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CONTROL OF CYNODON DACTYLON WITH SETHOXYDIM AND FLUAZIFOP-BUTYL

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CONTROL OF *CYNODON DACTYLON* WITH SETHOXYDIM AND FLUAZIFOP-BUTYL

by

Horacio A. de la Concha Duprat

A Thesis Submitted to the Faculty of the

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This thesis has been approved on the date shown below:

K. C. Hamilton — 10/17/83

K. C. HAMILTON
Professor of Plant Sciences

Date

To my wife, Griselda, and future child.

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TABLE OF CONTENTS

	Page
LIST OF TABLES	vi
LIST OF ILLUSTRATIONS	vii
ABSTRACT	viii
INTRODUCTION	1
LITERATURE REVIEW	3
History and Biology	3
Methods of Control	5
MATERIALS AND METHODS	13
Rates of Sethoxydim and Fluazifop-butyl	13
Effect of Clipping Intervals on Control	15
Comparison of Sethoxydim, Fluazifop-butyl, and Glyphosate	16
RESULTS AND DISCUSSION	17
Rates of Sethoxydim and Fluazifop-butyl	17
Effect of Clipping Intervals on Control	27
Comparison of Sethoxydim, Fluazifop-butyl, and Glyphosate	27
SUMMARY	33
LITERATURE CITED	34

LIST OF TABLES

Table		Page
1.	Bermudagrass composition and requirements for a 200 to 400 kg ruminant per day to have a daily gain of 0.7 kg	4
2.	Comparison of the effectiveness of dalapon and glyphosate with sethoxydim and fluazifop-butyl on various crops	11
3.	Dates when the experiments were planted, sprayed, and harvested	14
4.	Effect of rates of fluazifop-butyl on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes of common bermudagrass	20
5.	Effect of rates of sethoxydim on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes of common bermudagrass	21
6.	Effect of rates of fluazifop-butyl on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes on giant bermudagrass	23
7.	Effect of rates of sethoxydim on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes on giant bermudagrass	24
8.	Effect of fluazifop-butyl and sethoxydim on common and giant bermudagrass after clipping the foliage at 12 hour intervals after spraying	28
9.	Effect of fluazifop-butyl, sethoxydim, and glyphosate on common bermudagrass after removing the foliage 12 hours after spraying .	30
10.	Effect of fluazifop-butyl, sethoxydim, and glyphosate on giant bermudagrass after removing the foliage 12 hours after spraying .	31

LIST OF ILLUSTRATIONS

Figure		Page
1.	Effect of fusilade (fluazifop-butyl), at 0.4 lb/ac (0.45 kg/ha), on giant and common bermudagrass	18
2.	Effect of rates of poast (sethoxydim) on giant bermudagrass	22
3.	Effect of rates of fluazifop-butyl and sethoxydim on number of stems of common and giant bermudagrass (means of both herbicides and two experiments)	26
4.	Effect of rates of fluazifop-butyl and sethoxydim on height of common and giant bermudagrass (means of both herbicides and two experiments)	26

ABSTRACT

Sethoxydim (2-[1-(ethoxyimino)-butyl]-5-[2-ethylthio)propyl]-3-hydroxy-2-cyclohexene-1-one) and fluazifop-butyl (butyl[2-(4-[5-trifluoromethyl-2-pyridinyloxy]phenoxy)]propanate) were evaluated for their ability to control common bermudagrass [Cynodon dactylon (L.) Pers.] and giant bermudagrass (Cynodon dactylon var. airdus Harlan et de Wet.). From the rates tested (0, 0.11, 0.22, 0.45, and 0.9 kg/ha) doses over 0.22 kg/ha gave good results in common bermudagrass. However, 0.45 kg/ha was required to control giant bermudagrass. The treatment 0.45 kg/ha was considered the most effective and used in subsequent experiments. Clipping the treated foliage at 12-hour intervals after spraying showed that sethoxydim and fluazifop-butyl can translocate to the rhizomes within the first 12 hours to kill the buds. In the comparison of sethoxydim and fluazifop-butyl against glyphosate [N-(phosphonomethyl)glycine], applied at a rate of 2 kg/ha, there was no difference in control of common and giant bermudagrass.

INTRODUCTION

Perennial grasses such as johnsongrass [*Sorghum halepense* (L.). Pers.] and common bermudagrass [*Cynodon dactylon* (L.) Pers.] have become serious pests in irrigated agricultural land. Their reproduction by rhizomes is the factor that contributes the most to their spreading and establishment. The rhizomes store large amounts of carbohydrates which are used by the numerous buds in the nodes to grow. Rhizomes can be found in the soil as deep as 45 cm. For this reason mechanical methods or contact herbicides are ineffective in controlling these grasses because they only kill the aerial portion of the plant and leave the rhizomes untouched so they can continue sprouting. The best method seems to be the use of translocating herbicides that move within the plant to the underground organs to kill the buds.

Several herbicides with the capacity to translocate have been used. These herbicides are used at high rates. Most of them have no selectivity and require several applications. Today several experimental chemicals are being tested for control of perennial weeds. The purposes of this study were to (a) determine an effective rate of sethoxydim (2-[1-(ethoxyimino)-butyl]-5-[2-(ethylthio)-propyl]-3-hydroxy-2-cyclohexene-1-one) and fluazifopbutyl

(butyl[2-(4-[5-trifluoromethyl-2-pyridinyloxy]phenoxy)] propanate) to control bermudagrass, (b) evaluate the effect of clipping the foliage after spraying on their effectiveness, and (c) compare these chemicals with glyphosate [N-(phosphonomethyl)glycine].

