AN ABSTRACT OF THE THESIS OF

Carol J. Maggard for the degree of Master of Science

in Horticulture presented on June 3, 1983.

Title: Annual Bluegrass (Poa annua L.) Control in Turf with Ethofumesate

Abstract approved:

Garvin D. Crabtree

Ethofumesate (2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate) was examined for its efficacy in controlling annual bluegrass (*Poa annua* L.) and its phytotoxicity on three cool-season turfgrasses in the Willamette Valley of Oregon.

The herbicide caused little or no damage to established perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.) turfs. Trials with colonial bentgrass (*Agrostis tenuis* Sibth.), however, did indicate some lack of tolerance to the herbicide. In trials involving preemergence and postemergence applications of ethofumesate on annual bluegrass, results indicated excellent control up to the three-leaf stage, but only moderate control once the plant was tillered. Little difference was seen between biotypes of annual bluegrass in response to ethofumesate applications.

In another study, ten cultivars of perennial ryegrass varied in their response to preemergence treatments of ethofumesate. 'Regal' and 'Derby', in particular, exhibited a significant decrease in

emergence. A trial was undertaken to determine the optimum timing and rate of ethofumesate application for annual bluegrass control in newly seeded ryegrass. Best ryegrass growth, as well as excellent annual bluegrass control, was observed when sequential treatments of ethofumesate at low rates were applied early postemergence to the ryegrass.

ANNUAL BLUEGRASS (*POA ANNUA L.*) CONTROL IN TURF WITH ETHOFUMESATE

by

Carol J. Maggard

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 3, 1983

Commencement June 1984

APPROVED:

Professor of Horticulture in charge of major

Head of department of Horticulture

Dean of Graduate School

Date thesis is presented June 3, 1983

Typed by Carol Maggard

ACKNOWLEDGEMENTS

I would like to thank Dr. Garvin Crabtree and Mr. Tom Cook for their guidance, help, and most of all, their patience throughout the course of my graduate training at Oregon State University.

I also extend my sincere appreciation to Mr. Larry Burrill, Mr. Bill Brewster, Dr. Arnold Appleby, and past and present staff and graduate students of the weed science project in crop science. Their 'adoption' has not only greatly expanded my knowledge of weed science principles and practices, but they have provided much encouragement and support which has aided in the completion of this undertaking.

To my fellow graduate students, I offer my thanks for their assistance, and, most of all, their friendship. Appreciation is expressed especially to Rich Bonanno for his assistance when it came time for 'THE COMPUTER'. To Rich Beeson, Eric Hanson, Mosbah Kushad, Ricardo Silberman, and the many other friendships I have found over the years, I am especially grateful.

And to the office staff of the department, I give a sincere 'thank-you' for all of the help, support, and friendship I have received during my stay.

I would like to thank BFC Chemicals of Wilmington, Delaware for supplying the herbicides and partial funding needed for this research.

For the duration of my research, I gratefully acknowledge the financial support provided by the Oregon State University Agricultural Experiment Station, the Department of Horticulture, and the Department of Computer Science.

And especially to my husband, Tom, I express my gratitude for his ever-present understanding, encouragement, and love.

TABLE OF CONTENTS

Page

CHAPTER 1. INTRODUCTION 1

CHAPTER 2. REVIEW OF LITERATURE 3

I. THE PLANT: ANNUAL BLUEGRASS. 3

CONTROL OF ANNUAL BLUEGRASS 7

CULTURAL CONTROL 7

CHEMICAL CONTROL 9

PREEMERGENCE CONTROL 10

POSTEMERGENCE CONTROL 12

II. THE HERBICIDE: ETHOFUMESATE 16

SUSCEPTIBLE WEEDS 16

CROPS SHOWING SELECTIVITY 17

ETHOFUMESATE USE IN TURFGRASS 18

CROP RESPONSE 20

UPTAKE AND TRANSLOCATION 21

MODE OF ACTION AND SELECTIVITY 22

PERSISTANCE AND MOVEMENT IN SOIL. 22

OTHER FACTORS INFLUENCING
ETHOFUMESATE ACTIVITY 24

CHAPTER 3. EFFECT OF ETHOFUMESATE ON ANNUAL BLUEGRASS
AND THREE COOL-SEASON TURFGRASSES 25

ABSTRACT 25
INTRODUCTION 27
MATERIALS AND METHODS 29
RESULTS AND DISCUSSION 32
LITERATURE CITED 38

CHAPTER 4. PERENNIAL RYEGRASS RESPONSE TO ETHOFUMESATE 40

ABSTRACT 40
INTRODUCTION 42
MATERIALS AND METHODS 43
RESULTS AND DISCUSSION 45
LITERATURE CITED 51

CHAPTER 5. CONCLUSIONS 53

BIBLIOGRAPHY 55

APPENDICES. 65

LIST OF FIGURES

Figure		Page
1.	Effect of ethofumesate on annual bluegrass when applied at various growth stages	35
2.	Effect of ethofumesate on five biotypes of annual bluegrass when applied at the 5-tiller stage	37
3.	Effect of rate and timing of ethofumesate application on perennial ryegrass turf	48
4.	Percent annual bluegrass in perennial ryegrass seeded plots treated with ethofumesate	49

LIST OF TABLES

Table		Page
1.	Effect of formulation and rate of ethofumesate on the quality of three established turfgrasses 5 weeks after application.	33
2.	Effect of formulation and rate of ethofumesate on established colonial bentgrass turf. Fall, 1981.	34
3.	Perennial ryegrass response to preemergence treatments of ethofumesate. Trial 1.	46
4.	Perennial ryegrass response to preemergence treatments of ethofumesate. Trial 2.	47
5.	Herbicides used for control of annual bluegrass.	65
6.	Effect of formulation and rate of ethofumesate on established perennial ryegrass. Summer, 1980.	68
7.	Effect of formulation and rate of ethofumesate on established perennial ryegrass. Fall, 1980.	69
8.	Effect of formulation and rate of ethofumesate on established perennial ryegrass. Spring, 1981.	70
9.	Effect of formulation and rate of ethofumesate on established perennial ryegrass. Summer, 1981.	71
10.	Effect of formulation and rate of ethofumesate on established perennial ryegrass. Fall, 1981.	72
11.	Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Fall, 1980.	73
12.	Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Spring, 1981.	74
13.	Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Summer, 1981.	75
14.	Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Fall, 1981.	76
15.	Effect of formulation and rate of ethofumesate on established colonial bentgrass. Summer, 1980.	77

Table		Page
16.	Effect of formulation and rate of ethofumesate on established colonial bentgrass. Fall, 1980.	78
17.	Effect of formulation and rate of ethofumesate on established colonial bentgrass. Spring, 1981.	79
18.	Effect of formulation and rate of ethofumesate on established colonial bentgrass. Summer, 1981.	80
19.	Effect of ethofumesate applied to several growth stages of annual bluegrass. Seeded March, 1981.	82
20.	Effect of ethofumesate applied to several growth stages of annual bluegrass. Seeded June, 1981.	83
21.	Effect of ethofumesate applied to several growth stages of annual bluegrass. Seeded October, 1981.	84

Note: This thesis is presented as two papers written in the format required by Weed Science, journal of the Weed Science Society of America.

CONTRIBUTION OF AUTHORS

The senior author of the following manuscripts was responsible for the design, execution, and reporting of the described research. Dr. Garvin Crabtree served as major professor, providing guidance in research direction, data management, and editing of the manuscripts. Mr. Tom Cook was the resource person for the project, providing much help in research strategy and guidance, assisting in the execution of part of the research, as well as in editing of the manuscripts.

ANNUAL BLUEGRASS (*POA ANNUA* L.) CONTROL IN TURFGRASS WITH ETHOFUMESATE

CHAPTER 1

INTRODUCTION

Annual bluegrass (*Poa annua* L.) is one of the most widely distributed turfgrass weeds in the world, and one of the most serious in the Pacific Northwest. Mild, wet winters and relatively cool summers of this area are nearly ideal for annual bluegrass growth. Its light green color, prolific seedhead production at all mowing heights, and susceptibility to stress make it an unacceptable component of fine turf.

Extensive research on cultural and chemical control of this grass has been done over the last fifty years, and yet, it remains a serious problem. Annual bluegrass thrives under low mowing, frequent irrigation, and high fertility conditions, i.e. golf greens. Preemergence herbicides have been found to be effective on annual bluegrass, but often result in reduced growth and vigor of the desirable turf. Overseeding is also often delayed since germination of overseeded grass will usually be inhibited. Work with postemergence herbicides has been more limited than that with preemergence controls. These chemicals are often phytotoxic to desirable turfgrass. In addition, if annual bluegrass constitutes a high percentage of ground cover, death of these plants will result in large, unsightly patches of bare ground.

Ethofumesate (2-ethoxy-2, 3-dihydro-3, 3-dimethyl-5-benzofuranyl methanesulfonate) is a recent addition to the list of chemicals showing promise for annual bluegrass control. Developed for use in sugarbeets (Beta vulgaris L.), it is now being used as a broad spectrum herbicide in several crops. Perennial and Italian ryegrass (Lolium perenne L. and L. multiflorum Lam.) have exhibited particular tolerance to ethofumesate, and the herbicide has been extensively tested for use in ryegrass seed fields. Recently, investigations on turf have confirmed this tolerance of ryegrass, and have indicated ethofumesate may have potential for weed control in turfgrass.

This study examines effects of ethofumesate on annual bluegrass and desirable turfgrasses under Willamette Valley conditions. The herbicide was examined for its phytotoxicity to desirable turfgrasses in respect to timing of application, and to rate and formulation of herbicide. Trials were also conducted to determine its effectiveness on various growth stages and biotypes of annual bluegrass. In addition, a study was conducted with perennial ryegrass to detect any differences in germination due to timing of ethofumesate applications, or cultivar response.

CHAPTER 2

REVIEW OF LITERATURE

I. THE PLANT; ANNUAL BLUEGRASS

Annual bluegrass (*Poa annua* L.) is a tufted, generally low growing bright green grass that inhabits most populated regions of the world. It is thought to be of Mediterranean origin (112), and introduced to North America by Spanish explorers (63).

Annual bluegrass is considered an allotetraploid (2n=28) (114). Tutin (112) postulated that this species originated from a cross between *Poa infirma* H.B.K., an annual species, and *Poa supina* Schrad., a creeping perennial. However, Koshy (73) suggested that it might have been derived from one set of chromosomes from either *P. supina* or *P. infirma*, plus a second set from an unknown species.

Although in some cases an effort is made to establish and maintain annual bluegrass turf, the grass is generally considered a weed. Its light green color, prolific seed production, and susceptibility to diseases and environmental stresses make it an undesirable component in most turfgrass areas.

Several extensive literature reviews on annual bluegrass are available (6, 49, 108, 117). Complete taxonomical and physiological descriptions of the plant are included in these reviews, as well as adaptation, culture and control methods.

Several growth forms of annual bluegrass have been noted. Tutin (113) was first to acknowledge that variations of annual bluegrass existed. Although it has generally been considered an annual species, taxonomic and genealogical studies of annual bluegrass have indicated that perennial types also exist.

Most agree that two main variants of annual bluegrass exist: erect, quick-flowering annual types, and prostrate, perennial types that reproduce more slowly (24, 37, 49, 50, 63, 117). Gibeault (48) also describes a third main type -- var. aquatica, found mostly under wet conditions.

Gibeault and Goetze (50) have classified these variations as subspecies. However, Warwick (117) does not consider them to represent good subspecies according to definition by Stebbins (106) since they are not geographically isolated, and frequently can be found inhabiting the same area. A list of 48 recorded varieties compiled by Mr. C.E. Hubbard of Kew Botanic Gardens has been provided by Gibeault (48), with descriptions of most of these in a later publication (50). The term 'variety' here is used loosely, and refers to differences in growth habit, length of life, types of leaves, color, etc. According to Gibeault and Goetze (50), these variations could be due to physiological races, genetic mutations, or ecotypical adaptations. Koshy (73) has determined that annual bluegrass is fully self-compatible in breeding. Although most reproduction occurs by in-breeding, 0 to 15% of reproduction is attributed to out-crossing, depending upon environmental conditions and the population. Ellis (37) studied the variation in annual bluegrass and determined that the breeding system, chromosome pairing and phenotypic plasticity may be interrelated to control variability in the species. This paper will refer to the variations in growth form as biotypes.

As stated before, annual bluegrass falls into two main categories: annual and perennial. The annual types appear to have evolved more recently than perennials (106). Hovin (63) and Gibeault and Goetze (50) differentiate between these growth forms. In general, annual types of annual bluegrass occur at low elevations, while perennial biotypes are often found in mountainous areas or continually moist areas. While annuals exhibit an erect growth habit, and produce few tillers, perennials are prostrate or semi-prostrate and produce many tillers. Perennials are capable of forming tillers and roots from nodes to aid in stoloniferous spreading of the plants. A correlation has also been suggested between growth habit and leaf width. Cordukes (24) noted that annual plants often have wide leaves, while perennial types have narrow leaves.

