
fenoxaprop	5.8[c]	5.3	6.0	6.8
imazaquin	6.8	5.6	4.9*	5.1*
BAS 514	5.4	5.4	6.1	7.1
tridiphane	5.6	5.4	5.3*	5.5*
none	4.5	4.8	4.8*	4.8*
	----- Phytotoxicity[d] (0-10) ----			
fenoxaprop	2.0	0.0	4.1	0.0
imazaquin	1.6	0.0	1.1*	0.0
BAS 514	1.6	0.0	3.0	0.1
tridiphane	1.6	0.0	4.5	0.1
none	0.0*	0.0	0.3*	0.0

[a] Herbicide rates used (kg ai/ha) were: BAS 514 0.56 & 1.12, fenoxaprop-ethyl 0.14 & 0.28, imazaquin 0.28 & 0.56, and tridiphane 1.12 and 2.24.

[b] Turf quality is a 1 to 9 rating, where 6 and above are considered acceptable quality.

[c] Each number is the average for the high plus low concentration of each herbicide. Fenoxaprop-ethyl is contrasted with the other treatments at the .05 level. Asterisks within a column indicate significant difference from fenoxaprop-ethyl.

[d] Turf phytotoxicity is a 0 to 10 rating where 0 is no toxicity and 10 is complete loss of the turf.

Table 1.5. Influence of four herbicides on large crabgrass control and standcounts at bermudagrass sites[a].

	Location			
	KB87		KB88	
	Weeks After Application			
Herbicide	2	6	2	6
	---- Crabgrass control[b] (%) ----			
fenoxaprop	49	48	66	83
imazaquin	14	73*	29*	23*
BAS 514	45	73*	89*	84
tridiphane	11	25*	59	52*
none	0	0*	3*	5*
	-- Crabgrass standcounts (#/m^2) --			
fenoxaprop		13		9
imazaquin		9		5
BAS 514		7		5
tridiphane		20*		5
none		35*		25*

[a] Herbicide rates used (kg ai/ha) were: BAS 514 0.56 & 1.12, fenoxaprop-ethyl 0.14 & 0.28, imazaquin 0.28 & 0.56, and tridiphane 1.12 and 2.24.

[b] Large crabgrass control is a 0 to 100 rating, where 0 is no control and 100 is complete control of the weed.

[c] Each number is the average for the high plus low concentration of each herbicide. Fenoxaprop-ethyl is contrasted with the other treatments at the .05 level. Asterisks within a column indicate significant difference from fenoxaprop-ethyl.

Table 1.6. Comparison of large crabgrass control variances within each site due to each herbicide[a].

	Application Location			
Herbicide[a]	KB87	KB88	B87	B88
fenoxaprop	4.9	3.9	6.2	5.1
imazaquin	7.1	5.6	6.7	7.1
BAS 514	6.6B	3.2A	4.1AB	3.6A
tridiphane	5.5	5.4	6.3	4.1
none	6.9B	2.2A	6.0B	5.8B

[a] Analysis performed using Log transformed variances of each application site.

[b] Each number is the combined variance for the high plus low concentration of each herbicide. Variances within a row followed by the same letter are not significantly different at the 0.05 level.

CHAPTER II

INFLUENCE OF GROWTH STAGE, TEMPERATURE, AND IRRIGATION ON THE EFFICACY OF BAS 514 ON SOUTHERN CRABGRASS (*Digitaria ciliaris*)

Abstract. Control of southern crabgrass by BAS 514 as influenced by morphological, physical, and chemical factors were studied. This research indicated that BAS 514 efficacy was influenced by crabgrass growth stage. Flowering crabgrass plants were the most tolerant while preemergence and true-leaf stages were the most sensitive. Temperature and irrigation level also influenced crabgrass control. Plants held at moisture levels near soil saturation were the most sensitive to BAS 514. The optimum temperature for crabgrass control by BAS 514 was 25° C.

Nomenclature: BAS 514, 3,7-dichloro-8-quinolinecarboxylic acid; southern crabgrass, *Digitaria ciliaris* (Retz.) Koel. #-[1] DIGSP; Kentucky bluegrass, *Poa pratensis* L. # POAPR.

Additional index words. BAS 090, crabgrass control, environmental factors, herbicide, selectivity.

[1]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

INTRODUCTION

Many herbicides are available for preemergence control of crabgrass species in turf, however, the availability of postemergence herbicides is limited. One promising new herbicide for postemergence control of crabgrass species is BAS 514 (8), a quinolinecarboxylic acid type herbicide. BAS 514 has been shown to control barnyardgrass (Echinochloa crus-galli (L.) Beauv.) in rice (Oryza sativa L.) (12). One potential problem with BAS 514, as well as other postemergence grass herbicides is an apparent sensitivity to environmental effects[2].

Influences of the environment on herbicidal efficacy have been reported. Factors such as plant growth stage, temperature, and plant water status all influence herbicide efficacy. Research with several herbicides for control of barnyardgrass (1) and fluazifop-butyl for control of quackgrass (Agropyrons repens (L.) Beauv.) (9) indicates that plants in younger growth stages are more sensitive to herbicides than are older plants. Glyphosate uptake and movement in quackgrass has been shown to be influenced by air temperature (6, 10), and chlorsulfuron has caused less phytotoxicity to green foxtail (Setaria viridis (L.) Beauv.) at 30° C than at 10° or 20° C (13). Work with wild oat (Avena fatua L.) and quackgrass has demonstrated a positive

[2] Article submited to Weed Science November 1989.

correlation between soil moisture and diclofop-methyl activity (2). Diclofop-methyl has also shown sensitivity to soil moisture in control of yellow foxtail (Setaria lutescens (Weigel) Hubb.), wild oat , littleseed canarygrass (Phalaris minor Retz.), and barnyardgrass (7). High soil moisture has also been shown to increase the translocation of glyphosate in quackgrass (10).

This research was designed to determine how plants would respond to BAS 514 when treated under a range of morphological and physiological conditions. The specific objectives were to determine the influence of plant growth stage, air temperature, and irrigation on the control of southern crabgrass plants by BAS 514. Kentucky bluegrass was included in the growth stage research to evaluate the safety of the herbicide for control of southern crabgrass in Kentucky bluegrass turf.

MATERIALS AND METHODS

Growth stage experiments. Influence of plant growth stage on BAS 514 efficacy was studied during April and May of 1989 in a greenhouse at Blacksburg, VA. Average day/night temperatures were 35°/25° C, with noon ambient light levels of 650 μmol/m^2/sec. Kentucky bluegrass and southern crabgrass

plants[3] were grown in 7-cm pots using Appling sandy loam soil with a pH of 6.7 and an organic matter content of 1.9%. Soil was obtained from a home garden with no history of herbicide usage and acceptable fertility as indicated by laboratory analysis.