LITERATURE REVIEW

History and Biology

Bermudagrass, a member of the Eragrostoidea subfamily, tribe Chloridea, is a stoloniferous, rhizomatous perennial as described by Gould (24). Today, because of its great adaptability, bermudagrass is spread all over the world from 45° of latitude north to 45° of latitude south, and from sea level up to 2,200 m of altitude (32). There are several features that contribute to its spreading. The first, and probably the most important in arid climates, is its drought tolerance. Bermudagrass is found in areas with annual rainfall as low as 600 mm and up to 1,000 mm. The second most important feature is its adaptability to a wide range of soils, pH, and salinity. As stated by Varshney (59), bermudagrass has, "a wide hereditary potential to withstand the extreme adverse edaphic conditions of salt affected soils." Other important adaptations are indifference to photoperiod (48) and tolerance to low temperature (47), although bermudagrass has an optimum growth between 23 and 35 C (29, 32, 33).

Bermudagrass is believed to have originated in tropical Africa of the Indo-Malaysian area (29, 32), but its great adaptability, nutritional value (Table 1), and

Table 1. Bermudagrass composition and requirements for a 200 to 400 kg ruminant per day to have a daily gain of 0.7 kg.

	Bermudagrass	Requirements
Dry matter (hay)	91.5%	5.7 to 8.5 kg
Crude protein	9.5%	0.6 to 0.9 kg
Digestible protein	5.1%	0.4 to 0.5 kg
TDN	51.0%	3.6 to 7.0 %
Calcium	0.5%	18.0 to 23 g
Phosphorus	0.2%	16.0 to 21 g

Adapted from Church (11).

aesthetic properties as lawn grass (24) made this species attractive for many people to introduce into different parts of the world. In the case of the U. S., it was introduced by Governor H. Ellis of Georgia in 1751 to improve the quality of the native forage in the southern states, and by 1807 it was considered one of the most important forage grasses (42, 64). Unfortunately, the grass started to invade farmland. Between 1890 and 1907 it was considered a serious pest (42).

The reproduction of bermudagrass is mostly vegetative by rhizomes and stolons. Bermudagrass can produce shoots successively with an indefinite life span. To form a new plant only a segment with at least one bud, which contains 2 to 6 nodes, is needed (64). These characteristics of bermudagrass reproduction make it a very aggressive plant. Horowitz (34) in a 2-year study using small sprigs, determined that bermudagrass grows in an approximately circular shape that expands concentrically at a mean monthly area increment of 0.9 m^2 with almost no growth in the cold season, but exceeding 2 m^2 per month in the summer. In another study Horowitz (33) found that the rhizomes of bermudagrass formed more than 90% of the underground dry weight and that 62% of this weight was located in the first 15 cm of soil, 26% between 15 and 30 cm, and 12% between 30 and 45 cm of soil. As stated by Holm et al. (32), "this adaptation (production of rhizomes) may be the principal factor in its ability to be an excellent pioneer weed in waste places and arable land." This dense system of rhizomes in bermudagrass besides ensuring perennialness to the grass, seems to have allelopathic properties that inhibit growth of subsequent crops (22, 37).

Methods of Control

As mentioned before, the perennialness of bermudagrass is by virtue of continued production of new stems instead of maintenance of a primary shoot (64); therefore, one way to control this grass is by removing the aerial part to exhaust the subterranean organs. Unfortunately, this technique is impractical because the rhizomes of bermudagrass can tolerate weight losses of 40 to 50% and still survive the next season to regrow (36). Trying to determine the effect of frequent clipping on survival of bermudagrass, Horowitz (35) found that monthly clippings reduced dry matter of the top and rhizomes, but the grass showed good regrowth in the next warm season. He also established that the only effective treatment to control bermudagrass with this method was with bi-weekly clippings, which is impractical in commercial crop production. Consequently, the most convenient method to control this weed, economically and effectively, is with herbicides that will translocate to the subterranean growing points and kill the buds in the rhizomes, thus preventing further growth, expansion, or reproduction.

The first chemicals used to control bermudagrass that gave good results were sodium arsenite and other arsenicals. These chemicals were used in the late 1940's and early 1950's (62). By 1960 many new herbicides were tested against bermudagrass, and one that gave satisfactory results was dalapon (2-2-dichloropropionic acid). This herbicide in recent studies (9, 45) controlled bermudagrass by 81 to 96% with rates of 5.5 to 11.2 kg/ha. The reason dalapon has been widely used for control of perennial weeds is that this herbicide translocates via apoplast, more than symplast, to the meristematic regions where it seems to modify protein structure causing conformational changes that alter enzyme activity. There is also a change of membrane permeability that together with the enzyme alterations results in many modifications to metabolic pathways (3, 15). Dalapon toxicity is so acute that it is sometimes detrimental to its mode of action because a translocate herbicide must move across all membranes and accumulate to toxic levels in the plant (7). The reason why sudden death caused by acute toxicity reduces the chances of dalapon to translocate and accumulate in the meristems is that translocate herbicides depend on the flow of liquids in the vascular system of the plant which require that the tissues are functional (40).

Other herbicides that have been used with some success against bermudagrass are paraquat (1-1'-dimethyl-4,4'-bipyridinium ion) and atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine). Paraquat controls the grass using the same principle as the frequent clipping technique, exhaustion of the subterranean organs by continuous removal of the aerial part, because it is pr.marily a contact herbicide with little or no translocation. Its mode of action requires the presence of light because it interferes with NADP reduction by using one electron to form a free radical. This free radical is reoxidized to yield a superoxide which overtaxes normal defenses (superoxide dismutase enzymes) and eventually interacts with reduced paraquat to produce more toxic compounds. The most toxic radical produced is the hydroxyl free radical, which initiates lipid peroxidation causing disruption of membranes. After disruption of the membranes, there is a release of vacuolar content that changes the osmotic potential and breaks down organelles causing the death of the plant (17, 18). The case of atrazine is similar in the sense that it only controls the aerial part of weeds. This herbicide is a photosynthetic inhibitor that prevents the flow of electrons in the Hill reaction reducing the assimilation of CO_2 due to the lack of NADP and ATP (3), and enhancing accumulation of nitrite (41).