The reproductive system of the two growth forms differ considerably. Annuals reach maximum seedhead production in May and June, then die. Perennial types of annual bluegrass flower later in the season, and may live two to three years, although the life span is not certain (117). Hovin (63) found that seeds from annual types require a dormancy period in order to germinate, while perennials do not. This is contrary to Warwick and Briggs (118) who found little or no differences in seed dormancy requirements. Annuals generally will produce seedheads 44 to 55 days after germination, while it takes 81 to 93 days for perennials to flower (49, 114, 118).

The ecological conditions of an area play a very important role as to which growth form of annual bluegrass will be found. Annual types appear to be opportunistic, existing in habitats such as meadows, open fields (74), orchards (124), golf course roughs (50), and flower beds (118). Perennial types are more common in high density populations (74) such as golf course putting greens (50) and bowling greens (118). Under high density-dependent situations such as these, plants with the highest carrying capacity in the environment will prevail, while under density-independent situations, the plants with highest rate of population increase will dominate (74). Thus, perennial biotypes of annual bluegrass, with their more vigorous vegetative growth can survive densely populated situations better than annual types.

Cultural practices may also play a major role in determining the compositon of an annual bluegrass population. Hovin (63) observed that if annual bluegrass plants are cut slightly above ground level at the first seed formation, annuals will show only slight regrowth and will not survive a second clipping, but perennials will continue growth. Warwick and Briggs (118) observed that under clipping, more energy goes into vegetative production, encouraging adaptation of perennial types. Gibeault and Goetze (50) suggested that the population was correlated to water supply. Golf course roughs, which receive little water, contained basically all annual types of the species, whereas the frequently irrigated putting greens had mainly perennial types. Fairways, with deep, but infrequent irrigation, served as a habitat for both growth forms, but contained mostly annual types.

Hovin (63) reported that the annual form was much more common in the United States. However, surveys by Gibeault (49) and Cook (20) found that over 50% of the samples collected from Oregon and Washington golf courses were perennials. Most of these perennial types were found on putting greens and fairways. A survey of annual bluegrass in Canada by Cordukes (24) found more prostrate or semi-prostrate plants than erect ones.

Control of annual bluegrass

Cultural control

The best control for any weed in a turf situation is a healthy, dense stand of the desirable turfgrass. Any cultural practice that weakens turf will allow annual bluegrass invasion. Stress from lack of or excessive water, too-close mowing, compacted soils, improperly timed soil cultivation, traffic, wear, or disease will result in reduced turfgrass competition (5, 124). Selecting the proper turfgrass is important. New varieties of desirable turfgrasses offer more aggressive germination and growth, disease resistance, and adaptation to close mowing (6).

Mowing height affects annual bluegrass populations. Bogart and Beard (13) have found that the optimum cutting height for this species is 2.5 cm. But in later trials, Brede and Duich (15) observed more annual bluegrass at a cutting height of 1.3 cm than at 2.5 cm.

Vertical mowing and coring should be timed to avoid peak annual bluegrass germination (6). Under the mild conditions of the Pacific Northwest, germination occurs year around, but with peak periods in fall, and to a lesser extent, during spring. Overseeding should be done under conditions which allow the turfgrass to compete strongly.

Fertilization may be an effective tool in controlling this weed. Goss and his colleagues (54,55) observed that high levels of sulfur and low levels of phosphorus significantly reduced annual bluegrass levels. Low nitrogen levels had the same effect. Excessive nitrogen or phosphorus or an improper balance of nutrients often resulted in increased annual bluegrass. Heavy applications of acid-based fertilizers such as ammonium sulfate may lower soil pH below the tolerable level of annual bluegrass, which is 5.6 (105). However, this lower pH is likely to inhibit growth of desirable turfgrass.

Disease and insect control is also important in maintaining competitive ability of a turf. Fungicide treatments have been found to reduce annual bluegrass populations, presumably by increasing vigor of the desirable turfgrass and allowing it to compete with annual bluegrass for available resources (15). However, in situations where there is little competition, fungicide applications may allow annual bluegrass to thrive since they reduce the chance of invasion by disease organisms.

Chemical control

Although a cultural control program is a very important part of preventing infestation or controlling annual bluegrass in a turfgrass area, it will not accomplish this goal by itself. Even with an excellent cultural program, annual bluegrass eventually will become a problem, and chemical control measures will be necessary in order to maintain a quality turf.

Attempts at chemical control began in the 1930's when Sprague and Burton (105) observed that lead arsenate greatly reduced the amount of annual bluegrass in colonial bentgrass turf. Daniel (25) later reported that calcium arsenate, lead arsenate, and sodium arsenite removed annual bluegrass from Kentucky bluegrass and colonial bentgrass turfs. The arsenicals have been studied extensively for preemergence and early postemergence control of annual bluegrass (17, 18, 27, 38, 41, 52, 65, 69, 70, 71). Good annual bluegrass control has been observed with arsenicals, but often with turf injury (25, 40). Engel et al. (40) reported that bentgrass turfs suffered a 50% reduction in quality when calcium arsenate was applied.

Because of this phytotoxicity and removal of arsenicals from the market, many other chemicals have been examined for their effectiveness in controlling annual bluegrass and phytotoxicity to desirable turfgrasses. In general, these chemicals have fallen into one of two categories:

1. Preemergence control of annual bluegrass in established turf.

2. Selective postemergence control of established plants in an existing turf.

Preemergence Control

The list of preemergence herbicides which have shown promise for controlling annual bluegrass is extensive. Many of these chemicals, however, have exhibited inconsistant results in their effectiveness or their phytotoxic effects on the turfgrass. See Appendix A for listing of the herbicides mentioned below which have been evaluated for annual bluegrass control and their chemical names.

In the 1950's, several researchers observed good control with neburon, with very little damage to bentgrass turf (18, 52, 89). DSMA and chlorpropham were also shown by Mruk and DeFrance (89) to have possibilities of success. Several copper compounds were tested by DeFrance and Kollett (89) with some promising results. Dichlobenil provided effective control, but often with severe injury to bermudagrass turf (19, 29).

Since 1960, herbicides such as DCPA, DMPA, trifluralin, terbutol, benefin, and bensulide have been studied for annual bluegrass control in turf. These herbicides generally give very good preemergence control (10, 11, 18, 29, 41, 53, 70). However, some of these chemicals are mitotic inhibitors and produce phytotoxic effects on turfgrass. Others, for various reasons, have also proven unacceptable for annual bluegrass control. Goss (53) noted that DCPA, bensulide, and trifluralin inhibited root development of bentgrass. Juska and Hanson (70,71) observed retarded stand and vigor of several turfgrasses when DCPA, DMPA, and trifluralin were applied. These researchers also noticed that several of these preemergence herbicides showed a trend of less annual bluegrass control at higher soil phosphorus levels. DCPA and trifluralin have been found by Gaskin (46) to greatly inhibit rhizome and tiller production in Kentucky bluegrass. Bingham (8) reported that inhibition of root development in bermudagrass (Cynodon dactylon L.) was caused by DCPA, DMPA, benefin, and bensulide. Reduction of root and rhizome growth in Kentucky bluegrass due to these chemicals was also noticed by Engel and Callahan (40) and Juska and Hovin (72). In studies done by Downing et al., DCPA displayed low initial toxicity when applied to bermudagrass, but injury gradually increased. Continued use of these herbicides often resulted in loss of turf either as a result of direct phytotoxicity or because repeat applications weakend the grass' ability to withstand stress from disease organisms (17, 108, 111). Quality loss was found to often be associated with stress periods (109). Turgeon et al. (109) observed that Kentucky bluegrass was much more tolerant to repeated applications of seven common preemergence herbicides than red fescue (Festuca rubra L.). The residual effect of these herbicides is important in controlling annual bluegrass and in determining the consequence to established or overseeded grasses. Bingham and Schmidt (9) noted that persistance of bensulide in soil varied with formulation. They found that the emulsifiable concentrate degraded more rapidly than the flowable formulation. Residual effects of DCPA, DMPA, terbutol, and benefin delayed normal rooting from nodes in bermudagrass for twelve weeks. Juska and Hanson (70) found that 'Merion' Kentucky bluegrass was the most resistant of several turfgrass species to residual effects of various preemergence herbicides.

Neidlinger (90) examined bromacil as a preemergence control for annual bluegrass in seed fields, and found that it provided selective control. Gibeault (48) also reported that bromacil selectively controlled annual bluegrass and that it allowed overseeding of red fescue and colonial bentgrass one week after application.

Recent work with oxadiazon (11, 66, 68) has shown that this herbicide has potential for preemergence annual bluegrass control with fall treatments. Spring treatments often result in poor control and turfgrass injury.

Postemergence Control

Many of the herbicides used in preemergence trials have also been tested as postemergence herbicides. Engel et al. (41) noticed a more severe loss of turf quality with bensulide in turfgrass plots with a higher population of annual bluegrass. This was attributed to the postemergence action of the herbicide on the annual bluegrass. Similar results were reported by Neidlinger et al. (91), as well as moderate selective postemergence control with terbacil and bromacil.

Several chemicals have been examined for seedhead suppression of annual bluegrass. 4-Fluorophenoxyacetic acid suppressed seedhead production and induced sterility without damaging the vegetative plant or other turfgrasses (3). Maleic hydrazide (MH) was also promising for seedhead suppression. However, it often produced intolerable injury to the desired turfgrasses (38, 65, 122).

Endothal has been used alone as a growth regulator or in combination with MH to suppress seedhead production in annual bluegrass. Maestri and Currier (79) determined that MH enhanced penetration of endothal when used in combination. They also found that endothal is antagonistic to MH at certain concentration levels. Chlorflurenols have also been used in combination with MH (122, 123). Seedhead inhibition was observed, but often with unacceptable injury to turf.

Endothal has perhaps shown the most promise as a postemergence control for annual bluegrass. Cockerham and Whitworth (19) reported severe damage to the weed with repeat applications of endothal, and with no visible injury to bermudagrass. Engel and Aldrich (38) noticed that two to three applications of endothal at two-week intervals gave consistantly good reduction of annual bluegrass in bentgrass turf. Turgeon et al. (110, 111) observed that low rates of endothal suppressed annual bluegrass with little injury to Kentucky bluegrass or bentgrass turfs. Watschke et al. (123) also reported that multiple foliar applications of endothal at low rates gave better seedhead inhibition and longer-lasting results than single applications. These researchers also found that endothal caused foliar discoloration at any rate that resulted in at least 90% seedhead inhibition. Turgeon and Penner (111) observed that higher rates will often cause temporary browning of turf. Cook (21, 22) has found that discoloration with use of endothal is inevitable. However, recovery of Kentucky bluegrass turf will generally occur within three weeks (22, 110,121).

Turgeon and Penner (111) and others (16,122), in studies done in the northeastern and north central United States, have noted that the granular formulation of endothal provided greater selectivity than liquid formulation, and resulted in less browning of the turf. Soil type was noted as a factor in production of variable results, however. Watschke and Duich (121) reported that the chemical may accumulate in soil with repeated granular applications.

In general, effects of endothal are variable and depend upon type of turf (21) and timing of application (108). Other growth regulators have recently been tested on annual bluegrass. Mefluidide and MBR 18337 have produced seedhead inhibition and growth reduction of the grass (23, 100). However, growth of perennial ryegrass and bentgrass was also reduced and discoloration of desirable turfs was evident (16, 23, 100). One of the more recent herbicides to be examined for postemergence control of annual bluegrass has been linuron. In 1976, Jacquemin and Henderlong (64) reported that linuron provided satisfactory control in Kentucky bluegrass turf. Jagschitz (66, 67) has since reported similar results. Linuron does not appear to be selective in creeping bentgrass (Agrostis palustris Huds.), hard fescues (Festuca spp. L.), or perennial ryegrass (64).

Note should be made that biotypes of annual bluegrass have reacted differently to applications of endothal and linuron. Turgeon and Penner (111) reported that annual types of the species were far more sensitive to root treatments of endothal than perennial types.

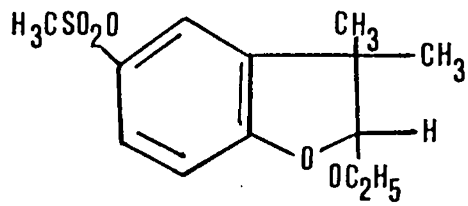
This was attributed to differences in absorption and action of the herbicide. Similar results were found following foliar application. Morphological differences between biotypes contributed to physiological variability in response to this herbicide. Likewise, the prostrate, perennial ecotype, in its mature form, was found somewhat more susceptible to linuron by Warwick et al. (120). The researchers attributed this difference to the assumption that a higher concentration of herbicide reached active sites within the plant because of greater root and vegetative growth.