Treatments were applied with a CO_2 backpack sprayer set at 210 kPa, using 8003VS flat fan nozzle tips[4] to apply 280 L/ha. BAS 514 was applied at 70, 140, 280, 560, and 112 g ai/ha with the addition of 0.6% v/v BAS 090[5] surfactant. Growth stages for treatment of southern crabgrass plants were: preemergence to the plant, three- to five-true leaf, two- to four-tillers, and mature flowering plants. All pots except the preemergence treatments had a 1 cm layer of vermiculite on top of the soil to preclude root uptake. Preemergence treatments had ten seeds per pot; all other growth stage treatments had one plant per pot. Pots receiving preemergence treatments were seeded the day of treatment. Three- to five-leaf plants were approximately 43 days old when treated. Two- to four-tiller plants were 61 days old when treated. Flowering plants were approximately 96 days old at treatment. Kentucky bluegrass (cv. Plush) plants from an established 1.5 year old field planting were treated at the same time.

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[3] Azlin Seed Co., P.O. Box 914, Leland, MS 38756.

[4] Spraying Systems Co., North Ave., Wheaton, IL 60187.

[5] Undisclosed chemistry, BASF Corp., 100 Cherry Hill Rd., Parsippany, NJ 07054.

Kentucky bluegrass was planted on a Groseclose loam (clayey, mixed, mesic typic Hapludalfs) with a ph of 5.1 and an organic matter content of 3.1%. Plants from all growth stages were treated on the same day and harvested at 14 days.

Plants receiving preemergence treatments had fresh weights of 0.5 g at harvest. Three- to five-leaf plants had an average fresh weight of 0.9 g at harvest. Two- to four-tiller plants had an average fresh weight of 3.6 g at harvest. Flowering plants had an average fresh weight of 4.4 g at harvest.

Plants were excised 14 days after treatment and oven dried at 50° C for two days to determine dry weight. The experiment was designed as a randomized complete block with four replicates, and the experiment was repeated. Since sample variances between runs were not significantly different, runs were combined (5). Comparisons within each growth stage were made using single degree of freedom contrasts at the 0.05 level (11). Polynomial equations were calculated for each growth stage for the response of plant weight to herbicide concentration (Table 2.3) (11).

Another method of comparing sensitivity of plant growth stage is inhibitory 50 (I_{50}) values (4). I_{50} values indicate the herbicide concentration necessary to reduce plant weight by 50% and were used to measure relative herbicide efficacy at different growth stages. I_{50} values were analyzed by analysis of variance, and means separated using LSD at the

0.05 level of significance.

Temperature and irrigation experiments. Experiments to test the influence of temperature and soil moisture on efficacy of BAS 514 were conducted in a growth chamber (Rheem Model # CEC38-15HLE[6]) in 1989. A 14-h daylength was used with maximum light level of 700 μmol/m^2/sec. Day/night temperature regimes tested were 15°/10°, 25°/20°, and 35°/30° C. Herbicides were applied as above, with BAS 514 applied at 4.5, 22.4, 112, and 560 g ai/ha with 0.6% v/v BAS 090 surfactant. Plants were grown and treated as in the growth stage experiment, but all pots began with the same weight of soil when the water content was at saturation. Plants were irrigated from the upper soil surface only.

In order to provide a range of moisture levels, plants received one of five different irrigation levels either once or twice a day during the course of the experiment. The 15°/10° and 25°/20° C plants were watered once a day. The 35°/30° C run plants were watered twice a day. The irrigation levels tested were 100, 80, 60, 40, and 20, all expressed as a percentage of the amount of water that the saturated soil plants (100) received each day. The highest level of irrigation, designated 100, was maintained by weighing each pot and adding enough water to bring the soil back to

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[6] Rheem Manu. Co., Scien. Prod. Div., Asheville, NC 28801.

saturation. The lowest level of irrigation, designated 20, received only 20% of the volume of water that the field capacity plants received. Leaf water potentials from the leaf tip of the youngest fully expanded leaf were measured with a J-14 Press[7] and calibrated against a dewpoint psychrometer. Southern crabgrass plants were treated at the three- to five-true leaf stage. The irrigation levels span the physiological range of this species since some of the 20% irrigation level plants died due to lack of water in the 25° C run, and all 20% irrigation level plants died in the 35° C run.

Plants were equilibrated for 5 to 7 days prior to treatment in the growth chamber, harvested 14 days after treatment, and then weighed as described above. The experiment was designed as a randomized complete block with three samples per treatment and two runs. Data were subjected to an analysis of variance using temperature, water regime and herbicide concentration as main effects (11). Means were separated using LSD at the 0.05 level of significance. Polynomial regressions were calculated at each temperature regime for each irrigation levels for the response of plant weight to herbicide concentration (Table 2.6). A multiple regression equation was calculated for the factors of temperature, herbicide concentration and irrigation level (Table 2.6).

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[7] Decagon Devices, Inc., P.O. Box 835, Pullman, WA. 99163

RESULTS AND DISCUSSION

Growth stage experiments. Fresh and dry weights of southern crabgrass at all growth stages tested were significantly reduced by BAS 514 (Fig. 2.1 & 2.2). Kentucky bluegrass was tolerant to BAS 514 under these conditions, with no reduction in fresh and dry weight ($\alpha = 0.05$) (data not presented). All growth stages tested revealed a significant reduction in fresh and dry weight when BAS 514 was applied (Table 2.1). I_{50} values for plant fresh weight (Table 2.2) indicated that the most sensitive growth stages were preemergence and three-to five-true leaf, followed by two- to four-tiller and flowering plants. The dry weight data indicated that preemergence, three- to five-true leaf and two- to four-tiller growth stages were equally sensitive and flowering plants were the least sensitive stage. The herbicide concentration necessary to produce a 50% dry weight inhibition at each growth stage did not appear to be related to plant weight. For example, the dry weight I_{50} value for three- to five-true leaf stage was 50 g ai/ha with a calculated plant weight of 0.16 g, while the two- to four-tiller stage had an I_{50} of 30 g ai/ha and calculated weight of 0.8 g (as can be calculated from Figure 2.1 and Table 2.2). The flowering stage had an I_{50} value of 340 g ai/ha and calculated weight of 1.18 g. While the mode of action of BAS 514 in grasses is not known (3), the response

of southern crabgrass to BAS 514 at low concentrations appeared to be a reduction in the accumulation of dry matter even though fresh weight did not appear to be inhibited, suggesting that its mode of action is not related to transpiration processes. The flowering stage appeared to be the most tolerant, with this tolerance not directly related to plant weight. Quadratic and linear (data not presented) equations were poorly correlated for crabgrass weight response to BAS 514 concentration (Table 2.3).