The most recent herbicide used to control bermudagrass with great effectiveness is glyphosate. This herbicide has broad spectrum, high unit activity, biodegradability by soil microorganisms, translocation, and low toxicity to mammals. Glyphosate is being widely used and studied. It can be used alone or in mixtures with other herbicides and in many different crops. For example, in pecan (*Carya illinoensis* (Wang.) K. Koch) at a dose of 4.5 kg/ha glyphosate gave 85% control of bermudagrass up to 12 weeks (2), in asparagus (*Asparagus officinalis* L.) (6) and grapes (*Vitis vinifera* L.) with 4.2 kg/ha of glyphosate (26) there was a satisfactory control of bermudagrass. The factor that contributed the most to the success of glyphosate in controlling perennial weeds is its facility to translocate to buds. Because as stated by Sprankle, Meggitt, and Penner (58), "Successful control of perennial weeds with foliar-applied herbicides depends on the rapid absorption and basipetal translocation of the biologically active compound into the underground organs in sufficient quantities to kill the entire plant before metabolism can degrade the compound." Also, glyphosate is readily absorbed after spraying as demonstrated by Sandberg, Meggitt, and Penner (55) who found that 25 to 50% of the foliar-applied glyphosate was abosrbed within the first 48 h after spraying. After absorption glyphosate is basipetally translocated in the phloem with photoassimilates. Its translocation follows a typical source-sink pattern (23, 53, 58) to the growing buds in the rhizomes and accumulates in them (55). Therefore, conditions affecting the source-sink relationship will affect glyphosate translocation (20) such as growth stage (1, 44), water stress (1, 54), transpiration, and climatic factors like relative humidity, temperature, and light (39, 58, 60).

There is some controversy about the mode of action with which glyphosate controls plants; in 1980 Cole, Dodge, and Caseley (14) indicated that the mode of action of glyphosate was by, "inhibiting protein synthesis via the depletion of the phenylalanine protein pool," with a consequent increase in activity of the enzyme phenylalanine ammonia-lyase (PAL), instead of by inducing the PAL activity by the addition of glyphosate as was stated in previous work (13, 25, 31). Glyphosate also has some effect on photosynthesis because it reduces Rb and P uptake, which in turn affects the ultrastructure formation of the cells causing the leaf to senecence (8, 51).

Currently, there are two chemicals with a promising future for controlling bermudagrass. They are in their late experimental stages and will probably be released to the market soon. These future herbicides are fluazifop-butyl and sethoxydim. In several tests, which also included the most widely used herbicides for perennials, dalapon and glyphosate, these herbicides showed good control of perennial weeds (4, 21, 52, 56) with relatively low rates (Table 2). Since fluazifop-butyl and sethoxydim are in their late experimental stage, most of the research is focused on solving practical problems such as effectiveness, dosage, crop tolerance, and susceptible weeds. Recent studies showed that fluazifop-butyl at doses ranging from 0.22 to 1.2 kg/ha and sethoxydim at doses of 0.22 to 2.24 kg/ha gave satisfactory control of grass weeds such as yellow foxtail [Setaria lutescens (Weigel) Hubbard], bermudagrass (61), quackgrass (Agropyron repens L.) (50, 63), and crabgrass (Digitaria sp.) (19, 30) in crops like soybeans [Glycine max (L.) Merril] (28, 43), cotton

Table 2. Comparison of the effectiveness of dalapon and glyphosate with sethoxydim and fluazifop-butyl on various crops.

	Dalapon		Glyphosate		Sethoxydim		Fluazifop-butyl		
Crop/weed	Rate	Degree of Control	Rate	Degree of Control	Rate	Degree of Control	Rate	Degree of Control	Source
	(kg/ha)		(kg/ha)		(kg/ha)		(kg/ha)		
Alfalfa/ Bromus			2.24	fair	.84-1.1	good	0.57	good	27
Cotton/ Bermudagrass			2.50	93%	1.1-1.1	94%			38
Cotton/ Bermudagrass	3.4 3.4-3.4 6.7	84% 90% 57%	1.1 2.2	90% 97%	0.56 1.10 2.20	69% 88% 91%			61
Cotton/ Grasses	5.5	42%	2.2 3.3	70% 100%	0.83 1.10	85% 98%			12
Cotton/ Perennial grasses	2.5-5.5	85%	2.2 3.3	68% 83%	0.55 1.67	34% 86%			10
Multicrop/ Grasses	4.48	poor			1.68-2.24	good			49
Sugarbeet/ Grasses	4.48	poo4			0.22-0.44	good	0.22	good	16
Potato/ Quackgrass	4.48	poo4	2.24	poor	0.84	good	0.56	good	5

(*Gossypium* sp.), alfalfa (*Medicago sativa* L.) and potatoes (*Solanum tuberosum* L.) (46, 57).