Ethofumesate is perhaps the most recent chemical to be tested for control of annual bluegrass in turf. An in-depth look at this chemical and its effectiveness is presented below.

II. THE HERBICIDE: ETHOFUMESATE

Ethofumesate is a methanesulfonate compound produced by BFC Chemicals of England (107).

Chemical structure:



Chemical name: 2-ethoxy-2, 3-dihydro-3, 3-dimethyl-5-benzofuranyl methanesulfonate

Ethofumesate has been marketed as Nortron by BFC Chemicals for several years. Nortron is available as a 1.5 lb ai/gallon (.18 kg/l) emulsifiable concentrate, a 4.0 lb ai/gallon (0.5 kg/l) flowable, and as a 10% granular formulation. The flowable formulation received registration in October, 1981 for use in turfgrass and is marketed by BFC Chemicals as Prograss.

Ethofumesate has a low vapor pressure, 6.45×10^{-7} mm Hg at 25 C. (115), and low water solubility, 110 ppm at 25 C. (7, 46). As active ingredient or formulated, ethofumesate has a low acute oral or dermal toxicity. The oral LD_{50} of the technical material in rats is greater than 6400 mg/kg (7, 46).

Susceptible Weeds

Ethofumesate has been proven an effective control of many annual grass and broadleaf weeds. It has been shown to provide excellent control of annual bluegrass (26, 36, 60, 76, 77, 78, 116), blackgrass (*Alopecurus myosuroides* Huds.) (84), red fescue (4, 12, 60), rattail fescue (Festuca myuros L.) (35), common chickweed (Stellaria media L.) (36, 60, 95), redroot pigweed (Amaranthus retroflexus L.) (31, 34, 92, 96), common lambsquarters (Chenopodium album L.) (34, 95, 96), and volunteer small grains (26, 36, 77). Excellent barleygrass (Hordeum murinum L.) control in pastures has been reported from New Zealand (1, 61, 87, 93). Other weeds such as wild oats (Avena fatua L.) (84), roughstalk bluegrass (Poa trivalis L.) (4, 94), prostrate knotweed (Polygonum aviculare L.) (96), velvetgrass (Holcus lanatus L.) (4), barnyardgrass (Echinochloa crus-galli L.) (92), and white clover (Trifolium repens L.) (1, 61, 93) appear to be controlled by this chemical.

Resistant weeds include red deadnettle (Lamium purpureum L.), field pennycress (Thlaspi arvense L.) and mustards (Brassica spp.). The Compositae family has proven markedly resistant to ethofumesate (7, 46, 87, 96).

Crops Showing Selectivity

Sugarbeets. Ethofumesate was originally developed for broad spectrum weed control in sugarbeets. It has been used in Europe, and more recently, in the United States, for this purpose (34, 62, 92, 96, 101). Sugarbeets have shown a high tolerance to preemergence and postemergence treatments of ethofumesate (62, 96).

Vegetables. McLean (82) reported good crop tolerance in onions (Allium cepa L.) when ethofumesate was applied preemergence and postemergence. Other crops showing selectivity include field beans (Phaseolus vulgaris L.), tobacco (Nicotiana tabacum L.), peas (Pisum *sativum* L.), carrots (*Daucus carota* L.), and sunflowers (*Helianthus annuus* L.) (35).

Ryegrass. Work in New Zealand and Europe in the early 1970's indicated high tolerance of ryegrass pastures to ethofumesate (1, 12, 61, 87, 93). Extensive studies in European ryegrass seed fields have determined that Italian and perennial ryegrass (*Lolium multiflorum* Lam. and *L. perenne* L.) are very tolerant to ethofumesate applied preemergence or postemergence (4, 60, 84, 95, 115). Subsequent work by Lee (76, 77, 78) has confirmed this tolerance in ryegrass seed fields under Willamette Valley environmental conditions.

Ryegrass has exhibited the greatest tolerance to ethofumesate when it is applied to the surface rather than by soil incorporation (4). No differences in ryegrass cultivar response to the herbicide have been noted.

Ethofumesate Use in Turfgrass

Ethofumesate has recently been tested for annual bluegrass control in fine turf areas. Test results have confirmed high tolerance of perennial ryegrass to preemergence and postemergence applications (57, 58, 125). Work in grass seed fields and pastures has also indicated that ethofumesate is selective in established stands of fescues, bentgrass, Kentucky bluegrass (26, 36), and orchardgrass (*Dactylis glomerata* L.) (1). Tolerance of tall fescue (*Festuca arundinacea* Schreb.) to preemergence treatments of ethofumesate has been noted (57). Growth inhibition and discoloration of other turfgrasses has been observed following postemergence application (28, 125).

Control of annual bluegrass in perennial ryegrass areas has proven promising. Dickens (28) reported that ethofumesate provided selective preemergence control of annual bluegrass in perennial ryegrass overseeded on dormant bermudagrass putting greens. Goldsworthy et al. (51) observed that ethofumesate applied preemergence at 2.0 kg/ha to newly sown ryegrass resulted in 98 to 100% control of annual bluegrass and 100% control of _Stellaria media_. They noted the best time of application was fall to early winter. Haggar and Bastian (58) observed in newly sown ryegrass that as ethofumesate rates increased, annual bluegrass yield decreased and ryegrass yields increased. Haggar and Passman (59) reported that ethofumesate caused a significant reduction in ryegrass tillering; however, total yield increased because of the lack of competition due to control of annual bluegrass. Goldsworthy et al. (51) reported a 35% increase in dry matter yield of ryegrass with use of ethofumesate.

Haggar and Bastian (58) found annual bluegrass more resistant to control as it matured. At least 3.0 kg ai/ha was required to reduce yield in fully tillered annual bluegrass, whereas, less than 1.0 kg ai/ha applied preemergence provided control. Control of annual bluegrass has been reported from a single postemergence application of ethofumesate at 1.0 kg ai/ha (83).

McLean (83) aimed at continuous preemergence or very early postemergence control by using sequential applications of ethofumesate at low rates to gradually remove annual bluegrass from established bentgrass and chewings fescue (Festuca rubra var. commutata Gaud.) turfs.

Preliminary investigations with ethofumesate in the Pacific Northwest on Kentucky bluegrass and bentgrass turfs revealed very little phytotoxicity to either turfgrass. Annual bluegrass control was reported, but with no significant differences between single and sequential applications. Ethofumesate did provide postemergence, as well as preemergence control (88).

Residual control of susceptible weeds for up to twelve weeks has been observed following applications of 2.0 kg ai/ha ethofumesate (35, 96).

Crop Response

Several researchers have reported occasional leaf deformities in sugarbeets treated with ethofumesate (34, 62, 96). Pfeiffer and Holmes (96) attribute these deformities to adhesion of the expanding leaf to itself. The condition is usually temporary, with rate of recovery dependent upon rate of ethofumesate applied and the rate of plant growth. High temperatures and light intensity may also cause an increase in frequency of leaf deformities (57, 62). These researchers suggest that varietal differences in response to ethofumesate may occur.

Temporary growth delays under wet, cool conditions have been noted for ryegrass (34) and sugarbeets (96). Allen et al. (1) reported a slight delay and reduction in ryegrass emergence when treated with a preemergence application of 4.5 kg ai/ha ethofumesate.

In several trials, ryegrass seed yields were found to be increased by application of ethofumesate (1, 45, 76). Increase in seed yields were attributed to less competition (77). However, in some trials, ethofumesate treated ryegrass fields exhibited increased growth and a darker green color (4).

Studies by Leavitt et al. (75) and Duncan et al. (31) have determined that ethofumesate inhibits epicuticular wax deposition on leaves. Gas-liquid chromatography analysis determined that ethofumesate decreased deposition of alkanes and sec-ketones, but increased deposition of long-chain waxy esters. Cuticular transpiration of ethofumesate treated leaves was increased.

Uptake and Translocation

Ethofumesate is generally taken into plants via the emerging hypocotyl growing through treated soil, with root absorption being important in some broadleaf species (35). Since it is non-volatile, uptake always occurs through an aqueous solution (7,46).

It has not been determined whether ethofumesate is actually translocated through the plant, or if it is converted to metabolites before, during, or after translocation (42).

Eshel et al. (42) studied uptake in sugarbeets and found that soil applied ethofumesate or a metabolite was absorbed mainly by roots and rapidly translocated upward. While these researchers found no accumulation of ethofumesate in roots, Duncan et al. (31) observed a higher concentration in roots of sugarbeet and other tolerant species than in susceptible species.

Foliar application to sugarbeets resulted in ethofumesate or a metabolite being translocated upwards immediately, but with no translocation out of treated leaves (32). These researchers concluded that ethofumesate or its metabolite was not capable of entering the phloem after foliar application.

Mode of Action and Selectivity

Duncan et al. (30) examined mode of action of ethofumesate and determined it to be a rapid inhibitor of respiration and photosynthesis. While tolerant and susceptible species showed this initial inhibition at the two to four-leaf stage, tolerant species recovered within 96 hours. Later studies by these researchers indicated that tolerant plants were able to metabolize the chemical rapidly, while susceptible species had a slow metabolic rate which contributed to their response. Results indicated that different mechanisms may be responsible for detoxifying ethofumesate in various tolerant species.

Persistance and Movement in Soil

Breakdown of ethofumesate in soil has been found to be almost entirely by microorganisms (115). Consequently, moisture and temperature have been found to be major factors determining persistance in soil. The herbicide has been found to decompose much more quickly under warm, wet conditions than cool, dry conditions

(97, 99, 115). Schweizer (104) found that ethofumesate applied in November persisted about twice as long as that applied in March.

Under moderate conditions of temperature and moisture, ethofumesate is relatively resistant to enzymatic or chemical decomposition (115). However, McAuliffe and Appleby (81) found that ethofumesate activity was greatly decreased when applied to a dry soil, even when moisture was applied in 48 hours. They suggested chemical degradation was responsible for this loss of activity. Further studies have confirmed this hypothesis (80).

Soil type also influences persistance of ethofumesate. Schweizer (104) found the average half-life in sandy loam soil to be 7.7 weeks, while in loam soil it was 12.6 weeks. He reported that the rate of degradation was not dependent upon the rate of application. The work of van Hoogstraten et al. (115) and Rahman (97) suggested that the amount of residual activity was regulated by the rate of application.

Ethofumesate has been classified as a moderately mobile herbicide (7,46). Because of its low water solubility and soil adsorption, it generally has not been found to leach beyond five to ten centimeters depth in soil (99, 115). Rahman (97) reported that concentration of ethofumesate was much higher in the top five centimeters than in the five to ten centimeter layer. Movement of the chemical was found to be similar in sandy loam and loam soils, and was independent of the rate of application (104).

Other Factors Influencing Ethofumesate Activity

Besides the above mentioned factors of soil moisture and temperature, other edaphic or environmental conditions may influence ethofumesate activity. Rahman (98) has reported increased phytotoxicity when ethofumesate was applied with phosphorus to soil. Van Hoogstraten et al. (115) indicated that pH may play a role in soil persistance. Haggar and Burton (58) observed that herbicidal activity was reduced by organic matter, but other research does not support this finding (57).

CHAPTER 3

EFFECT OF ETHOFUMESATE ON ANNUAL BLUEGRASS (*POA ANNUA* L.) AND THREE COOL-SEASON TURFGRASSES

Maggard, C.J., G.D. Crabtree, and T.W. Cook

Department of Horticulture, Oregon State University, Corvallis, Oregon 97331

Additional index words. *Lolium perenne* L., *Poa pratensis* L., *Agrostis tenuis* Sibth., biotype, phytotoxicity

ABSTRACT. Ethofumesate (2-ethoxy-2. 3-dihydro-3, 3-dimethyl-5-benzofuranyl methanesulfonate) was examined for its effect on three established cool-season turfgrasses and annual bluegrass (*Poa annua* L.) in the Willamette Valley of Oregon. Perennial ryegrass (*Lolium perenne* L.) and Kentucky bluegrass (*Poa pratensis* L.) were found to be very tolerant of ethofumesate. Little activity was apparent up to the 1.5 kg/ha rate applied and no significant differences were found among the emulsifiable concentrate, flowable, or granular formulations. Colonial bentgrass (*Agrostis tenuis* Sibth.) showed considerable injury at higher rates. Ethofumesate exhibited excellent control of annual bluegrass when applied preemergence. Control was also observed with early postemergence applications, but injury was slight once the plant was tillered, and the grass

recovered quickly. Little difference was found in the response of several biotypes of annual bluegrass to the herbicide.

INTRODUCTION

Annual bluegrass (Poa annua L.) is a widely distributed weed, and one of the most serious in the Willamette Valley of Oregon. The mild, wet winters and relatively cool summers are ideal for annual bluegrass growth. This species is found ranging in growth habit from an upright, annual, bunch grass to a prostrate creeping perennial (3,5,7,12).