Temperature and irrigation experiments. The plant fresh and dry weight data indicated that BAS 514 efficacy was significantly influenced by temperature, irrigation, and herbicide concentration, with an interaction of temperature and irrigation (Table 2.4). In addition, the dry weight data indicated a temperature by herbicide concentration interaction for BAS 514. Both fresh and dry weight data followed the same trends, and only the dry weight data are presented.

At all irrigation levels at 15° C, the lowest herbicide concentration tested reduced dry weight relative to the control (Fig. 2.4). Equal sensitivity at all irrigation levels to BAS 514 concentration may have occurred due to the moderate leaf water potentials in these plants (Table 2.5). At 25° C, the 100% and 80% irrigation level plants responded to herbicide concentration at 4.5 and 22.4 g ai/ha, respectively. The 40% irrigation level plants responded to

herbicide concentration at 11.2 g ai/ha, while the 60 and 20 irrigation level plants did not respond to herbicide concentration at all. At 35° C, the 100% irrigation level plants were the most responsive and were affected by 4.5 g ai/ha. The 80% and 40% irrigation level plants responded to herbicide concentration at 22.4 g ai/ha while the 60 irrigation level plants required 56 g ai/ha to produce a reduction in plant weight. The 20% irrigation level plants died due to water deficiency. Quadratic and linear (data not presented) equations were calculated for each temperature and irrigation level. These equations had a low correlation for crabgrass dry weight response to BAS 514 concentration (Table 2.6).

Leaf water potentials greater than -1.2 MPa appear to coincide with reduced efficacy of BAS 514 (Table 2.5 and 2.7). The data (Fig. 2.3) suggest that a temperature and irrigation optimum exists at 25° C and 80 to 100 irrigation levels. These irrigation levels produced a leaf water potential of -1.2 MPa. Because southern crabgrass is a warm-season annual, it may be that growth rate and herbicide activity are both well suited to a temperature of 25° C and leaf water potentials of -1.2 MPa. Stomatal conductance measurements were highest on the 25° C plants. This supports the idea of 25° C as an approximate temperature optimum for plant growth. The lowest reduction in plant dry weight due to BAS 514 occured at low irrigation levels for the 25° and 35° C plants.

All 35° C plants as well as some 25° C plants died at the 20% irrigation level due to drought stress suggesting that leaf water potentials at or below -3.0 MPa coincided with lethality in southern crabgrass. Plants at 15° C did not demonstrate this sensitivity to irrigation level. Plants at 15° C appeared to respond to BAS 514 in a similar manner regardless of the irrigation level they were grown under.

This research demonstrates that BAS 514 activity is influenced by several plant and environmental factors. Plant growth stage, ambient temperature, and irrigation all significantly influenced control of southern crabgrass. Southern crabgrass was shown to be most sensitive to BAS 514 at early growth stages, at 25° C, and a leaf water potential equal to or less than -1.2 MPa. Higher rates of BAS 514 may be required if the temperature is at 15° C or if the temperature is at 35° C accompanied by low levels of moisture.

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Table 2.1. Contrast analysis of influence of growth stage and BAS 514 concentration on efficacy of southern crabgrass control.

Treatment stage	Fresh weight	Dry weight
	-------- (Prob > F)	--------
Preemergence	.0001	.0005
Three- to five-true Leaf	.0001	.0001
Two- to four-tiller	.0001	.0008
Flowering	.006	.117

Table 2.2. Inhibitory$_{50}$ values for BAS 514 on four growth stages of southern crabgrass.

Growth stage	Fresh weight[a]	Dry weight
	---------- (g ai/ha) ----------	
Preemergence	6	7
Three- to five-true leaf	5	5
Two- to four-tiller	16	3
Flowering	34	18
LSD (0.05)	18	9

[a] I_{50} calculated for the herbicide concentration necessary to cause a 50% reduction in plant fresh and dry weight.

Table 2.3. Quadratic regressions for influence of concentration of BAS 514 (X) on crabgrass fresh and dry weight (Y).

Stage	Equation	R^2	Prob>F
	---------- (Fresh weight data) ----------		
Preemergence	$Y = .389 - 1.23\ X + .816\ X^2$	.60	.0001
3- to 5- true lvs	$Y = .599 - 1.82\ X + 1.23\ X^2$	.41	.004
2- to 4-tillers	$Y = 3.01 - 6.94\ X + 4.24\ X^2$	.55	.002
Flowering	$Y = 4.32 - 8.00\ X + 4.58\ X^2$	.50	.015
	---------- (Dry weight data) ----------		
Preemergence	$Y = .122 - .358\ X + .227\ X^2$	.35	.003
3- to 5- true lvs	$Y = .171 - .355\ X + .232\ X^2$	.28	.037
2- to 4-tillers	$Y = .87 - 1.36\ X + .887\ X^2$	.21	.082
Flowering	$Y = 1.42 - 1.84\ X + 1.23\ X^2$	.17	.104

Table 2.4. Probability values for statistical analysis of influence of temperature, irrigation, and BAS 514 concentration on efficacy of southern crabgrass control.

Factor	Fresh weight	Dry weight
	------ (Prob > F) ------	
Temperature	.0001	.0001
Irrigation Level	.0001	.0001
Herbicide Concentration	.0001	.0001
Temperature * Irrigation	.0001	.0001
Temperature * Herbicide	.205	.004
Irrigation * Herbicide	.45	.20
Temp. * Irr. * Herb.	.99	.71
Rep	.003	.67

Table 2.5. Average leaf water potentials[a] of southern crabgrass plants for each irrigation level.

Temperature day/night	Irrigation Level 20	40	60	80	100	LSD[b]
--- (°C) ---	----------	----------	-MPa	----------	----------	
15/10	3.0	1.1	1.0	0.7	0.7	0.4
25/20	3.0	1.5	1.5	1.2	1.2	0.4
35/30	4.0	1.8	1.6	1.1	1.1	0.2

[a] Leaf water potentials from leaf tip of youngest fully expanded leaf (n=3).

[b] Protected LSD at the 0.05 level of significance for comparison within a row.

Table 2.6. Polynomial regressions for each irrigation level and temperature regime describing influence of concentration of BAS 514 (X) on crabgrass dry weight (Y).