MATERIALS AND METHODS

Several experiments were conducted at the University of Arizona Campbell Avenue Greenhouse, between April and October 1982. The objective was to determine the rate, and effectiveness of sethoxydim and fluazifop-butyl to control common and giant bermudagrass. For all tests, plastic pots (400 ml) were filled with soil (60% sand, 25% silt, 15% clay, and 1% organic matter, v/v/v/w) and a pinch of fertilizer (16-20-0) was added. The pots were perforated at the bottom to allow drainage and uptake of water when subirrigated. Prior to planting, the pots were surface irrigated and allowed to drain, then segments of rhizomes with several buds were placed in the pots and covered with 1 cm of dry soil. After planting the pots were placed on a tin tray and subirrigated as needed. Before treatment in all tests, the pots were selected for uniform grass height and stage of development based on the number of leaves and stems. To treat the pots with herbicides, a sprayer with a single nozzle fitted with a 8004 flat fan spray tip was used.

Rates of Sethoxydim and Fluazifop-butyl

The following tests were used to determine the most effective rate of the herbicides for control of bermudagrass. Four experiments, one with each chemical on each variety of bermudagrass, were conducted at two different dates (1 to 4 and 5 to 8 in Table 3). When the grass was 3 to 5 weeks old, and 25 cm high for common and 40 cm for giant bermudagrass, it was sprayed. The different rates tested were 0, 0.11, 0.22, 0.45, 0.9 kg/ha. The herbicides were applied in a mixture with 2.3 l/ha of crop oil in 374 l/ha of water. Each treatment was replicated six times in a randomized block design.

Table 3. Dates when the experiments were planted, sprayed, and harvested.

	Date of		
Experiment	Planting	Spraying	Harvest
1-4	April 29	June 1	July 19
5-8	May 6	June 4	July 25
9-12	June 1	June 30	July 24
13-16	June 6	July 5	July 27
17-18	July 27	August 26	October 5
19-20	August 20	September 14	October 26

Height and damage of the grass were determined 3 weeks after treatment and the aerial portion of the grass was clipped. Height was measured from the top soil to the last internode, and damage was evaluated on a 0 to 10 scale where 0 is no damage and 10 is complete necrosis of the tissue. The number of stems regrown and their height were measured 28 and 27 days after clipping for experiments 1 to 4 and 5 to 8 respectively. At the conclusion of the experiments, the rhizomes were removed from the pots with water, cleaned, and sun dried to determine the dry weight of rhizomes.

Effect of Clipping Intervals on Control

The following tests (9 to 16) were used to determine the time needed by the herbicides to translocate from the foliage to the subterranean organs and control the grass. The rate of the herbicide used was 0.45 kg/ha (and 2.3 l/ha of crop oil) since this was the best treatment in previous experiments. Both chemicals were tested on both varieties on two different dates. After spraying, the treated plants were clipped at 12 hour intervals (12, 24, 36, and 48 h) and a control was clipped at 24 h for comparison. Each treatment was replicated six times in a randomized block design. Height of stems and dry weight of rhizomes were measured 3 weeks after spraying.

Comparison of Sethoxydim, Fluazifop-butyl, and Glyphosate

The following tests were used to compare the efficiency of sethoxydim and fluazifop-butyl against glyphosate to control bermudagrass when the foliage was removed 12 h after spraying. Sethoxydim and fluazifop-butyl, at a dose of 0.45 kg/ha plus 2.3 l/ha of crop oil, and glyphosate, at a dose of 2.4 kg/ha were sprayed on 4-weeks-old bermudagrass. The three herbicides were tested on the two varieties of bermudagrass on two different dates. Each treatment was replicated six times. Height, number of stems, damage to the rhizomes, and dry weight of rhizomes were measured 5 weeks after treatment.

RESULTS AND DISCUSSION

Rates of Sethoxydim and Fluazifop-butyl

The symptomatology shown by both varieties of bermudagrass was similar for both herbicides. The initial response to the herbicides was wilting of the tips, some epinasty, and stunting (Fig. 1). Giant bermudagrass showed these symptoms earlier than common, 2 and 4 days respectively after treatment. Ten days after spraying, the difference in growth with respect to the control was dramatic and the reddening of the leaves started. Again giant bermudagrass showed the redcening of the leaves first. Approximately 5 days later, the leaves that showed the reddening were wilting. To determine if the herbicide was translocated to the buds in the rhizomes, the treated aerial part of the grass was clipped when no more chlorosis developed. This way it was easy to evaluate if there was any regrowth in the pots, but before clipping height was measured. In experiments 1 to 4 height was measured 20 days after spraying, and experiments 5 to 8 were measured 24 days after treatment. The controls for common and giant bermudagrass started to regrow 5 and 3 days, respectively, whereas the treated plants started 8 to 10 days after clipping.