The extensive list of chemicals tested for annual bluegrass control can be divided into two categories: 1) those used for pre-emergence control of annual bluegrass in established turf, and 2) those for selective postemergence control of established plants in existing turf.

Ethofumesate is one of the newest chemicals to be tested for effectiveness in controlling annual bluegrass in turf. Early studies of the herbicide for this purpose were conducted in European ryegrass seed fields. Results indicated that Italian ryegrass (Lolium multiflorum Lam.) and perennial ryegrass are tolerant to ethofumesate applied preemergence or postemergence to the crop. Subsequent work by Lee (8, 9, 10) has confirmed tolerance of ryegrass in seed fields and control of annual bluegrass under Willamette Valley environmental conditions.

Tests in grass seed fields indicated that ethofumesate is selective in established fescues (Festuca spp. L.), bentgrass (Agrostis spp. L.) and Kentucky bluegrass (Poa pratensis L.) (2). However, growth inhibition and discoloration of these turfgrasses have been observed following postemergence applications (13).

Herbicide performance in grass seed fields should not be directly compared with herbicide use in turfgrass. Aesthetic quality is more important in turf, and stress caused by frequent low mowing, wear, and compaction may reduce tolerance of desirable grasses to ethofumesate. Increased foliar density due to mowing may also result in increased uptake of the herbicide. In spite of these potential problems, control of annual bluegrass in perennial ryegrass turfs has proven promising. Dickens (1) reported that ethofumesate provided selective preemergence control of annual bluegrass in perennial ryegrass overseeded on dormant bermudagrass (Cynodon spp. L.) putting greens. Other researchers have also noted very good control of annual bluegrass when ethofumesate was applied to newly sown ryegrass areas (4,6).

Haggar and Bastian (6) found annual bluegrass more resistant to control as it matured. They found at least 3.0 kg ai/ha of ethofumesate necessary to reduce dry matter yield in fully tillered plants. However, in another case, control was reported from a single postemergence application of ethofumesate at 1.0 kg ai/ha (11).

Objectives of the research reported here were: 1) to determine the phytotoxicity of ethofumesate to turfgrasses under Willamette Valley conditions, 2) to determine the efficacy of ethofumesate applied at various growth stages to annual bluegrass, and 3) to determine differences, if any, between selected biotypes of annual bluegrass in their response to ethofumesate.

MATERIALS AND METHODS

Turfgrass phytotoxicity. Ethofumesate was applied to perennial ryegrass ('Fiesta', 'Blazer', and 'Dasher' blend), colonial bentgrass ('Highland' and 'Astoria'), and Kentucky bluegrass ('Glade', 'Sydsport', and 'Baron' blend) turf located in the mid-Willamette Valley of Oregon during 1980 and 1981. The trials were conducted on established turf areas growing on a Chehalis silty loam soil.

Treatments were applied in separate trials during spring, summer, and fall to each turfgrass. Three formulations of ethofumesate were tested - emulsifiable concentrate (.18 kg/l), flowable (.5 kg/l) and the 10% granular formulation. Each formulation was applied at 0.3, 0.6, 1.0, and 1.5 kg ai/ha. The 0.3 kg ai/ha rate was omitted in the bentgrass trials due to shortage of turf. Treatments were applied when soil moisture was high or plots were irrigated immediately after application.

The emulsifiable concentrate and flowable formulations were applied with a fixed boom, wheeled plot sprayer using CO_2 as a pressure source, and the granular material was applied uniformly with a hand shaker.

Plots in all trials were 1.5- by 1.5- m. Treatments in each experiment were arranged in a randomized complete block design with three replications.

Visual evaluations were made periodically of ethofumesate effect on aesthetic quality of turfgrass. Ratings were based on turfgrass color, density, and overall quality. A 1 to 9 rating scale was used, in which 1 = no live turf; 6 = acceptable, 9 = ideal. Data were statistically analyzed and treatment means separated using the LSD at the .05 level of probability. Data from each trial were analyzed separately.

Sequential treatments. The flowable formulation of ethofumesate was applied to established Kentucky bluegrass turf growing on a Chehalis silty loam soil. A single application of 1.0 kg ai/ha was applied to all treated plots. This was followed by sequential treatments of 0.5 kg ai/ha at intervals of 1, 2, or 3 weeks. This program was followed for 12 weeks. Every 2 weeks during this time, the plots were evaluated visually using the 1 to 9 rating scale.

Plots 1.5- by 1.5- m were arranged in a randomized complete block design with three replicates. Treatments were applied with the small plot sprayer described earlier.

Susceptibility of various growth stages of annual bluegrass. An annual biotype of annual bluegrass was seeded at 9 g/m^2 in 42- by 42-cm flats filled with coarse sand. Greenhouse temperatures were maintained at 24 C during the day and 18 C at night. A regular fertilization schedule was maintained, with each flat receiving 0.23 kg N/1000 ft^2 every 2 weeks during the trial. A randomized complete block design with four replications was used.

The emulsifiable concentrate formulation of ethofumesate at 1.0, 1.5, and 2.0 kg ai/ha was applied to separate flats. Each rate was applied: (1) immediately following seeding, (2) at the first leaf, (3) third leaf, (4) first tiller, and (5) third tiller stages.

The grass in each flat was visually rated for appearance 3, 5, and 7 weeks after treatment on a 1 to 9 scale.

The experiment was repeated three times, with seeding taking place in March, June, and October. Each trial was analyzed as a separate experiment and means separated using Duncan's multiple range test.

Biotype differences. Annual bluegrass seeds collected from several sources were grown under greenhouse conditions. Several distinct biotypes were vegetatively propagated in coarse sand. Five biotypes were selected and kept as nursery plants. Tillers of each biotype were transplanted into 10- by 10- cm pots and maintained at 24 C during the day and 18 C at night.

Treatments were arranged in a completely randomized design with seven replications. At the five tiller stage of the plants, separate treatments of the flowable formulation of ethofumesate at 1.0, 1.5, and 2.0 kg ai/ha were applied. Plants were rated biweekly for appearance on a 1 to 9 scale for the duration of the test.

The trial was repeated, and the two experiments combined for analysis. Treatment means were separated by the use of Duncan's multiple range test.

RESULTS AND DISCUSSION

Turfgrass phytotoxicity. Established perennial ryegrass was very tolerant of all rates of ethofumesate. There was no visual difference between grass in treated and untreated plots regardless of rate, herbicide formulation, or treatment timing. Kentucky bluegrass exhibited similar tolerance, although some injury was noted at 1.5 kg/ha. Differences were apparent in turf quality more than in color or density. Quality ratings for three turf species are summarized in Table 1.

Colonial bentgrass was less tolerant to ethofumesate than either perennial ryegrass or Kentucky bluegrass. Treatment effects were most apparent from fall, 1981 applications (Table 2). Injury symptoms developed slowly, but were obvious after 5 weeks. Color, density, and quality all declined at higher rates.

Sequential treatments. Sequential applications at 0.5 kg/ha caused no visual injury to Kentucky bluegrass turf, regardless of number of applications.

Susceptibility of various growth stages of annual bluegrass. Ethofumesate provided complete preemergence control of annual bluegrass when applied immediately after seeding. Treatments at the first and third leaf stage gradually killed the plants in most cases. Plants tillered at treatment time were temporarily injured, but regained full growth about 2 months after treatment. In general, the younger the plant, the more severe the injury. This finding was in agreement with McLean (11). There was no significant difference between 1.0, 1.5, and 2.0 kg/ha rates. Figure 1 shows combined

Table 1. Effect of formulation and rate of ethofumesate on the quality of three established turfgrasses 5 weeks after application. Summer (S), Fall (F), and Spring (SP) trials.

Formulation	Rate (kg/ha)	Perennial Ryegrass					Kentucky Bluegrass				Colonial Bentgrass				
		S 1980	F 1980	SP 1981	S 1981	F 1981	F 1980	SP 1981	S 1981	F 1981	S 1980	F 1980	SP 1981	S 1981	F 1981
Emulsifiable Concentrate	0.0	8.0	8.0	8.0	8.7	7.0	7.0	8.0	8.7	6.0	7.0	8.0	8.0	7.0	7.0
	0.3	7.7	8.0	8.0	8.7	6.7	7.0	8.0	9.0	6.0	---	---	---	---	---
	0.6	8.0	8.0	8.0	9.0	6.7	7.0	8.0	8.3	6.0	7.0	8.0	8.0	7.0	6.3
	1.0	8.0	8.0	8.0	9.0	7.0	7.0	7.7	8.3	6.0	7.0	7.7	8.0	7.0	5.7
	1.5	8.0	8.0	8.0	9.0	6.7	7.0	7.7	8.0	6.0	7.0	7.3	7.3*	7.0	3.7*
Flowable	0.0	8.0	8.0	8.0	9.0	7.0	7.0	8.0	8.7	6.0	7.0	8.0	8.0	7.0	7.0
	0.3	8.0	8.0	8.0	9.0	6.7	7.0	8.0	9.0	6.0	---	---	---	---	---
	0.6	8.0	8.0	8.0	8.7	6.3	7.0	8.0	9.0	6.0	7.0	7.7	8.0	7.0	5.7
	1.0	8.0	8.0	8.0	8.7	6.3	7.0	8.0	9.0	6.0	7.0	7.3	8.0	7.0	3.3*
	1.5	7.3	8.0	8.0	9.0	6.3	7.0	7.3*	8.3	6.0	7.0	7.0*	7.3*	7.0	2.7*
Granular	0.0	8.0	8.0	8.0	8.7	7.0	7.0	8.0	8.7	6.0	7.0	8.0	8.0	7.0	7.0
	0.3	8.0	8.0	8.0	8.7	6.7	7.0	8.0	8.7	6.0	---	---	---	---	---
	0.6	7.7	8.0	8.0	8.7	6.7	7.0	7.7	8.7	6.0	---	---	---	---	---
	1.0	7.7	8.0	8.0	8.7	6.7	7.0	8.0	8.3	6.0	7.0	7.7	8.0	7.0	6.0
	1.5	7.3	8.0	8.0	9.0	6.7	7.0	7.3*	8.0	6.0	7.0	7.3	8.0	7.0	5.7

[a]Values based on 1 to 9 rating scale where 1 = no live turf, 6 = acceptable, 9 = ideal growth.
[b]*Means within a column are significantly different than 0.0 kg/ha rate according to LSD ($P > 0.05$).

Table 2. Effect of formulation and rate of ethofumesate on established colonial bentgrass turf. Fall, 1981. [ab]

Formulation	Rate (kg/ha)	Weeks after application: 3			5			7		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	7.0	6.7	6.3	7.0	7.0	7.0	6.3	7.0	7.0
	0.6	7.0	6.3	7.0	7.0	5.7	6.3	6.7	6.0	6.0
	1.0	7.0	6.7	6.7	6.7	6.0	5.7	6.3	5.3*	5.3*
	1.5	6.7	5.7	6.0	3.3*	3.7*	3.7*	3.7*	3.0*	3.3*
Flowable	0.0	7.0	6.7	6.3	7.0	7.0	7.0	6.3	7.0	7.0
	0.6	7.0	6.7	6.3	7.0	7.0	7.0	6.3	7.0	7.0
	1.0	7.0	6.0	6.0	3.3*	3.7*	3.3*	4.3*	3.7*	3.7*
	1.5	7.0	5.7	5.7	2.7*	3.3*	2.7*	3.3*	3.0*	3.0*
Granular	0.0	7.0	6.7	6.3	7.0	7.0	7.0	6.3	7.0	7.0
	0.6	7.0	6.3	6.3	7.7	6.3	6.7	7.0	6.3	7.0
	1.0	7.0	6.0	6.3	6.7	5.3	6.0	6.3	5.7*	6.0
	1.5	7.0	5.7	6.3	7.0	5.3	5.7	6.0	5.3*	5.7

[a] Values bases on 1 to 9 rating scale, where 1 = no live turf, 6 = acceptable, 9 = ideal growth.
[b] *Means within a column significantly different than the 0.0 kg/ha rate according to LSD ($P > 0.05$)