Temperature/ Irrigation	Equation	R^2	Prob>F
15/10° C			
20 %	$Y = .211 - .0008\ X + .0001\ X^2$	.41	.03
40 %	$Y = .214 - .0005\ X + .0000001\ X^2$	.13	.12
60 %	$Y = .211 - .0003\ X + .000004\ X^2$	.06	.56
80 %	$Y = .202 - .0002\ X + .000002\ X^2$	.11	.86
100 %	$Y = .245 - .0011\ X + .000002\ X^2$	.16	.07
25/20° C			
20 %	$Y = .047 - .000068\ X + .000008\ X^2$	.04	.69
40 %	$Y = .086 - .00004\ X + .0000024\ X^2$	.24	.06
60 %	$Y = .079 + .00012\ X + .0000003\ X^2$	.16	.22
80 %	$Y = .152 - .0082\ X + .000001\ X^2$	.48	.01
100 %	$Y = .161 - .0006\ X + .0000008\ X^2$	.42	.07
35/30° C			
20 %	[a]		
40 %	$Y = .113 - .00021\ X + .0000003\ X^2$	.10	.50
60 %	$Y = .152 - .00018\ X + .0000003\ X^2$	.02	.44
80 %	$Y = .185 - .00016\ X + .0000002\ X^2$	.04	.69
100 %	$Y = .242 - .00037\ X + .0000005\ X^2$	.10	.53

[a] All plants died due to drought stress.

Table 2.7. Multiple regression equation for influence of temperature (X_T), herbicide concentration (X_H), and irrigation level (X_I) on southern crabgrass dry weight.

Equation	R^2	Prob>F
$Y = .189 - .0025\ X_T - .015\ X_H + .0011\ X_I$	.30	.0001

Figure 2.1. Fresh weight per plant of southern crabgrass as influenced by growth stage and concentration of BAS 514 (n=6).

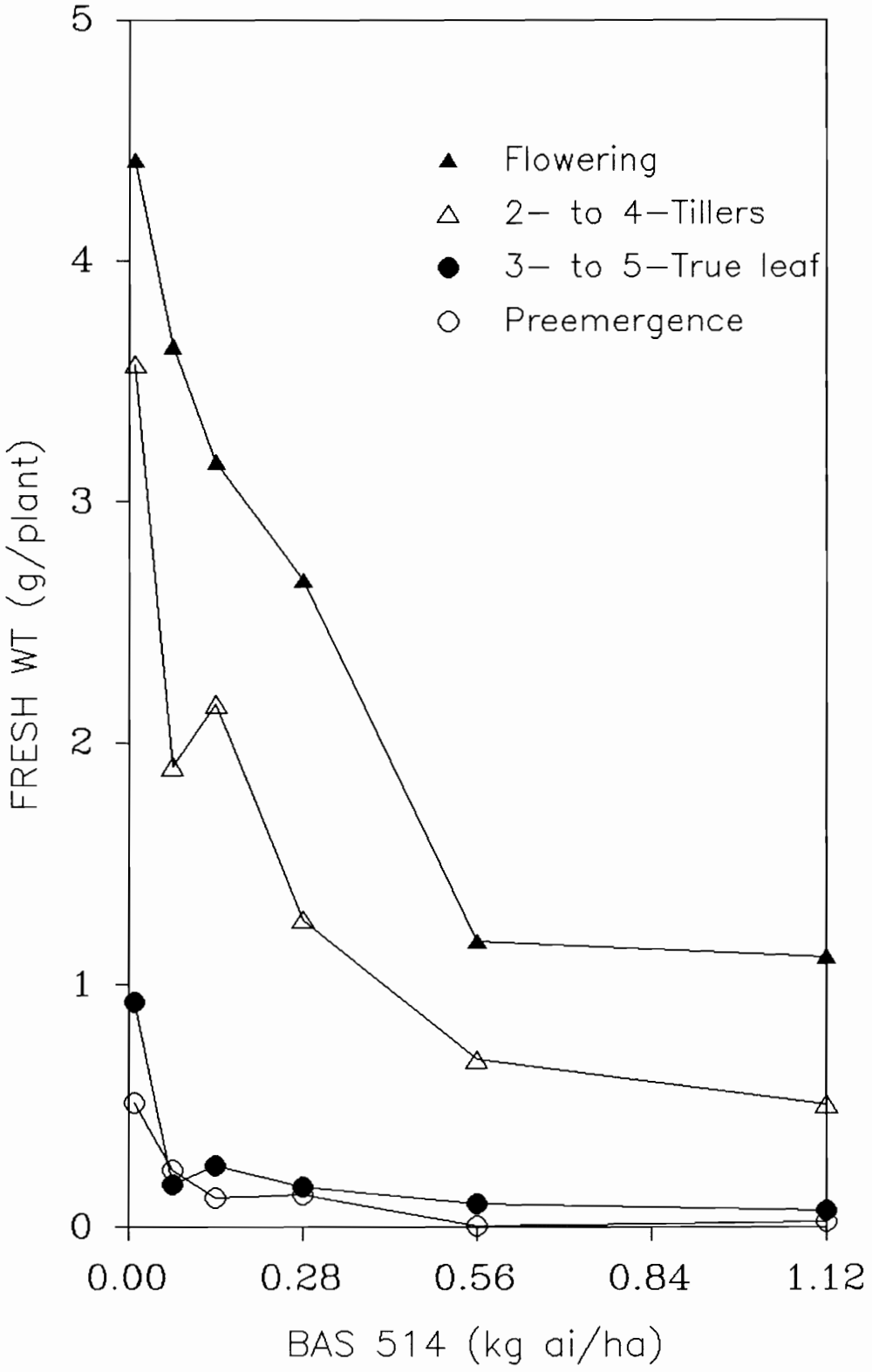

5
4
3
2
1
0
FRESH WT (g/plant)
Flowering
2– to 4–Tillers
3– to 5–True leaf
Preemergence
0.00
0.28
0.56
0.84
1.12
BAS 514 (kg ai/ha)

Figure 2.2. Dry weight per plant of southern crabgrass as influenced by growth stage and concentration of BAS 514 (n=6).