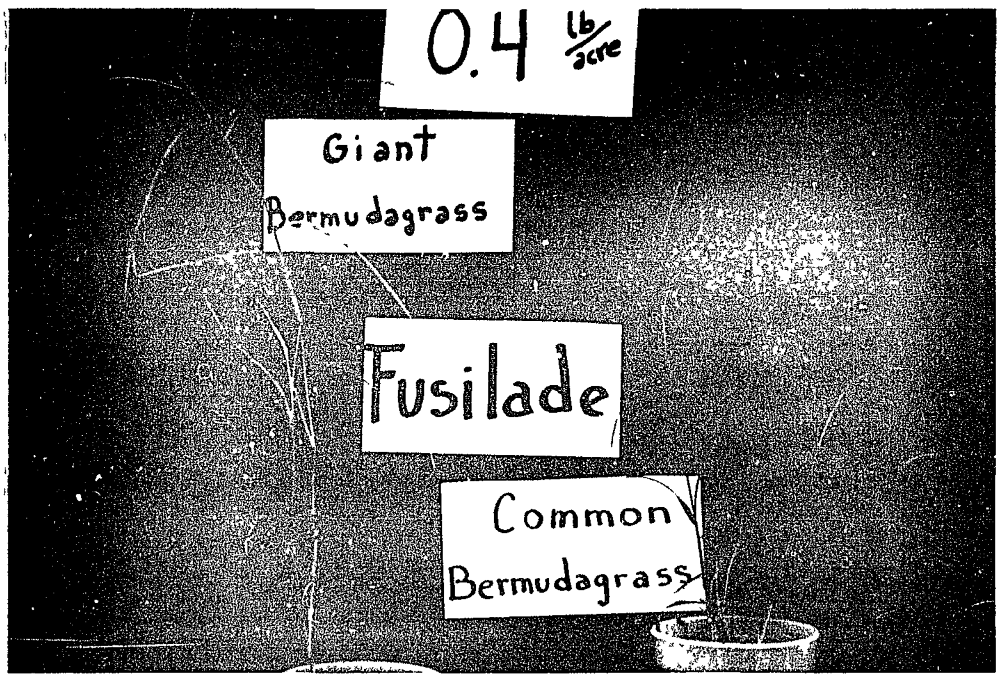

Fig. 1. Effect of fusilade (fluazifop-butyl), at 0.4 lb/ac (0.45 kg/ha), on giant and common bermudagrass.

Any rate of fluazifop-butyl on common bermudagrass stopped growth (Table 4), but the degree of damage to the leaves varied with the rate. As the rate increased the damage to the foliage increased. The difference between rates is seen in their effect on later regrowth. The response of common bermudagrass to sethoxydim (Table 5) was similar to that of fluazifop-butyl. The dry weight of rhizomes was affected by the herbicides, but the difference between rates was not statistically significant except in experiment 6.

Although giant bermudagrass has a faster growth rate than common, the response to sethoxydim (Fig. 2) and fluazifop-butyl was similar with very small discrepancies. For example, the damage to the foliage increased with the rate and the growth was stopped with the application of the herbicides, but the effect on regrowth at lower rates (0.11 and 0.22 kg/ha) was less in giant bermudagrass. In the case of fluazifop-butyl, giant bermudagrass (Table 6) did not show a significant difference in the dry weight of rhizomes between treated and non-treated plants. Sethoxydim at low rates on giant bermudagrass (Table 7) caused the regrowth of treated plants to be higher than the control. This effect was probably due to the fact that the control had more stems per pot so there was more competition while the treated pots had fewer stems and the grasses were able to grow more. The effect on dry weight of rhizomes of

Table 4. Effect of rates of fluazifop-butyl on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes of common bermudagrass.

Rate of fluazifop-butyl	Damage[ab]	Height: Before clipping	Height: After clipping	Number of stems	Dry weight of rhizomes
(kg/ha)		(cm)	(cm)		(g)
			Experiment 1		
0.00	0.0 c	31 a	9 a	9 a	2.6 a
0.11	2.2 b	17 b	6 b	4 b	1.5 b
0.22	2.8 b	14 b	3 c	1 c	1.2 b
0.45	5.7 a	9 b	1 c	1 c	1.5 b
0.90	5.8 a	9 b	0 c	0 c	1.0 b
			Experiment 5		
0.00	0.0 d	22 a	12 a	12 a	2.6 a
0.11	2.3 c	12 b	13 a	6 b	1.5 b
0.22	2.8 c	10 b	7 b	3 c	1.6 b
0.45	5.0 b	11 b	2 c	1 c	1.3 b
0.90	6.2 a	8 b	0 c	0 c	1.1 b

[a]On a 0 to 10 scale where 0 is no damage and 10 is complete kill.

[b]In each experiment, means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 5. Effect of rates of sethoxydim on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes of common bermudagrass.

Rate of sethoxydim	Damage[ab]	Height: Before clipping	Height: After clipping	Number of stems	Dry weight of rhizomes
(kg/ha)		(cm)	(cm)		(g)
			Experiment 2		
0.00	0.0 d	28 a	10 a	10 a	2.9 a
0.11	3.3 c	12 b	7 a	4 b	1.9 b
0.22	3.8 c	11 b	3 b	1 c	1.3 b
0.45	5.3 b	10 b	0 b	0 c	0.9 b
0.90	6.8 a	7 b	0 b	0 c	1.3 b
			Experiment 6		
0.00	0.0 d	33 a	13 a	10 a	2.6 a
0.11	3.0 c	11 b	12 a	7 b	1.8 b
0.22	3.3 c	10 b	11 a	3 c	1.3 bc
0.45	5.2 b	10 b	3 b	1 c	1.5 bc
0.90	7.0 a	6 b	0 b	0 c	1.0 c

[a]On a 0 to 10 scale where 0 is no damage and 10 is complete kill.

[b]In each experiment, means within a column followed by the same letter are not significantly different at the 5% level using the Duncan's multiple range test.