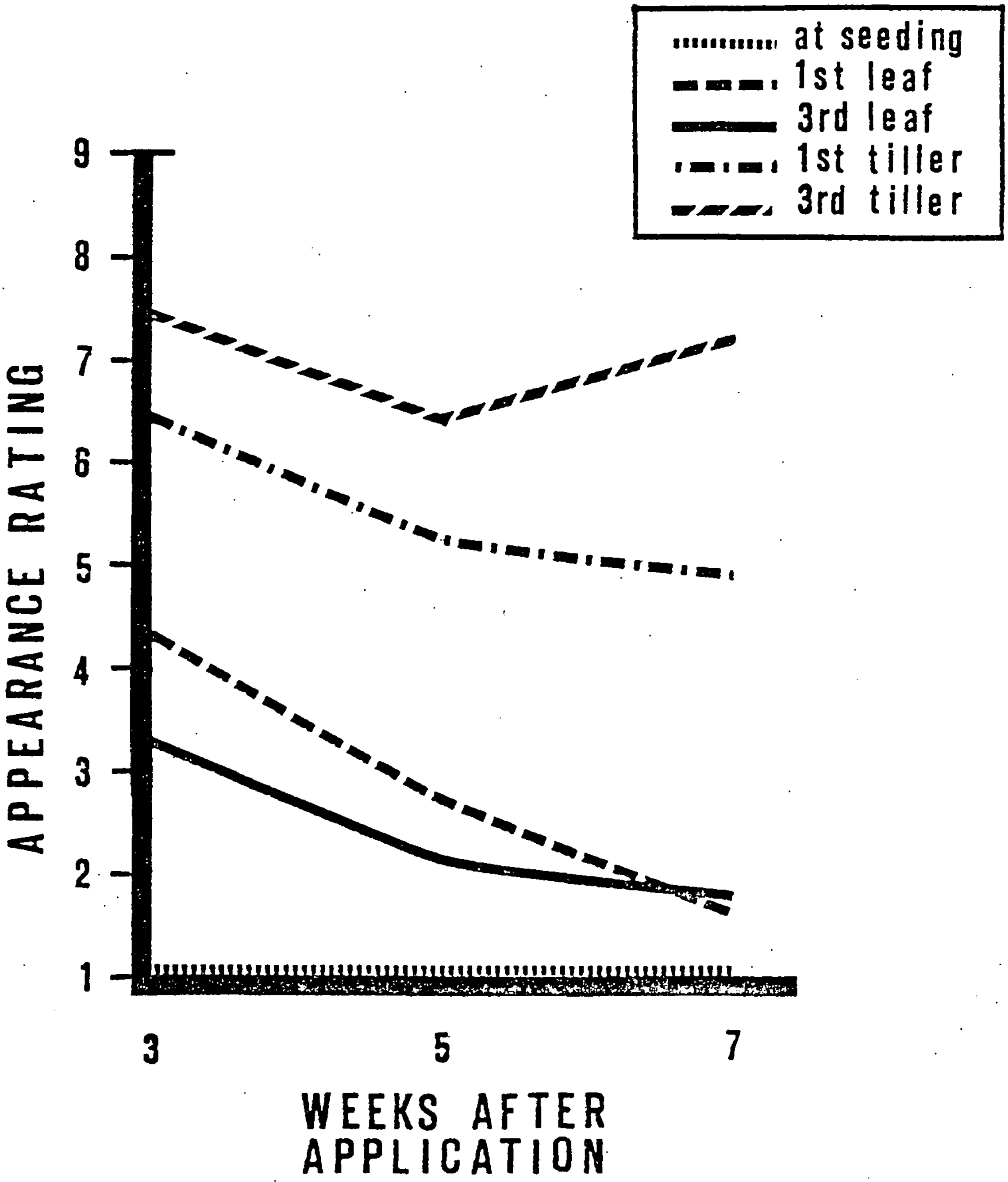


Figure 1. Effect of ethofumesate on annual bluegrass over time when applied at various growth stages. Appearance ratings are based on a 1 to 9 scale where 1 = no live turf, 6 = acceptable stand and quality, 9 = ideal growth. Data are combined results of three trials.

results of the 1.0 kg/ha rate of the three trials over a 5 week period. This evaluation period was chosen to be representative of the response induced by each of the growth stage treatments.

Ethofumesate retarded growth when applied to tillered annual bluegrass. Although not measured, growth rate of treated plants appeared to be considerably less than untreated plants.

Biotype differences. Significant injury was observed at all herbicide rates on all biotypes (Figure 2). Little differences in herbicide tolerance were found between biotypes, however. Injury symptoms included necrotic spots on blades, severe growth reduction, deformed seed heads, and some twisting and deformity of grass blades.

Results of this study indicate that established perennial ryegrass and Kentucky bluegrass turfs are very tolerant of ethofumesate under Willamette Valley conditions. Use of this herbicide for preemergent control of annual bluegrass in these turf species appears feasible. Further experimentation is needed to determine if ethofumesate can be safely applied to these turfgrasses at earlier stages of development, or even before seeding. If so, ethofumesate may be useful for annual bluegrass control in new turf areas. Ethofumesate use in colonial bentgrass and other turfs should also be examined in more depth.

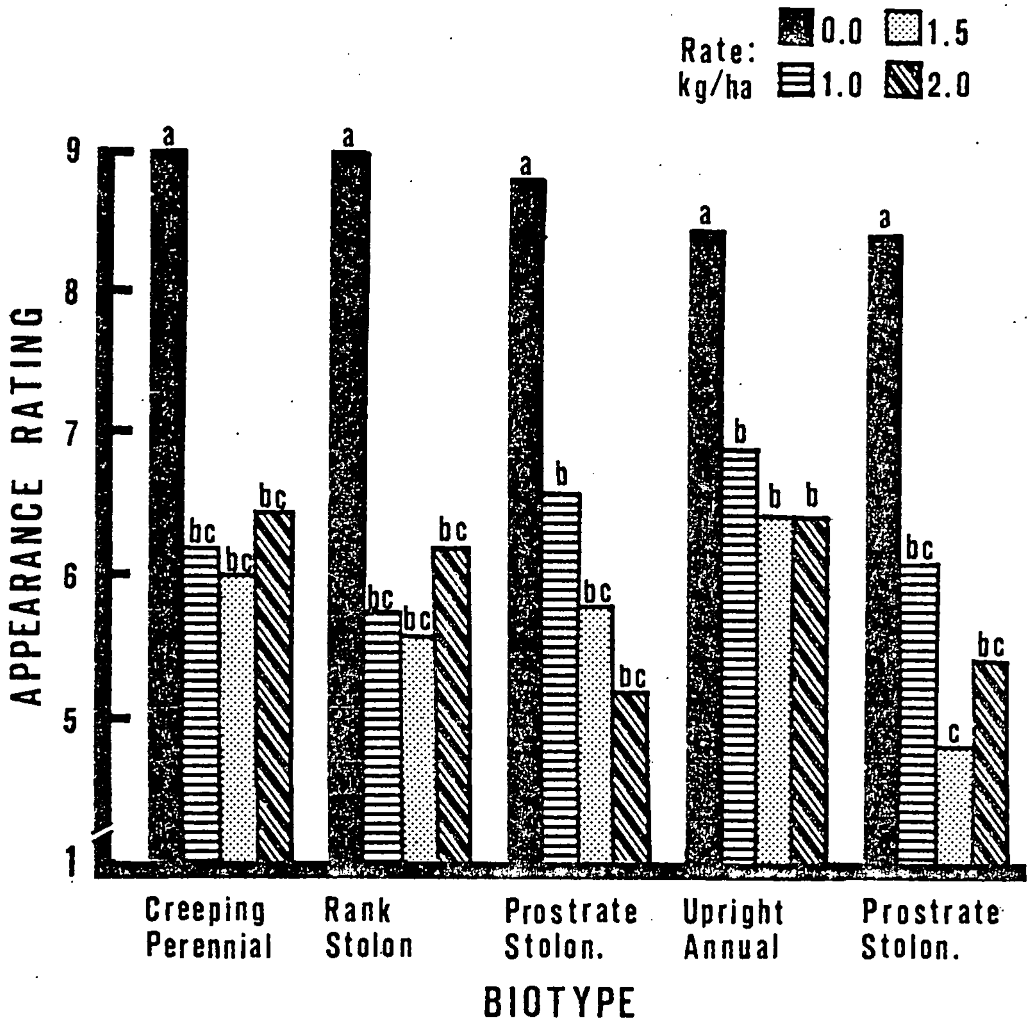


Figure 2. Effect of ethofumesate on five biotypes of annual bluegrass when applied at the 5 - tiller stage. Evaluation date was 5 weeks after application. Appearance ratings are based on a 1 to 9 scale, where 1 = no live grass, 6 = acceptable growth, 9 = ideal growth. Columns with the same letter(s) above are not significantly different at the 0.05 level by Duncan's multiple range test.

LITERATURE CITED

1. Dickens, R. 1979. Control of annual bluegrass (Poa annua) in overseeded bermudagrass (Cynodon spp.) golf greens. Weed Sci. 27:642-644.

2. Ekins, W.L. and M.G. Day. 1978. The results of two years' testing with ethofumesate under an experimental use permit in grass seed crops. Proc. West. Soc. Weed Sci. 31:98.

3. Ellis, W.M. 1973. The breeding system and variation in populations of Poa annua L. Evolution 27:656-662.

4. Goldsworthy, J.A., L.G. Duke, and R. Whitehead. 1980. Control of weed grasses and Stellaria media in grass with ethofumesate. Proc. Br. Crop Prot. Conf. - Weeds 15:483-488.

5. Gibeault, V.A. and N.R. Goetze. 1972. Annual meadow-grass. J. Sports Turf Res. Inst. 48:9.

6. Haggar, R.J. and C.J. Bastian. 1976. Controlling weed grasses in ryegrass by ethofumesate with special reference to Poa annua. Proc. Br. Crop Prot. Conf. 13: 603-610.

7. Hovin, A.W. 1957. Variations in annual bluegrass. Golf Course Rep. 25:18-19.

8. Lee, W.O. 1977. Winter annual grass weed control in Italian ryegrass with ethofumesate. Weed Sci. 25:252-255.

9. ________ 1980. Control of volunteer wheat (Triticum aestivum) in fall-planted perennial ryegrass (Lolium perenne) with ethofumesate. Weed Sci. 28:292-294.

10. ________ 1981. Control of annual bluegrass (Poa annua) in perennial ryegrass (Lolium perenne) seed fields. Weed Sci. 29:444-447.

11. McLean, J.R.F. 1978. Control of Poa annua in fine turf using ethofumesate. Proc. N.Z. Weed Pest Conf. 31: 192-194.

12. Warwick, S.J. 1979. The biology of Canadian weeds. 37. Poa annua L. Can. J. Plant Sci. 59.1053-1066.

13. Ziegenbein, G. 1976. New experimental results on growth retardation in turf. I. The responses of ornamental lawn grasses to growth regulators. Rasen. Grunflachen. Begrunungen 7(2):42-46.

CHAPTER 4

EFFECT OF ETHOFUMESATE ON PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.) EMERGENCE

Maggard, C.J., G.D. Crabtree, and T.W. Cook

Department of Horticulture, Oregon State University, Corvallis, Oregon 97331

Additional index words. annual bluegrass control, *Poa annua*, turfgrass, cultivars

ABSTRACT. Ten cultivars of perennial ryegrass were given preemergence treatments of ethofumesate at 0.3 and 0.6 kg/ha. Percent emergence of each cultivar was calculated two and four weeks after application. Emergence of all cultivars was inhibited by ethofumesate treatments; however, there were considerable differences in the cultivars' response to the herbicide. 'Regal' and 'Derby', in particular, exhibited a significant decrease in emergence, while 'Palmer' was the most tolerant of those cultivars tested. In another study, ryegrass was slice-seeded into an annual bluegrass infested area. Ethofumesate at 0.6, 1.0, and 1.5 kg/ha was applied, as well as a 0.6-0.6-0.6 kg/ha sequential treatment. Treatments were applied immediately before seeding, immediately after seeding, and at the first leaf and first tiller stages of the ryegrass. Sequential applications applied

preemergence provided the best control of annual bluegrass, but all preemergence treatments appeared to delay ryegrass emergence. Best ryegrass growth, as well as excellent annual bluegrass control, was observed when ethofumesate was applied early postemergence to the ryegrass.

INTRODUCTION

Annual bluegrass (Poa annua L.) is probably the most serious weed of turfgrass in the Willamette Valley of Oregon. Many attempts have been made at selective control of this aggressive weed, with little success.

One of the newest herbicides being used for annual bluegrass control in fine turf is ethofumesate. Research has shown that perennial ryegrass is especially tolerant to ethofumesate when it is applied postemergence (1,4,8,9) or preemergence (2,3,5,6).

European research has shown no difference in response of perennial ryegrass cultivars to preemergence or early postemergence applications of ethofumesate (7,10). However, no reports of studies on commonly used American cultivars could be found.

Objectives of the research reported herein were: 1) to determine if differences exist between cultivars of perennial ryegrass in their response to preemergence treatments of ethofumesate, and 2) to determine the best timing and rate of ethofumesate applications for controlling annual bluegrass when establishing a ryegrass turf under Willamette Valley conditions.

MATERIALS AND METHODS

Response of ryegrass cultivars to ethofumesate. In a greenhouse study, ten cultivars of perennial ryegrass were examined for their response to preemergence applications of ethofumesate. These cultivars were 'Barry', 'Citation', 'Derby', 'Elka', 'Omega', 'Palmer', 'Prelude', 'Premier', 'Regal', and 'Yorktown II'.

Fifty seeds of each cultivar were sown in a 42- by 42- cm flat of coarse sand. Annual bluegrass was also included as a comparison. The sequence of cultivars was randomized in each flat. Immediately after seeding, treatments of the flowable formulation of ethofumesate were applied at rates of 0.3 and 0.6 kg/ha.