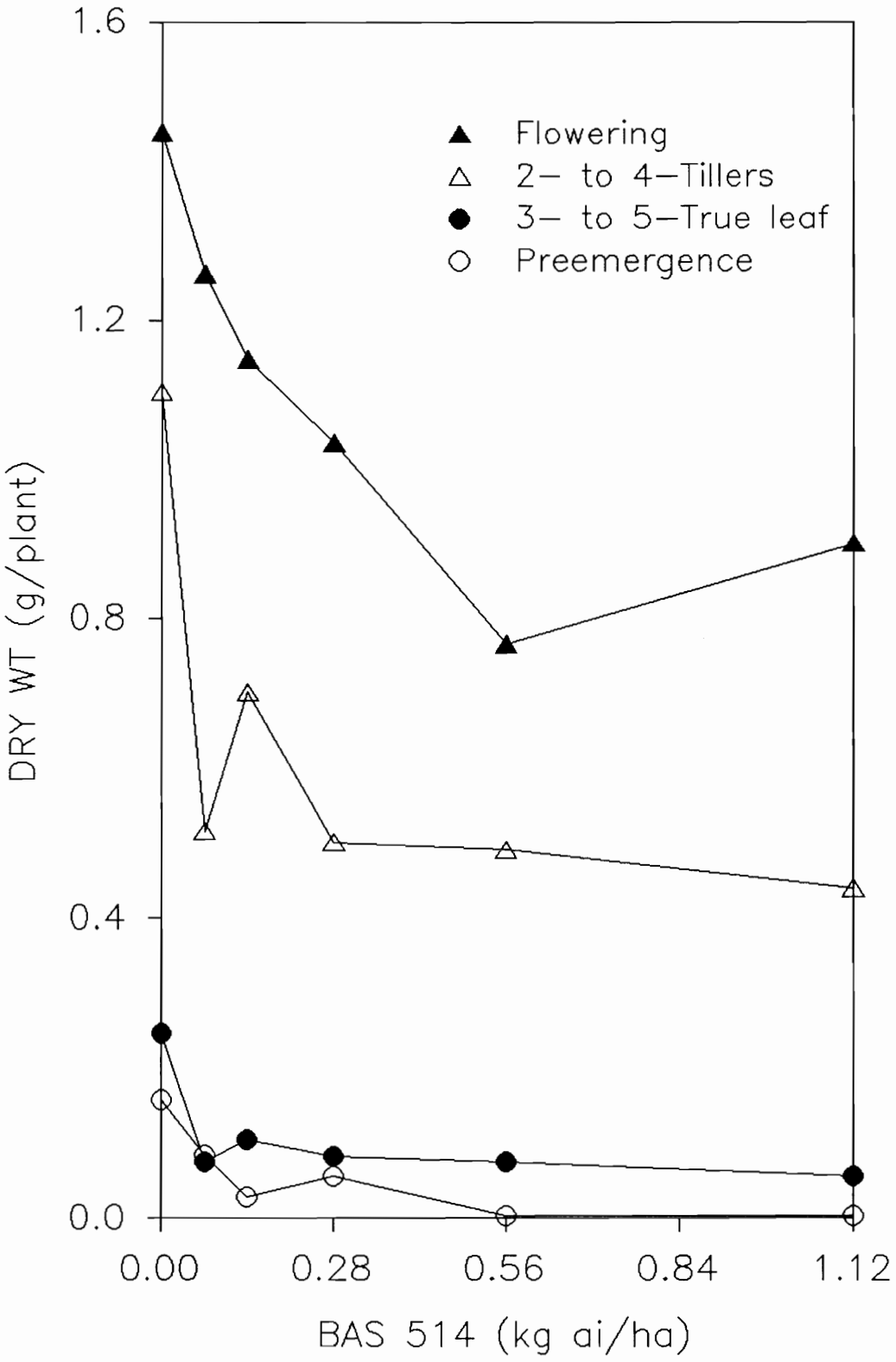
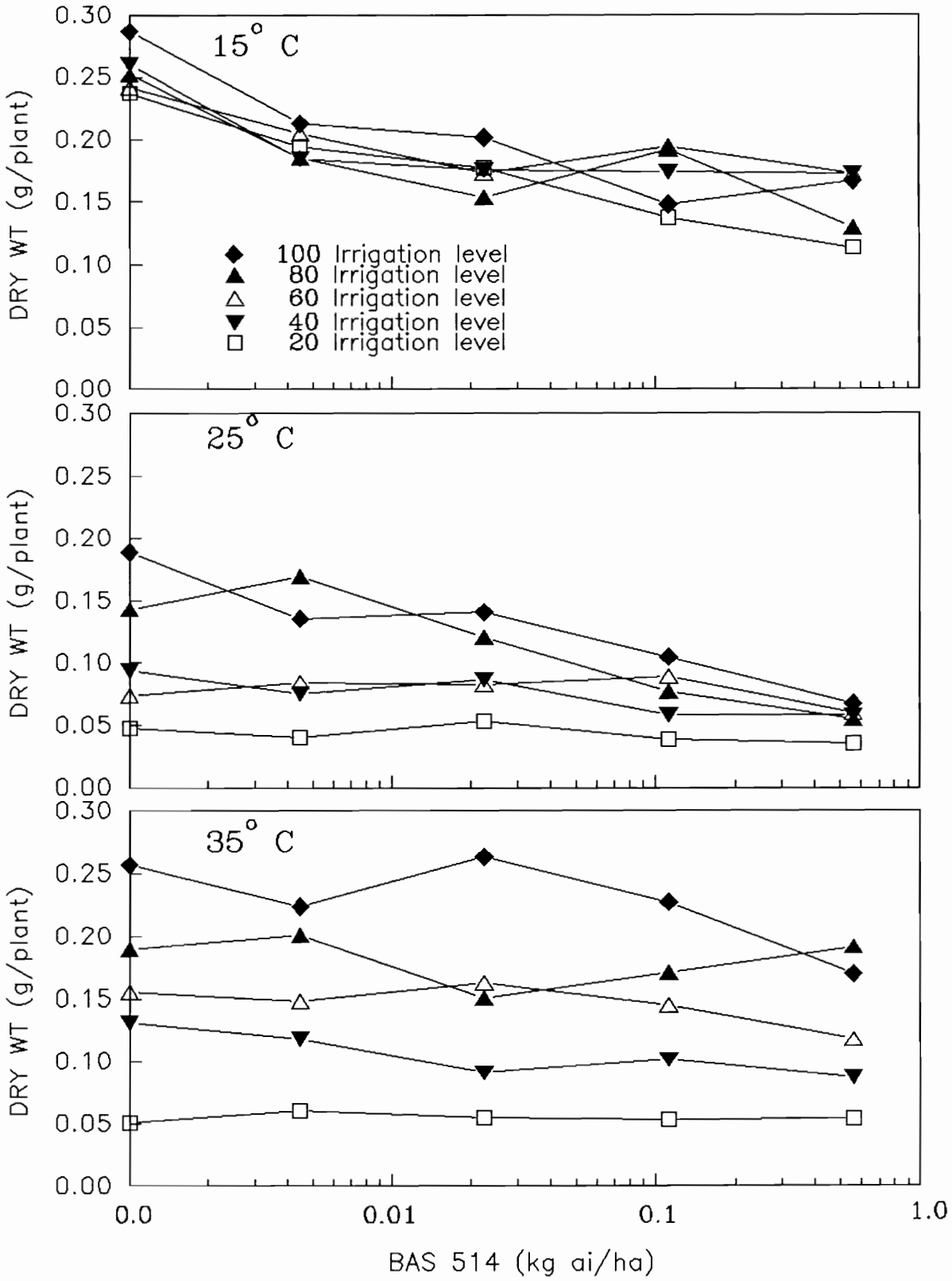

1.6
1.2
0.8
0.4
0.0
DRY WT (g/plant)
Flowering
2– to 4–Tillers
3– to 5–True leaf
Preemergence
0.00
0.28
0.56
0.84
1.12
BAS 514 (kg ai/ha)

Figure 2.3. Influence of temperature, irrigation, and concentration of BAS 514 on dry weight of southern crabgrass (n=6). Symbols used in each graph indicate the respective irrigation level.