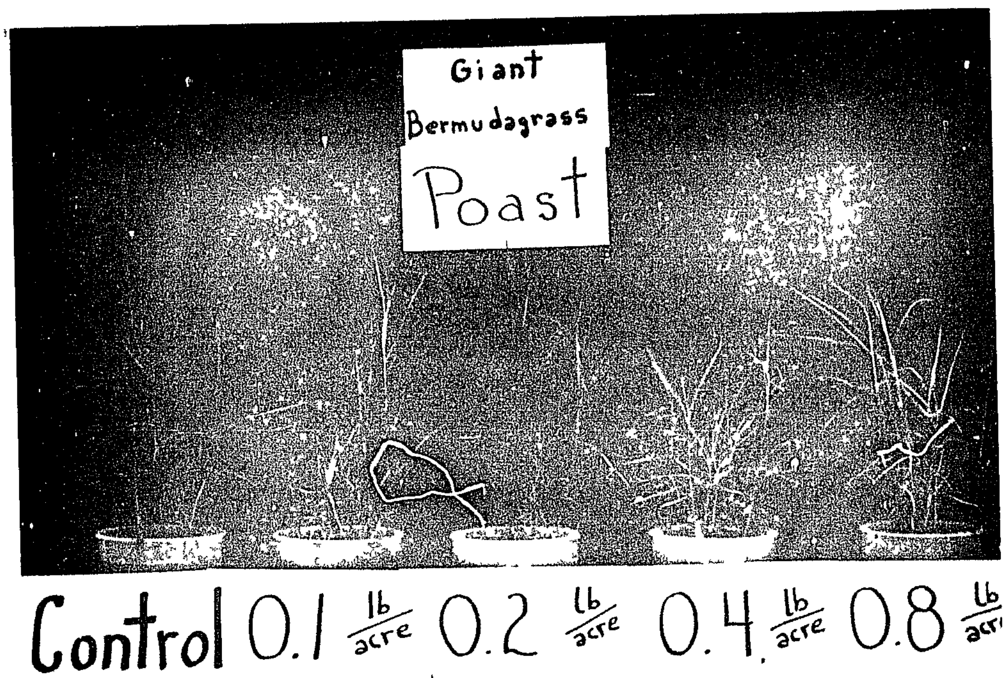

Fig. 2. Effect of rates of poast (sethoxydim) on giant bermudagrass.

Table 6. Effect of rates of fluazifop-butyl on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes on giant bermudagrass.

Rate of fluazifop-butyl	Damage[ab]	Height: Before clipping	Height: After clipping	Number of stems	Dry weight of rhizomes
(kg/ha)		(cm)	(cm)		(g)
			Experiment 3		
0.00	0.0 c	43 a	18 a	10 a	2.8 a
0.11	1.8 b	24 b	15 a	4 b	1.9 ab
0.22	2.3 b	23 b	2 b	1 c	1.8 b
0.45	2.7 b	24 b	0 b	0 c	1.4 b
0.90	4.7 a	22 b	0 b	0 c	1.9 ab
			Experiment 7		
0.00	0.0 d	43 a	21 a	8 a	2.3 a
0.11	2.3 c	21 b	16 ab	6 ab	2.3 a
0.22	3.7 b	25 b	21 a	4 b	2.0 a
0.45	3.8 b	18 b	10 b	3 bc	1.9 a
0.90	5.2 a	19 b	1 c	1 c	1.8 a

[a]On a 0 to 10 scale where 0 is no damage and 10 is complete kill.

[b]In each experiment, means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

Table 7. Effect of rates of sethoxydim on damage, height of sprayed plants and regrowth, number of stems, and dry weight of rhizomes on giant bermudagrass.

Rate of sethoxydim	Damage[ab]	Height: Before clipping	Height: After clipping	Number of stems	Dry weight of rhizomes
(kg/ha)		(cm)	(cm)		(g)
		Experiment 4			
0.00	0.0 d	40 a	17 b	7 a	2.2 a
0.11	2.3 c	23 b	25 a	4 b	1.9 ab
0.22	2.8 b	20 bc	25 a	3 bc	2.0 a
0.45	3.5 b	18 bc	3 c	1 c	1.7 ab
0. [illegible]	4.3 a	15 c	0 c	0 c	1.1 b
		Experiment 8			
0.00	0.0 c	41 a	20 a	9 a	2.8 a
0.11	3.5 b	16 b	26 a	4 b	1.8 b
0.22	3.5 b	20 b	28 a	3 b	1.8 b
0.45	6.2 a	10 b	2 b	0 c	1.6 b
0.90	6.3 a	14 b	0 b	0 c	1.5 b

[a]On a 0 to 10 scale where 0 is no damage and 10 is complete kill.

[b]In each experiment, means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

giant bermudagrass with sethoxydim varied in both experiments (Table 7). In the first test (no. 4), the only treatment that was different was the highest rate (0.9 kg/ha) whereas in the second experiment (no. 8) the control was significantly greater than the treatments, and there was no difference between the rates.

The effect of fluazifop-butyl and sethoxydim on common and giant bermudagrass is summarized in Figs. 3 and 4. As the rate increased, both number of stems and height decreased significantly. However, at low rates where there was not enough herbicide translocated down into the rhizomes the grass was able to form new stems almost as well as the control, in terms of height. The data indicate that doses over 0.22 kg/ha give good results in common bermudagrass, and that it required 0.45 kg/ha or more in giant bermudagrass to get good results. This difference in response could be due to the faster growth rate of giant bermudagrass. Since there was no significant difference between the treatments 0.45 and 0.9 kg/ha for both grasses, the treatment 0.45 kg/ha was considered the most effective and chosen to use in subsequent experiments. These results agree with the work of Plowman, Stonebridge, and Hawtree (52) who determined that a rate of 0.56 kg/ha of fluazifop-butyl applied to johnsongrass when it is 40 cm tall was enough for a 98% kill for 28 days after treatment.