The greenhouse was maintained at 24 C during the day and 18 C at night. Two weeks after herbicide application, the percentage of emerged plants of each cultivar was calculated. Ryegrass was considered emerged if the seedling was at least 2.5 cm tall. Annual bluegrass was emerged at 1.25 cm. Emergence was again calculated 4 weeks after application.

A randomized complete block design with four replications was used. The experiment was conducted twice, each trial being analyzed separately.

Timing and rate of application of ethofumesate on seeded ryegrass. This field experiment was conducted on Chehalis silty loam soil in the mid-Willamette Valley. An area infested with annual bluegrass was treated with glyphosate [N - (phosphonomethyl)glycine] in the summer of 1981 to kill the existing vegetation. Perennial ryegrass ('Fiesta', 'Blazer', 'Dasher' blend) was sown into this area using a Roger's slicer-seeder in September. Ethofumesate (flowable formulation) was applied at different stages of ryegrass growth - immediately prior to seeding, immediately after seeding, first leaf stage, and first tiller stage. Rates used were 0.6, 1.0, 1.5 kg/ha and a sequential treatment of 0.6 kg/ha applied three times at 4 week intervals, the initial treatment being applied at each growth stage.

Plots in this experiment were 1.5- by 1.5- m. A randomized complete block design was used, with three replications. Application was made with a fixed boom, wheeled plot sprayer using CO_2 as a pressure source.

Evaluation of treatments was undertaken in early spring of 1982, 3 months after the last herbicide application. The ryegrass stand was visually evaluated on a 1 to 9 scale, in which 1 = no live ryegrass, 6 = acceptable stand and quality, and 9 = ideal stand and quality of ryegrass. The percentage of annual bluegrass in the plot was also visually evaluated.

RESULTS AND DISCUSSION

Response of ryegrass cultivars to ethofumesate. Ethofumesate treatments decreased emergence of all cultivars of ryegrass (Tables 3 and 4). Less inhibition of emergence was seen at the lower rate of herbicide application than at the 0.6 kg/ha rate, though the extent of this difference varied considerably with cultivar. Complete control of annual bluegrass was observed at both rates. Emergence of 'Derby' and 'Regal' was most severely affected, being drastically reduced from untreated flats. Delayed emergence occurred in some cultivars, as shown by much higher emergence percentages at 4 weeks after application than at 2 weeks.

Timing and rate of application of ethofumesate on seeded perennial ryegrass. Nearly all treatments appeared to increase the amount and quality of ryegrass compared to the untreated plots, though these differences were not statistically significant (Figure 3). Single applications of ethofumesate applied preemergence to ryegrass seemed to result in higher ratings for ryegrass stand and quality than sequential treatments; however, repeated applications improved the ryegrass stand once it was emerged. Sequential applications did provide excellent control of annual bluegrass when applied at all stages of ryegrass growth (Figure 4). Single treatments applied postemergence to ryegrass also controlled the weed effectively.

Results of the research reported herein indicate that preemergence applications of ethofumesate retard ryegrass emergence, and extent of retardation may depend a great deal on the cultivar of

Table 3. Perennial ryegrass response to preemergence treatments of ethofumesate. Trial 1.[a]

Cultivar	Emergence Two weeks after application Rate (kg/ha)			Emergence Four weeks after application Rate (kg/ha)		
	0.0	0.3	0.6	0.0	0.3	0.6
	--------% emergence--------			--------% emergence-------		
Barry	96a	72efg	39l	95a	76fghi	47kl
Palmer	91ab	71fg	74efg	91ab	78efghi	77fhgi
Prelude	87bc	66gh	56ij	89abc	73hi	62j
Premier	92ab	61hi	41l	94a	73ghi	50k
Omega	83bcd	56ij	18o	84cde	60j	27o
Yorktown II	80cde	56ij	31mn	80efg	60j	37mn
Elka	87bc	50jk	43kl	87bcd	57j	50k
Citation	77def	38lm	26n	79efgh	41lm	32no
Derby	70fg	12op	8pq	72i	19p	18p
Regal	84bcd	7pq	5pq	82def	17p	8q
Annual bluegrass	28n	0q	0q	45kl	0r	0r

[a] Means within and between columns within evaluation dates followed by the same letter(s) are not significantly different at the 5% level as determined by Duncan°s multiple range test.

Table 4. Perennial ryegrass response to preemergence treatments of ethofumesate. Trial 2.[a]

Cultivar	Emergence Two weeks after application Rate (kg/ha) 0.0	0.3	0.6	Emergence Four weeks after application Rate (kg/ha) 0.0	0.3	0.6
	--------% emergence--------			--------% emergence-------		
Barry	83ab	42i	23mn	90ab	64de	42hi
Palmer	86a	70ef	43i	94a	76c	57fg
Prelude	82ab	60g	44i	91ab	70d	62ef
Premier	84ab	64fg	40ij	92ab	77c	54g
Omega	72de	30kl	19no	80c	42hi	27k
Yorktown II	75cde	51h	27lm	86b	70d	32jk
Elka	87a	73cde	34jk	93a	78c	44h
Citation	78bcd	33kl	11p	88ab	45h	18l
Derby	74cde	28klm	12p	79c	37ij	20l
Regal	79bc	13op	1q	89ab	32jk	8m
Annual bluegrass	31kl	0q	0q	40hi	0n	0n

[a] Means within and between columns within evaluation dates followed by the same letter(s) are not significantly different at the 5% level as determined by Duncan's multiple range test.

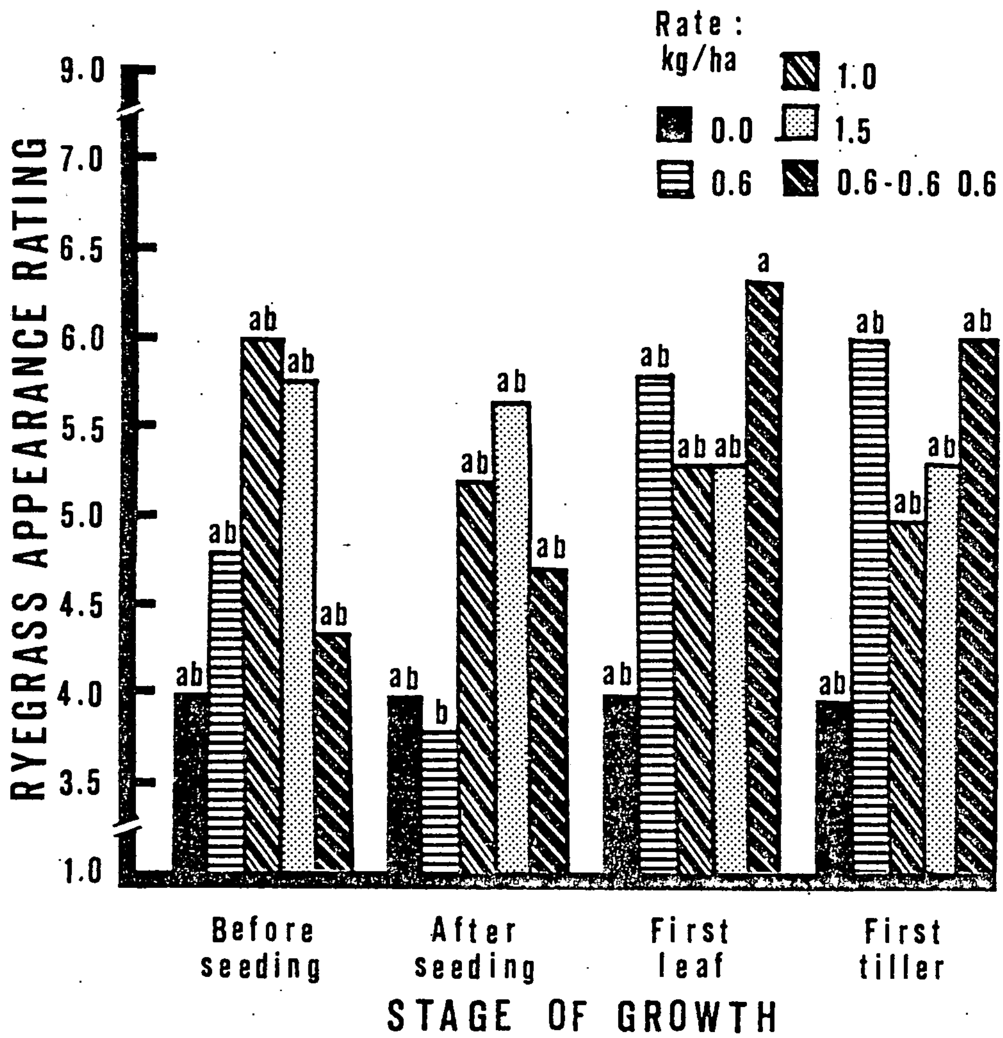


Figure 3. Effect of rate and timing of ethofumesate application on perennial ryegrass turf. Evaluation date was 3 months after final treatment. Appearance ratings were on a 1 to 9 scale, 1 = no live turf, 6 = acceptable stand and quality, 9 = ideal ryegrass stand. Columns with the same letter(s) above are not significantly different at the 0.05 level by Duncan's multiple range test.

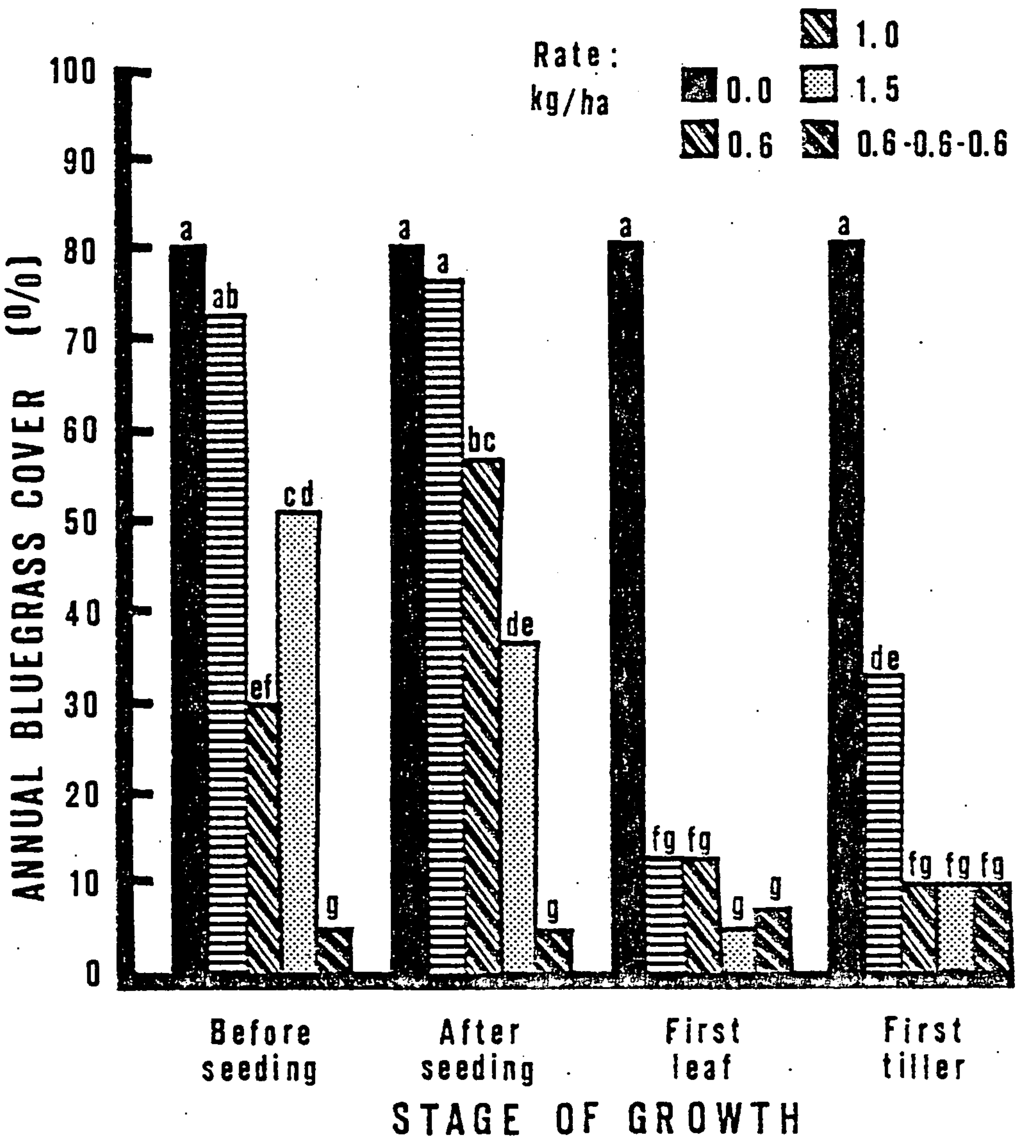


Figure 4. Percent annual bluegrass in perennial ryegrass seeded plots treated with ethofumesate. Growth stage is of ryegrass at time of application. Columns with same letter(s) above are not significantly different at the 0.05 level by Duncan's multiple range test.

ryegrass used. However, if treatment is delayed until after emergence, ryegrass growth is not as severely affected and excellent control of annual bluegrass is still achieved. Removal of competition by this aggressive weed will allow a healthy, vigorous stand of ryegrass to develop.