15° C
25° C
35° C
DRY WT (g/plant)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
100 Irrigation level
80 Irrigation level
60 Irrigation level
40 Irrigation level
20 Irrigation level
0.0
0.01
0.1
1.0
BAS 514 (kg ai/ha)

CHAPTER III

UPTAKE, TRANSLOCATION, AND METABOLISM OF BAS 514 IN SOUTHERN CRABGRASS (*Digitaria ciliaris*) AND KENTUCKY BLUEGRASS (*Poa pratensis*)

ABSTRACT. Laboratory research was conducted to determine the uptake, distribution, and metabolism of BAS 514 in southern crabgrass and Kentucky bluegrass. BAS 514 was rapidly absorbed by leaves. At 0.5 h, absorbance was 85% and 66% of the herbicide applied for crabgrass and bluegrass, respectively. Uptake and distribution was similar in both species from 0.5 to 32 h but different at 128 h, with bluegrass more uniformly distributing the herbicide and exuding 17% of the applied herbicide from the roots into Hoagland solution. Metabolism of BAS 514 was limited with only 2.8 and 3.6% metabolized in crabgrass and bluegrass, respectively. This research indicates that uptake, translocation, distribution, and metabolism were not involved in differential sensitivity to BAS 514 in these two species. Nomenclature: BAS 514, 3,7-dichloro-8-quinolinecarboxylic acid; southern crabgrass, *Digitaria ciliaris* #[1] DIGSP; Kentucky bluegrass, *Poa pratensis* L. # POAPR. Additional index words. BAS 090, herbicide physiology, profile analysis.

[1]Letters following this symbol are a WSSA-appproved computer code from Composite List of Weeds. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

INTRODUCTION

BAS 514 is a broad-spectrum herbicide in the quinolinecarboxylic acid family (2) for control of both grass and broadleaf weeds postemergence in rice and turfgrass. BAS 514 is being tested for selective control of crabgrass species in turfgrass (7). While the selectivity of the herbicide is well established, the mechanism of selectivity is unknown (3). Plant tolerance to herbicides can result from such factors as differential uptake or translocation (5, 9), site of action sensitivity, or metabolic inactivation (4, 10).

The objectives of this research were to determine if the herbicidal selectivity of BAS 514 could be accounted for by differences in uptake, translocation, or metabolism between southern crabgrass and Kentucky bluegrass.

MATERIALS AND METHODS

General procedures. Southern crabgrass plants[2] were greenhouse germinated in vermiculite and transferred at one-true leaf stage to 7-cm pots containing Appling fine sandy loam soil having a pH of 6.7 and an organic matter content of 1.9%. Plants with four-true leaves were transferred to glass jars containing 130 ml full-strength Hoagland and Arnon

[2] Azlin Seed Co., P.O. Box 914, Leland, MS 38756.

nutrient solution (6) modified by doubling the iron concentration (pH 6.5). Kentucky bluegrass (cv. Plush) plants from an established field planting (1.5 years old) were transferred directly into modified nutrient solution. Plants were maintained in a greenhouse with average day/night temperatures of 35° /25° C, noon ambient light levels of 650 μmol/m^2/sec and a photoperiod of 14 h.

Uptake and translocation studies. Four plants of each species grown as above were treated by spotting 10 ul of 4.5 to 6.75 nCi of uniformly ring labelled ^{14}C-BAS 514 (specific activity 40.4 μCi/mg) plus surfactant (0.06% BAS 090[3]) dissolved in methanol to one leaf of each plant. Plants were harvested at 0.5, 2, 8, 32, and 128 h after treatment. The treated leaf was washed twice with 2 ml acetone and plants were divided into treated leaf, non-treated leaves, and roots. Samples were oven-dried at 50° C for 48 h, weighed and combusted in a sample oxidizer[4], and evolved $^{14}CO_2$ trapped in 20 ml of CO_2 absorber[5] plus scintillation fluid[6]. Radioactivity in the

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[3] Undisclosed chemistry, BASF Corp., 100 Cherry Hill Rd., Parsippany, NJ 07054.

[4] Packard tricarb sample oxidizer, Packard Instruments Co., Inc. Downer Grove, IL 60515.

[5] Carbo-sorb carbon dioxide absorber for scintillation counting, Packard Instrument Co., Downers Grove, IL 60515.

[6] Permafluor V, Packard Instrument Co., Inc. Downer Grove, IL 60515.

acetone wash and the nutrient solution was quantified by subsampling these solutions into scintillation fluid[7]. All radioactivity was determined using liquid scintillation spectrometry[8], with corrections for quenching. Recovery of ^{14}C was 95 to 100% of the applied herbicide. Distribution of ^{14}C in each fraction was expressed as disintegrations per minute (DPM) and percentage of total ^{14}C recovered from the whole plant.

A completely randomized design with four samples was used and each experiment was repeated. Statistical analysis on ^{14}C recovered was conducted using profile analysis with $\alpha = 0.05$, a modification of the standard analysis of variance (11). This procedure was utilized because the variables to be compared (plant parts) were not statistically independent and violate the assumption of independance of error variances of the univariate design (8). Profile analysis provides a statistical comparison of the overall distribution of ^{14}C BAS 514 between the two species, of the average DPM accumulated in each species, and compares distribution between sample component parts using the pooled average of both species.

Metabolism studies. Plants were grown as above and treated by applying 1.35 μCi of ^{14}C-BAS 514 (specific activity 40.4

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[7] Ecolume, ICN Biomedicals, Inc. Irvine, CA. 92713.

[8] Model LS-255, Beckman Instrument Co., Fullerton, CA 92634.