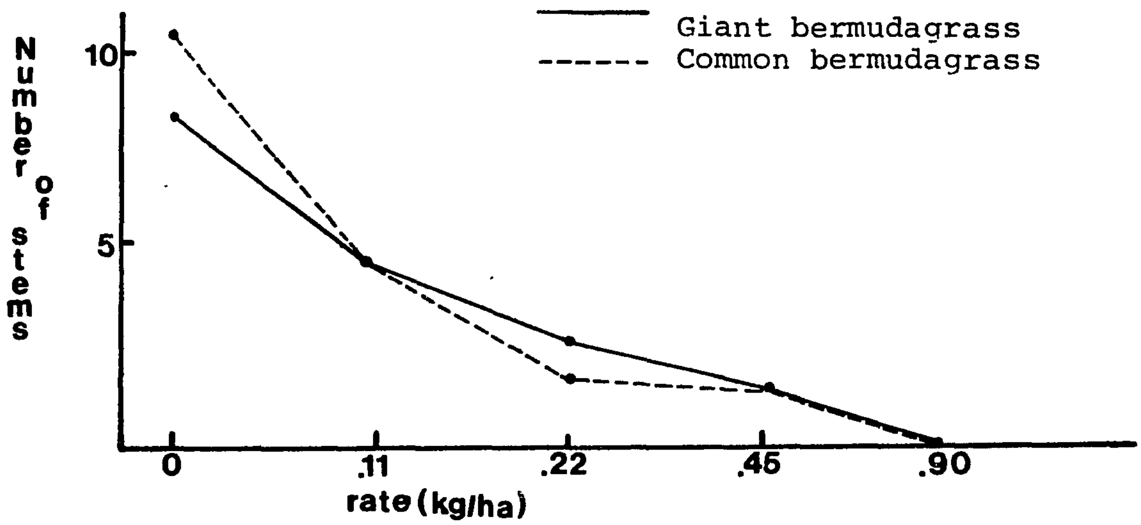

Fig. 3. Effect of rates of fluazifop-butyl and sethoxydim on number of stems of common and giant bermudagrass (means of both herbicides and two experiments).

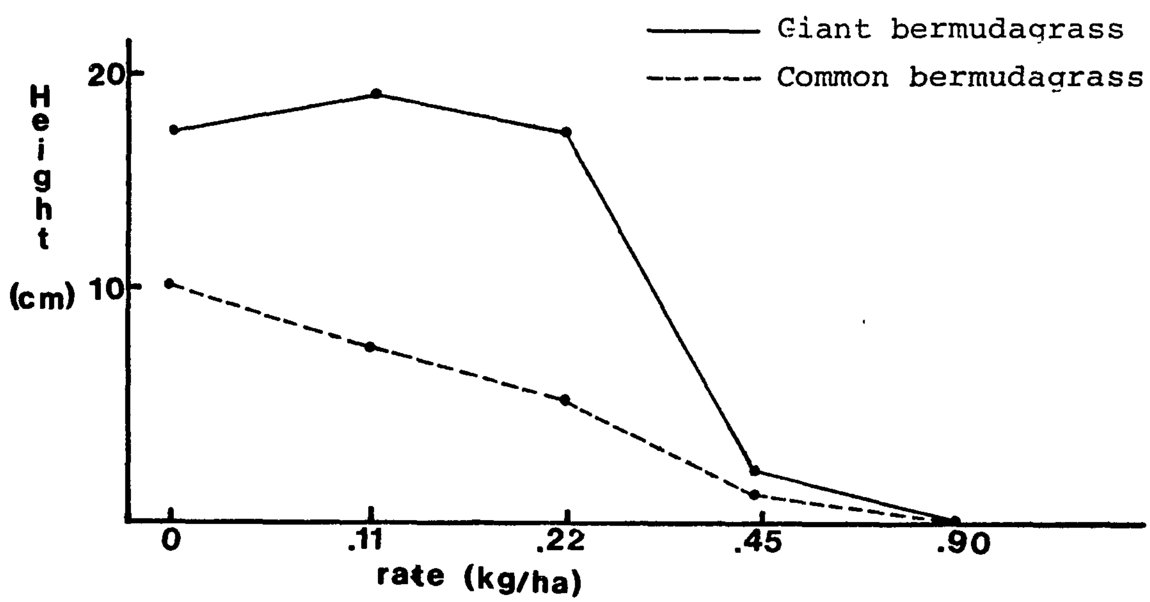

Fig. 4. Effect of rates of fluazifop-butyl and sethoxydim on height of common and giant bermudagrass (means of both herbicides and two experiments).

Effect of Clipping Intervals on Control

Fluazifop-butyl and sethoxydim stopped growth of common and giant bermudagrass (Table 8) even when the foliage was removed 12 hours after spraying. The response was the same in all the experiments. The controls started to regrow 3 to 5 days after clipping. The treated plants required more than 10 days to show some regrowth. This regrowth was abnormal, chlorotic in some cases, and similar to the witch's broom effect (sprouting of greater number of buds than normal, but without internode elongation) in others. There was no difference in dry weight of rhizomes in any of the experiments probably because the plants did not have enough time to show the effect of the herbicides. The plants were 4 weeks old when treated and were allowed only 3 weeks to regrow until harvest. These results indicate that fluazifop-butyl and sethoxydim did not require more than 12 h to translocate to the rhizomes to kill the buds. These high absorption and translocation rates of the herbicides agree with the work by Plowman et al. (52) who showed that, "even after 1 hour of spraying, rainwashing had little effect on fluazifop-butyl activity."

Comparison of Sethoxydim, Fluazifop-butyl, and Glyphosate

In common bermudagrass there was no significant difference between herbicides. Sethoxydim, fluazifop-butyl, and glyphosate reduced the height, the number of

Table 8. Effect of fluazifop-butyl and sethoxydim on common and giant bermudagrass after clipping the foliage at 12 hour intervals after spraying.