Ethofumesate has the potential for being a valuable tool in controlling annual bluegrass when establishing perennial ryegrass turf under Willamette Valley conditions. Further research with perennial ryegrass cultivar response to ethofumesate is being undertaken, as well as more complete investigations into the use of ethofumesate in establishment of perennial ryegrass and other turf species.

LITERATURE CITED

1. Ball, A.P. and A.R. Roberts, 1974. The use of ethofumesate for weed control in ryegrass seed crops. Proc. Br. Weed Cont. Conf. 12:727-732.

2. Dickens, R. 1979. Control of annual bluegrass (Poa annua) in overseeded bermudagrass (Cynodon spp.) golf greens. Weed Sci. 27:642-644.

3. Goldsworthy, J.A., L.G. Duke, and R. Whitehead, 1980. Control of weed grasses and Stellaria media in grass with ethofumesate. Proc. Br. Crop Prot. Conf. - Weeds 15:483-488.

4. Griffiths, W. C.H. Hammond and C.J. Edwards. 1978. Weed control in new leys and established pastures with ethofumesate. Proc. Br. Crop Prot. Conf. - Weeds 14:309-316.

5. Haggar, R.J. and C.J. Bastian. 1976. Controlling weed grasses in ryegrass by ethofumesate with special reference to Poa annua. Proc. Br. Crop Prot. Conf. 13:603-610.

6. ------------ and A. Passman. 1978. Some consequences of controlling Poa annua in newly sown ryegrass leys. Proc. Br. Crop Prot. Conf. - Weeds 14:301-308.

7. Hammond, C.H., W. Griffiths, S.D. van Hoogstraten, R.J. Whiteoak. 1976. The use of ethofumesate in grass seed crops. Proc. Br. Crop Prot. Conf. - Weeds. 13:657-663.

8. Lee, W.O. 1981. Control of annual bluegrass (Poa annua) in perennial ryegrass (Lolium perenne) seed fields. Weed Sci. 29:444-447.

9. McLean, J.R.F. 1978. Control of Poa annua in fine turf using ethofumesate. Proc. N.Z. Weed Pest Conf. 31:192-194.

10. Oswald, A.K. and R.J. Haggar. 1974. The tolerance of ten grass varieties to six herbicides with a potential for wild oat control in herbage seed crops. Proc. Br. Weed Control Conf. 12:715-722.

CHAPTER 5

CONCLUSIONS

Results from these trials have indicated that ethofumesate has potential for being a very valuable tool for annual bluegrass control in turf under Willamette Valley conditions. Established perennial ryegrass and Kentucky bluegrass appeared to be very tolerant of the herbicide, while colonial bentgrass showed some injury susceptibility. Ethofumesate was extremely effective in preemergence control of annual bluegrass. This effectiveness continued until the plants were tillered. Control was then moderate, being evidenced mainly by a reduction of growth. Biotypes of annual bluegrass did not appear to differ significantly in their response to ethofumesate.

Potential for annual bluegrass control during establishment of perennial ryegrass and other turf species was especially promising. It appeared that ryegrass emergence was delayed or inhibited with preemergence treatment of ethofumesate, with cultivar responses being significantly different. However, early postemergence applications of ethofumesate did not seem to injure ryegrass while providing excellent control of annual bluegrass. Periodic reapplication of low rates of ethofumesate during establishment theoretically should then keep the turf area free of this aggressive weed. At the very least, it should allow the ryegrass to become established and competitive.

Further research should be undertaken to determine tolerance of other turfgrasses, such as the fescues, to ethofumesate. A greater knowledge of the effects of ethofumesate on various growth stages of these turf species would be useful in determining its potential use in establishment or maintenance of turf areas. More cultivars of ryegrass should also be screened in order to select those most tolerant to the herbicide. Residual effectiveness of ethofumesate under Willamette Valley conditions should also be examined. This would help in determining the interval of time allowed between applications for the most efficient annual bluegrass control.

If ethofumesate proves as effective in selectively controlling annual bluegrass as these studies indicate, application could become a standard procedure in establishing new turf areas. Use of this herbicide, alone or in conjunction with other herbicides, could provide the Willamette Valley with lawns, golf courses, and other turf areas free of this annoying and aggressive weed.

BIBLIOGRAPHY

1. Allen, F.C., M.J. Hartley, and F.A. Mecklah. 1974. Control of barley grass by ethofumesate. N.Z. Weed Pest Control Conf. 27:85-89.

2. Allen, F.C., T.J. Smallridge, and G.W. Bourdot. 1974. Wild oat control in ryegrass for seed production. Proc. N.Z. Weed Pest Control Conf. 27:67-71.

3. Anderson, B.R. and S.R. McLane. 1958. Control of annual bluegrass and crabgrass in turf with fluorophenoxyacetic acids. Weeds 6:52-58.

4. Ball, A.P. and A.R. Roberts. 1974. The use of ethofumesate for weed control in ryegrass seed crops. Proc. Br. Weed Control Conf. 12:727-732.

5. Beard, J.B. 1970. An ecological study of annual bluegrass. USGA Green Sec. Rec. 8:13-18.

6. Beard, J.B., P.E. Rieke, A.J. Turgeon, and J.M. Vargas, Jr. 1978. Annual bluegrass (*Poa annua* L.) Description, adaptation, culture, and control. Mich. St. Univ. Agric. Exp. Sta. Res. Rep. 352. 31pp.

7. BFC Chemicals, Inc. 1981. Prograss flowable herbicide. Technical information bulletin. Wilmington, DE. 6 pp.

8. Bingham, S.W. 1967. Influence of herbicides on root development of bermudagrass. Weeds 15:363-365.

9. ______________ and R.E. Schmidt. 1967. Residue of bensulide in turfgrass soil following annual treatments for crabgrass control. Agron. J. 59:327-329.

10. ______________, R.E. Schmidt, and C.K. Curry. 1969. Annual bluegrass control in overseeded bermudagrass putting green turf. Agron. J. 61:908-911.

11. ______________ and R.L. Shaver. 1969. Effectiveness of herbicide programs for annual bluegrass (*Poa annua*) control in bermudagrass (*Cynodon dactylon*). Weed Sci. 27:367-370.

12. Blair, A.M. 1972. Selectivity of NC 8438 between ryegrass and weed grass species. Proc. Br. Weed Control Conf. 11:301-305.

13. Bogart, J.E. and J.B. Beard. 1973. Cutting height effects on the competitive ability of annual bluegrass (*Poa annua* L.). Agron. J. 65:513-514.

14. Bray, W.E. and J.G. Hilton. 1980. Herbicide programmes for season long weed control in sugar beet. Proc. Br. Protection Conf. - Weeds. 15:511-515.

15. Brede, A.D. and J.M. Duich. 1981. Annual bluegrass encroachment affected by Kentucky bluegrass seeding rate. Proc. Northeast Weed Control Conf. 35:307-311.

16. Breuninger, J.M. and T.L. Watschke. 1982. Postemergent Poa annua control with growth retardants. Proc. Northeast Weed Control Conf. 86:314.

17. Callahan, L.M. 1972. Phytotoxicity of herbicides to a Penncross bentgrass green. Weed Sci. 20:387-391.

18. Chappell, W.E. and R.E. Schmidt. 1961. Pre and postemergence crabgrass and Poa annua control studies in turf. Proc. South. Weed Conf. 14:91-97.

19. Cockerham, S.T. and J.W. Whitworth. 1967. Germination and control of annual bluegrass. Golf Course Supt. 35:10-46.

20. Cook, T.W. 1975. 1975 Poa annua survey. Proc. Northwest Turfgrass Conf. 29:127-129.

21. __________ 1977. Poa annua can be controlled. Proc. Northwest Turfgrass Conf. 31:34-47.

22. __________ 1978. Control of Poa annua in lawn and putting turf in the Pacific Northwest using endothal. Proc. Northwest Turfgrass Conf. 32:103-112.

23. __________ 1981. Growth regulator research on turf. Proc. Northwest Turfgrass Conf. 35:95-103.

24. Cordukes, W.E. 1977. Growth habit and heat tolerance of a collection of Poa annua plants in Canada. Can. J. Plant Sci. 57:1201-1204.

25. Daniel, W.H. 1955. Poa annua control with arsenic materials. Golf Course Rep. 23(1):5-9.

26. Day, M.G. and W.L. Ekins. 1977. Evaluation of NC 8438 (Nortron) in grass seed crops under an experimental use permit. Proc. West. Soc. Weed Sci. 30:43-46.

27. DeFrance, J.A. and J.R. Kollett. 1959. A bluegrass (Poa annua L.) control with chemicals. Golf Course Rep. 26:14-18.

28. Dickens, R. 1979. Control of annual bluegrass (Poa annua) in overseeded bermudagrass (Cynodon spp.) golf greens. Weed Sci. 27:642-644.

29. Downing, C., H. H. Williams, V.A. Gibeault, J. Van Dam, and A.H. Lange. 1970. Studies on the initial effect and residual characteristics of several selective preemergence herbicides in relation to overseeding and Poa annua control. Cal. Turfgrass Culture 20:25-28.

30. Duncan, D.H., W.F. Meggitt, and D. Penner. 1977. A mode of action of ethofumesate.

31. ______________________ 1982. The basis for selectivity of root-applied ethofumesate in sugarbeet (Beta vulgaris) and three weed species. Weed Sci. 30:191-194.

32. ______________________ 1982. Basis for increased activity from herbicide combinations with ethofumesate applied on sugarbeet (Beta vulgaris). Weed Sci. 30:195-200.

33. Eggens, J.L. 1979. The responses of some Kentucky bluegrass cultivars to competitive stress from annual bluegrass. Can. J. Plant Sci. 59:1123-1128.

34. Ekins, W.L. 1976. Results from experimental programs in sugar beet and grass seed crops with NC 8438. Proc. West. Soc. Weed Sci. 29:190-191.

35. ____________ and J.M. Bennett. 1975. 2-ethoxy-2, 3-dihydro-3, 3-dimethyl-5-benzofuranyl methanesulphonate (NC 8438), a new herbicide for sugarbeet and grass seedcrops. Proc. West. Soc. Weed Sci. 28:31.

36. ____________ and M.G. Day. 1978. The results of two year's testing with ethofumesate under an experimental use permit in grass seed crops. Proc. West. Soc. Weed Sci. 31:98.

37. Ellis, W.M. 1973. The breeding system and variation in populations of Poa annua L. Evolution 27:656-662.

38. Engel, R.E. and R.J. Aldrich. 1955. Control of annual bluegrass (Poa annua) in fair-way type turf. Proc. Northeast Weed Control Conf. 9:353-355,

39. ______________________ 1960. Reduction of annual bluegrass (Poa annua) in bentgrass turf by the use of chemicals. Weeds 8:26-28.

40. Engel, R.E. and L.M. Callahan, 1967. Merion Kentucky bluegrass response to soil residue of preemergence herbicides. Weeds 15:128-130.

41. ____________, A. Morrison, and R.D. Ilnicki. 1968. Preemergence chemical effects on annual bluegrass. Golf Supt. 36:20-39.

42. Eshel, J., E.E. Schweizer and R.L. Zimdahl. 1976. Sugarbeet tolerance of post-emergence applications of desmedipham and ethofumesate. Weed Res. 16:249-254.

43. __________, R.L. Zimdahl, and E.E. Schweizer. 1976. Basis for interactions of ethofumesate and desmidipham on sugarbeets and weeds. Weed Sci. 24:619-626.

44. ____. 1978. Uptake and translocation of ethofumesate in sugar-beet plants. Pestic. Sci. 9:301-304.

45. Evans, A.W. and D.S. Muncey. 1974. Observations on the effect of three herbicides with promise in the control of Graminaceous weeds on the seed production of ryegrass. Proc. Br. Weed Control Conf. 12:723-726.

46. Fisons, Inc. 1974. Herbicide: Nortron. Technical Information Bulletin. Bedford, Ma. 9 pp.

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

48. Gibeault, V.A. 1967. Investigations on the control of annual meadowgrass. J. Sports Turf Res. Inst. 42:17-40.

49. _______________ 1971. Perenniality in Poa annua L. Ph.D. thesis. Oregon State University.

50. _______________ and N.R. Goetze. 1972. Annual meadow-grass. J. Sports Turf Res. Inst. 48:9.