μCi/mg) with 0.06% BAS 090 dissolved in methanol to the leaves of five plants using an atomizer. Plants were harvested 128 h after treatment and divided into leaves and roots, weighed, and frozen at -10° C. Metabolite extraction followed the methods of Evans[9]. Plants were ground in a blender, washed with 25 ml phosphate buffer pH 7.0 (0.1 M KH_2PO_4:0.1 M K_2HPO_4) and buffer discarded. Twenty-five ml of methanol:water (80:20 v/v), were added and allowed to evaporate overnight at room temperature. Plant residue was extracted with 25 ml methanol for separation of parent compound (a weak acid). Insoluble residue was resuspended in 25 ml water to partition polar residues. All fractions were evaporated at room temperature to 1.5 ml. These extracts, untreated plant extracts spiked with 45 nCi ^{14}C BAS 514, and 1.0 nCi ^{14}C BAS 514 standard were spotted on a 0.25 mm silica gel TLC plate[10]. The mobile phase was methanol:water (80:20 v/v). TLC plates were scraped every 1 cm, from origin to solvent front. Each scraping was added to scintillation cocktail and tested for radioactivity to calculate R_f values of metabolites. Recovery of ^{14}C was 85 to 90% of the applied herbicide.

A completely randomized design with four samples was used. Statistical analysis on R_f values for metabolites were

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[9] Evans, R. 1989. Extraction of metabolites of BAS 514, (3,7-dichloro-8-quinolinecarboxylic acid). Unpublished. BASF Corp., Research Triangle Park, N.C. 27709.

[10] Number 60 F-254. Alltech Assoc., Inc. Deerfield, IL 60015.

conducted using profile analysis with $\alpha = 0.05$ (8,11).

RESULTS AND DISCUSSION

Uptake and translocation studies. Profile analysis revealed that both species distributed the herbicide similarly until 32 and 128 h after treatment (Table 3.1). Average DPM values for both species were equal at all times after 0.5 h. The uptake of foliar applied ^{14}C BAS 514 was rapid with total uptake of 87% and 68% within 0.5 h in crabgrass and bluegrass, respectively (Table 3.2 and Fig. 3.1). Bluegrass translocated 18% of the herbicide into other leaves by 0.5 h. Distribution of ^{14}C BAS 514 into different sample components demonstrated a difference at 0.5 h between treated leaf versus other leaves, due to the lag time between application and movement throughout the plant. Differences were seen at 32 h between treated leaf versus other leaves. Here, the herbicide had moved inside the treated leaf but had not yet moved to the other leaves. Maximum herbicide uptake and accumulation occured at 32 h for both species. At 128 h herbicide distribution was no longer equal between species. The 128 h sample indicated differences between treated leaf versus other leaves and roots versus nutrient solution. These differences between sample components were more indicative of a steady state condition.

It is interesting to note that bluegrass plants

partitioned more herbicide into other leaves and exuded 17% of the herbicide from roots into the nutrient solution. Rice roots also exude BAS 514 (1). In general, both species have rapid absorption and translocation of the herbicide, with bluegrass moving more of the herbicide into the non-treated leaves. Very little material was accumulated in the roots, and bluegrass was able to exude the parent compound into nutrient solution.

METABOLISM STUDIES. Many plant species are able to detoxify herbicides through a range of metabolic processes. Studies with other classes of herbicides indicate that effective metabolic detoxification occurs when the herbicide concentration is reduced by 90% (4) or the half life is reduced from 30 days to 3 days (10).

In this study a water soluble BAS 514 metabolite with an R_f value of 0.88 from crabgrass and bluegrass was extracted. Metabolites were below the level of detection in the P buffer and MeOH solvent systems. The BAS 514 metabolite levels detected were 2.8 and 3.6% of the total radioactivity in crabgrass and bluegrass, respectively. Metabolite concentrations were not significantly different from each other. The low level of metabolism was not enough to account for the selectivity of BAS 514.

BAS 514 was readily taken up, moved throughout the plant, and was not significantly metabolized, indicating that uptake,

translocation, distribution, and metabolism do not play a role in differential selectivity. Exudation may be involved in differential selectivity.

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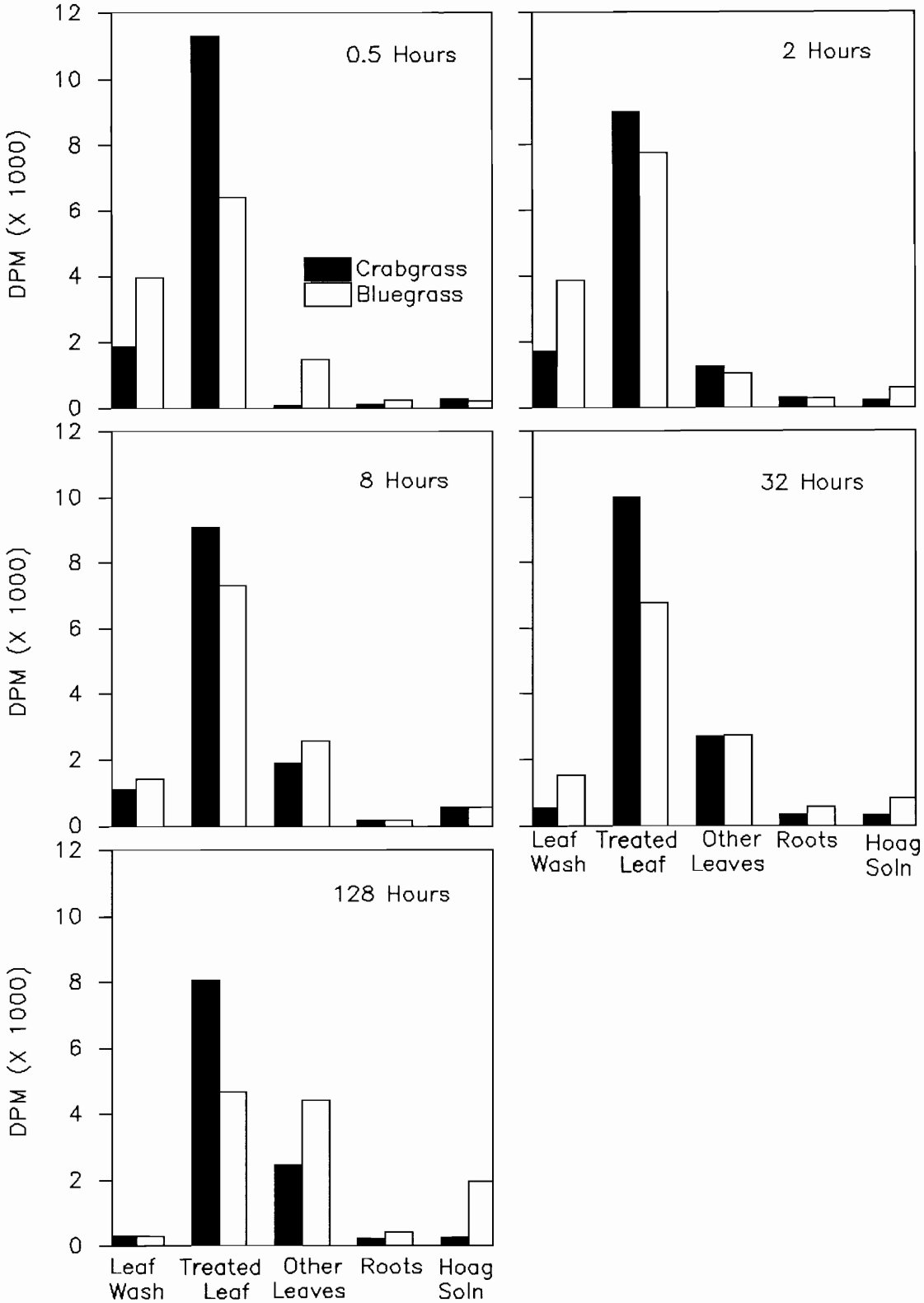
Table 3.1. Probability values for profile analysis of distribution of ^{14}C BAS 514 in southern crabgrass and Kentucky bluegrass.