Interval after spraying	Fluazifop-butyl Height[ab]	Fluazifop-butyl Dry weight of roots[ab]	Sethoxydim Height[ab]	Sethoxydim Dry weight of rhizomes[ab]
(h)	(cm)	(g)	(cm)	(g)
		Common bermudagrass		
24 untreated	12.0 a	1.9 a	13.0 a	1.9 a
12	0.1 b	1.8 a	0.2 b	1.8 a
24	0.4 b	1.8 a	0.1 b	1.9 a
36	0.2 b	1.7 a	0.1 b	2.3 a
48	0.0 b	1.9 a	0.0 b	2.2 a
		Giant bermudagrass		
24 untreated	16.0 a	2.0 a	16.0 a	2.3 a
12	0.4 b	1.9 a	0.7 b	1.8 a
24	0.5 b	1.6 a	0.5 b	1.8 a
36	0.0 b	2.2 a	0.0 b	1.8 a
48	0.0 b	1.9 a	0.0 b	1.8 a

[a]Means of two experiments.

[b]Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

stems, and the dry weight of rhizomes, and also caused considerable damage to the rhizomes (Table 9). Regrowth, on the pots where it occurred, was weak, small, and similar to the witch's broom effect.

In giant bermudagrass the effect was similar (Table 10). Height, number of stems, and damage to the rhizomes were affected by all the herbicides, and even though there was no significant difference between herbicides, glyphosate showed slightly better control. This apparent superiority of glyphosate in giant bermudagrass could be attributed to its faster growth rate. Glyphosate moves following a source-sink relationship, and as stated before, growth stage affects translocation; therefore, the faster growth rate of the young giant bermudagrass used in these experiments probably favored the translocation of glyphosate more than the other two herbicides, causing more damage to the rhizomes.

Dry weight of rhizomes varied in both experiments. In experiment 20 (Table 10) there was no significant difference between herbicides and the control, and in experiment 18 only sethoxydim and glyphosate were different from the control. In spite of this difference the pattern was the same. In both experiments, glyphosate reduced the dry weight of rhizomes more, probably because of the greater translocation. Sethoxydim showed more damage and less dry weight of rhizomes than fluazifop-butyl; however, there was

Table 9. Effect of fluazifop-butyl, sethoxydim, and glyphosate on common bermudagrass after removing the foliate 12 hours after spraying.

Herbicide	Height[a]	Number of stems	Damage[ab]	Dry weight of rhizomes[a]
	(cm)			(g)
		Experiment 17		
Control	15.1 a	4.3 a	0 a	4.7 a
Sethoxydim	0.0 b	0.0 b	6 b	2.0 b
Fluazifop-butyl	1.0 b	0.1 b	7 b	2.0 b
Glyphosate	2.3 b	1.2 b	7 b	1.9 b
		Experiment 19		
Control	16.6 a	7.6 a	0 a	3.5 a
Sethoxydim	0.5 b	0.3 b	7 b	1.7 b
Fluazifop-butyl	0.3 b	0.3 b	7 b	1.5 b
Glyphosate	0.6 b	0.6 b	6 b	1.6 b

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]On a 0 to 10 scale where 0 is no damage and 10 is complete kill.

Table 10. Effect of fluazifop-butyl, sethoxydim, and glyphosate on giant bermudagrass after removing the foliage 12 hours after spraying.

Herbicide	Height[a]	Number of stems	Damage[ab]	Dry weight of rhizomes[a]
	(cm)			(g)
			Experiment 18	
Control	18.4 a	4.6 a	0 a	3.7 a
Sethoxydim	4.4 b	1.0 b	6 a	2.2 b
Fluazifop-butyl	4.4 b	1.6 b	7 b	2.7 ab
Glyphosate	0.0 b	0.0 b	9 b	1.5 b
			Experiment 20	
Control	13.5 a	8.5 a	0 a	3.4 a
Sethoxydim	3.8 b	0.8 b	5 b	2.6 a
Fluazifop-butyl	2.0 b	1.0 b	5 b	3.2 a
Glyphosate	2.2 b	1.8 b	7 b	2.2 a

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]On a 0 to 10 scale where 0 is no damage and 10 is complete kill.

no statistical difference between these herbicides in both experiments. Finally, fluazifop-butyl apparently did not affect the rhizomes because in the first experiment it did not show a statistical difference. In the second experiment, the accelerated growth rate of giant bermudagrass, besides increasing the translocation rate of glyphosate, was probably the reason why there were no differences in the dry weight of rhizomes between the herbicides and the control. The giant bermudagrass grew so fast after planting that when the plants were treated the amount of soil in the pots was limiting the growth. Therefore, after spraying the plants the lack of soil in the pots prevented root development and thus the increase of dry weight was not sufficient to differentiate between the treated and the non-treated plants.

SUMMARY

Sethoxydim and fluazifop-butyl showed good potential for controlling common and giant bermudagrass. Doses as low as 0.11 kg/ha damaged these grasses, and over 0.22 kg/ha gave satisfactory control on common bermudagrass, but for giant bermudagrass 0.45 kg/ha was required. There was no significant difference between 0.45 and 0.9 kg/ha in both varieties, so 0.45 kg/ha was determined as the most effective rate of these herbicides to control bermudagrass. Clipping the foliage at different intervals did not affect the control of common and giant bermudagrass. Therefore, the translocation of sethoxydim and fluazifop-butyl seems to occur within the first 12 hours after spraying. The response of the varieties of bermudagrass was different when the herbicides were compared against glyphosate. In common bermudagrass, the three herbicides caused the same effect and control. In giant bermudagrass glyphosate showed slightly better control; however, there was not statistical difference with sethoxydim and fluazifop-butyl. In spite of this difference, the control with sethoxydim and fluazifop-butyl was satisfactory in both varieties and comparable with that of glyphosate. Further studies on crop tolerance are needed before making recommendations for their use in control of common and giant bermudagrass.

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