	Hours after application				
Comparison	0.5[a]	2	8	32	128
	-------- (Prob > F) --------				
Parallelism	.19	.20	.62	.04	.01
Averages	.04	.73	.21	.13	.81
Treated leaf vs other leaves	.06	.71	.37	.06	.04
Other leaves vs roots	.42	.84	.62	.84	.24
Roots vs nutrient solution	.29	.16	.99	.17	.01

Table 3.2. Distribution of ^{14}C BAS 514 in southern crabgrass and Kentucky bluegrass.

	Hours after application				
Tissue fraction	0.5	2	8	32	128
southern crabgrass					
	-------- (% of applied) ----------				
leaf wash	14	14	8	4	3
total uptake	87	86	91	96	97
	-------- (% of absorbed) ---------				
treated leaf	95	84	78	75	73
other leaves	1	12	16	21	23
roots	1	2	1	2	2
Hoag. solution	2	2	4	2	2
Kentucky bluegrass					
	-------- (% of applied) ----------				
leaf wash	32	28	12	12	3
total uptake	68	71	88	89	98
	-------- (% of absorbed) ---------				
treated leaf	76	80	68	62	41
other leaves	18	11	24	25	38
roots	3	3	2	6	4
Hoag. solution	3	6	6	8	17

Figure 3.1. Distribution of ^{14}C BAS 514 into sample components of southern crabgrass and Kentucky bluegrass (n=4). Time of harvest (h) after herbicide application is indicated in each graph. Sample components were acetone leaf wash, treated leaf, other leaves, roots, and Hoagland solution.


0.5 Hours
2 Hours
8 Hours
32 Hours
128 Hours
DPM (X 1000)
0
2
4
6
8
10
12
Crabgrass
Bluegrass
Leaf Wash
Treated Leaf
Other Leaves
Roots
Hoag Soln

SUMMARY AND CONCLUSION

This dissertation was designed to elucidate the response of postemergence crabgrass herbicide efficacy to environmental influences. Varying field test sites were used to select an environmentally sensitive herbicide. Responses in herbicide activity to temperature, moisture, and morphological conditions were quantified. Uptake, translocation, and metabolism were evaluted to ascertain their role in this responses.

Influence of variable environments. Analyses of data indicated that environment can significantly influence plant response to herbicides. By conducting multiple comparisons of the variances of each herbicide across sites, it was determined that BAS 514 had significantly different variances. This suggests that BAS 514 was more sensitive to variable environments than the other herbicides and that field testing was able to detect this difference. BAS 514 provided efficacious postemergence control of crabgrass in turf. BAS 514 and fenoxaprop (the cool-season turfgrass herbicide standard) were shown to be equal in terms of turf quality, phytotoxicity to turf, and the control and number of crabgrass plants.

Influence of growth stage, temperature, and moisture. This section of research demonstrated that southern crabgrass control by BAS 514 was influenced by plant growth stage, ambient temperature, and irrigation. Mature Kentucky bluegrass was not adversely affected by BAS 514 at any herbicide rate tested. Crabgrass was shown to be most sensitive to BAS 514 at early growth stages, at 25° C, and when leaf water potentials were equal to or less than -1.2 MPa. Higher rates of BAS 514 may be required if the temperature is at 15° C or if the temperature is at 35° C accompanied by low levels of moisture.

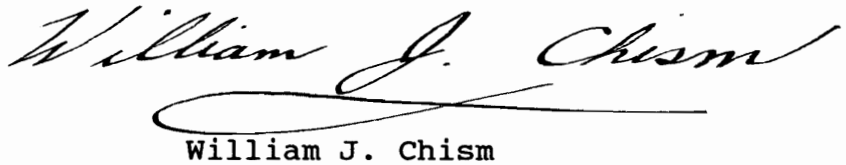
Uptake, translocation and metabolism studies. Southern crabgrass and Kentucky bluegrass distribute BAS 514 similarly from 0.5 to 32h and differently at 128 h after treatment. Significant uptake occured within 0.5 h in both species. Maximum herbicide uptake and accumulation occured at 32 h for both species. At 128 h, bluegrass plants had partitioned more herbicide into non-treated leaves and exuded 17% of the herbicide from roots into the nutrient solution. Very little herbicide was accumulated in the roots of either species.

Crabgrass and bluegrass produced a water-soluble BAS 514 metabolite with an R_f value of 0.88. The BAS 514 metabolite accounted for approximately 3% of the applied herbicide in

both species. This low level of metabolism did not seem adequate to account for a selectivity mechanism for BAS 514. Root exudation may be a factor in the selectivity of this herbicide.

VITA

William John Chism was born to Betty Ogden and Lyman Conwell Chism on May 20, 1955 in Nogales, Arizona. He received his B.S. in Entomology from the University of California at Davis in 1978. He completed an M.S. in Agriculture from California Polytechnic State University at San Luis Obispo in 1982 under Dr. A. Charlie Crabb. He worked from 1982 to 1984 for the University of California Cooperative Extension with Dr. A. H. Lange, a state-wide Weed Specialist at the Kearney Horticultural Field Station. In June of 1983, he enrolled in the Botany Department of the University of California at Riverside, and in 1986 received a second M.S. degree in Plant Physiology under Dr. Jodie S. Holt. In January of 1987, he began his doctoral studies in the Department of Plant Pathology, Physiology and Weed Science at Virginia Polytechnic Institute and State University under the direction of Dr. S. Wayne Bingham.



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