51. Goldsworthy, J.A., L.G. Duke, and R. Whitehead. 1980. Control of weed grasses and Stellaria media in grass with ethofumesate. Proc. Br. Crop Prot. Conf. - Weeds. 15:483-488.

52. Goetze, N.R. 1958. Poa annua control in turf. Proc. North Cent. Weed Control Conf. 15:36-37.

53. Goss, R.L. 1964. Preemergence control of annual bluegrass (Poa annua). Agron. J. 56:479-481.

54. ___________ 1979. The influence of nitrogen sources and variable rates of S and P on bentgrass color, Poa annua quality and fusarium patch disease. Proc. Northwest Turfgrass Conf. 33:119-124.

55. ___________, S.E. Brown, and S.P. Orton. 1975. The effects of N,P,K, and S on Poa annua L. in bentgras putting green turf. J. Sports Turf Res. Inst. 51:74-82.

56. __________ and F. Zook. 1971. New approach for Poa annua control. Golf Supt. 39:46-48.

57. Griffiths, W., C.H. Hammond and C.J. Edwards. 1978. Weed control in new leys and established pastures with ethofumesate. Proc. Br. Crop Prot. Conf. - Weeds. 14:309-316.

58. Haggar, R.J. and C.J. Bastian. 1976. Controlling weed grasses in ryegrass by ethofumesate with special reference to Poa annua. Br. Crop Prot. Conf. 13:603-610.

59. __________ and A. Passman. 1978. Some consequences of controlling Poa annua in newly sown ryegrass leys. Proc. Br. Crop Prot. Conf. - Weeds. 14:301-308.

60. Hammond, C.H., W. Griffiths, S.D. van Hoogstraten, and R.J. Whiteoak. The use of ethofumesate in grass seed crops. Proc. Br. Crop Prot. Conf. - Weeds. 13:657-663.

61. Hartley, M.J. 1972. NC 8438 for control of seedling barley grass. Proc. N.Z. Weed Pest Control Conf. 25:62-63.

62. Holmes, H.M., R.K. Pfeiffer, and W. Griffiths. 1974. Preemergence and post-emergence use of ethofumesate in sugar beet. Proc. Br. Weed Control Conf. 12:493-501.

63. Hovin, A. W. 1957. Variations in annual bluegrass. Golf Course Rep. 25:18-19.

64. Jacquemin, P.L. and P.R. Henderlong. 1976. Selective control of Poa annua in Kentucky bluegrass. Proc. Northeast. Weed Control Conf. 30:345-350.

65. Jagschitz, J.A. 1970. Chemical control of Poa annua L. in turfgrass and the effect of various chemicals on seed production. Proc. Northeast. Weed Control Conf. 24:393-400.

66. __________ 1979. Annual bluegrass control in Kentucky bluegrass turf with herbicides. Proc. Northeast. Weed Control Conf. 33:308-313.

67. __________ 1982. Postemergent control of annual bluegrass and bentgrass in Kentucky bluegrass turf. Proc. Northeast. Weed Control Conf. 36:326-331.

68. Johnson, B.J. 1977. Effect of herbicide treatments on overseeded putting green turf. Weed Sci. 25:343-347.

69. Juska, F.V. 1961. Pre-emergence herbicides for crabgrass control and their effects on germination of turfgrass species. Weeds 9:137-144.

70. ____________ and A.A. Hanson. 1964. Effect of preemergence crabgrass herbicides on seedling emergence of turfgrass species. Weeds 12:97-101.

71. ______________________________ 1967. Factors affecting Poa annua L. control. Weeds 15:98-101.

72. Juska, F.V. and A.W. Hovin. 1970. Preemergence herbicide effects on the growth of Newport Kentucky bluegrass (Poa pratensis L.) seedlings. Proc. Northeast. Weed Control Conf. 24:387-392.

73. Koshy, T.K. 1968. Evolutionary origin of Poa annua L. in the light of karyotypic studies. Can. J. Genet. Cytol. 10:112-118.

74. Law, R, A.D. Bradshaw, and P.D. Putwain, 1977. Life-history variation in Poa annua. Evolution 31:233-46.

75. Leavitt, J.R.C., D.N. Duncan, D. Penner, and W.F. Meggitt. 1978. Inhibition of epicuticular wax deposition on cabbage by ethofumesate. Plant Physiol. 61: 1034-1036.

76. Lee, W.O. 1977. Winter annual grass weed control in Italian ryegrass with ethofumesate. Weed Sci. 25:252-2

77. _________ 1980. Control of volunteer wheat (Triticum aestivum) in fall-planted perennial ryegrass (Lolium perenne) with ethofumesate. Weed Sci. 28:292-294.

78. _________ 1981. Control of annual bluegrass (Poa annua) in perennial ryegrass (Lolium perenne) seed fields. Weed Sci. 29:444-447.

79. Maestri, M. and H.B. Currier. 1958. Interactions of maleic hydrazide and endothal. Weeds 6:315-326.

80. McAuliffe, D. 1982. Personal communication. Oregon State University, Corvallis, Oregon.

81. ______________ and A.P. Appleby. 1981. Effect of a pre-irrigation period on the activity of ethofumesate applied to dry soil. Weed Sci. 29:712-717.

82. McLean, J.R.F. 1977. Weed control in onions utilizing ethofumesate. Proc. N.Z. Weed Pest Control Conf. 30:124-129.

83. ______________ 1978. Control of Poa annua in fine turf using ethofumesate. Proc. N.Z. Weed Pest Control Conf. 31;192-194.

84. Mead, H., B.L. Ross, and R.J. Finch. 1974. Preliminary investigations on the control of wild-oat (Avena fatua), cultivated oat (Avena sativa L.), and blackgrass (Alopecurus myosuroides Huds.) in seed crops of various varieties of perennial and Italian ryegrass. Proc. Br. Weed Control Conf. 12:707-714.

85. Menck, B.-H., U. Luning, W. Nuyken, D. Klingenschmitt. 1980. BAS 483 . .H, Ready mixes of chloridazon and ethofumesate for the control of a broad spectrum of weeds in sugar beets. Proc. Br. Crop Prot. Conf. - Weeds. 15:537-541.

86. Meyers, H.G. and W.J. McCarthy. 1974. Effects of activated charcoal and time of application on established Kerb treated Poa annua. Proc. Florida State Hort. Soc. 87:513-515.

87. Minter, L.K. 1974. Control of barley grass and other pasture weeds with ethofumesate. Proc. N.Z. Weed Pest Control Conf. 27:82-84.

88. Morris, T. 1979. The effects of pre/post emergence herbicides on control of Poa annua L. in lawn and putting turf. Unpublished data. Washington State University. Puyallup, Wa.

89. Mruk, C.K. and J.A. DeFrance. 1957. A comparison of chemicals for the control of annual bluegrass (Poa annua L.) in lawn turf. Golf Course Rep. 25:5-7.

90. Neidlinger, T.J. 1965. Poa annua L.: Susceptibility to several herbicides and temperature requirements for germination. M.S. Thesis. Oregon State University. 97pp.

91. ________________, W.R. Furtick, and N.R. Goetze. 1968. Susceptibility of annual bluegrass and turfgrasses to bensulide and three uracil herbicides. Weed Sci. 16:16-18.

92. Norris, R.F. 1971. Evaluation of new herbicides for weed control in furrow-irrigated sugarbeets. 1971 West. Soc. Weed Sci. Res. Prog. Rep. pp. 107-110.

93. O'Connor, B.P., I.C. Logan, and G.R. Rowe. 1975. Effect of ethofumesate on barley grass and other pasture species. Proc. N.Z. Weed Pest Control Conf. 28:12-16.

94. Oswald, A.K. 1980. The use of sequential herbicide treatments to control Poa trivialis in two perennial ryegrass crops grown for seed. Proc. Br. Crop Prot. Conf. - Weeds. 15:489-493.

95. ______________ and R.J. Haggar. 1974. The tolerance of ten grass varieties to six herbicides with a potential for wild oat control in herbage seed crops. Proc. Br. Weed Control Conf. 12;715-722.

96. Pfeiffer, R.K. and H.M. Holmes. 1972. Control of annual grasses and broad-leaved weeds in sugar beet with NC 8438. Proc. Br. Weed Control Conf. 11:487-490.

97. Rahman, A. 1978. Effect of climatic and edaphic factors on the persistance and movement of ethofumesate. Proc. Br. Crop Prot. Conf. - Weeds. 14:557-563.

98. ___________ 1979. Enhancement of ethofumesate phytotoxicity by phosphorus. Proc. Asian Pac. Weed Sci. Soc. Conf. 7:463- 465.

99. ___________, B.E. Manson, and B. Burney. 1978. Residual activity of ethofumesate under different soil and climatic conditions. Proc. N.Z. Weed Pest Control Conf. 31:203-207.

100. Roberts, J.M. and R.L. Goss. 1978. A new plant growth regulator with potential post emergence Poa annua control? Proc. Northwest Turfgrass Conf. 32:125-128.

101. Sarpe, N., O. Segarceanu, L. Ciorlaus, I. Popovici, I. Clotan, and C. Nagy. 1974. The efficiency of herbicides based on pyrazone, ethofumesate, lenacil, and phenmedipham, used alone or in combination, in sugar beet grown under Romanian conditions. Proc. Br. Weed Control Conf. 12;477-483.

102. Schery, R.W. 1968. Bluegrass/bentgrass checks Poa annua. Golf Supt. :32-34.

103. Schweizer, E.E. 1975. Crop response to soil applications of ethofumesate. Weed Sci. 23;409-413.

104. _______________ 1976. Persistance and movement of ethofumesate in soil. Weed Res. 16:37-42.

105. Sprague, N.B. and G.W. Burton. 1937. Annual bluegrass (Poa annua L.) and its requirements for growth. N.J. Agric. Exp. Sta. Bull. 630. 24 pp.

106. Stebbins, G.L. 1950. Variation and evolution in plants. Columbia University Press. New York. 643 pp.

107. Thomsom, W.T. (ed.). 1981. Agricultural chemicals II. Herbicides. Thomson Publications, Fresno, Ca. 274 pp.

108. Turgeon, A.J. 1971. The role of 7-oxabicyclo[2.2.1]heptane-2, 3-dicarboxylic acid (endothall) in annual bluegrass (Poa annua) control in turf. Ph.D. Thesis. Michigan State University. 101 pp.

109. _______________, J.B. Beard, D.P. Martin, and W.F. Meggitt. 1974. Effects of successive applications of preemergence herbicides on turf. Weed Sci. 22:349-352.

110. ______________ and W.F. Meggitt. 1971. Role of endothall in the control of annual bluegrass. (Abst.). Proc. Northeast. Weed Control Conf. 25:399.

111. ________________________________, and D. Penner. 1972. Role of endothall in the control of annual bluegrass in turf. Weed Sci. 20:562-565.

112. Tutin, T.G. 1952. Origin of Poa annua L. Nature. 169:160.

113. ___________ 1954. The relationships of Poa annua L. Int. Cong. Bot. 9:88.

114. ___________ 1957. A contribution to the experimental taxonomy of Poa annua L. Watsonia 4:1.

115. van Hoogstraten, S.D., C. Baker, and S.D. Horne. 1974. Ethofumesate behavior in the soil. Proc. Br. Weed Control Conf. 12;503-509.

116. ________________________, C.H. Hammond, and W. Griffiths. 1975. Ethofumesate, a new herbicide for ryegrass seed crops and pastures. Proc. Eur. Weed Res. Soc. Symp. - Status Control of Grassweeds in Europe. p. 196-203.

117. Warwick, S.I. 1979. The biolgy of Canadian weeds. 37. Poa annua L. Can. J. Plant Sci. 59:1053-1066.

118. ______________ and D. Briggs. 1978. The genecology of lawn weeds. I. Population differentiation in Poa annua L. in a mosaic environment of bowling green lawns and flower beds. New Phytol. 81:711-723.

119. ______________________________ 1978. The genecology of lawn weeds II. Evidence for disruptive selection in Poa annua L. in a mosaic environment of bowling green lawns and flower beds. New Phytol. 81;725-737.

120. Warwick, S.I., A.S. Hamill, and P.B. Marriage. 1980. Response of different growth forms of Poa annua L. (Annual bluegrass) to herbicides applied before or after emergence. Can. J. Plant Sci. 60:947-952.

121. Watschke, T.L. and J.M. Duich. 1977. Control of Poa annua with endothal. Proc. Northeast. Weed Control Conf. 31:357-363.

122. _______________, J.M. Duich, and F.W. Long. 1973. Seedhead inhibition and postemergence Poa annua control on turfgrass areas. (Abst.). Proc. Northeast. Weed Control Conf. 27:315.

123. _______________, F.W. Long, and J.M. Duich. 1979. Control of Poa annua by suppression of seedheads with growth regulators. Weed Sci. 27:224-231.

124. Younger, V.B. 1959. Ecological studies on Poa annua in turfgrasses. J. Br. Grassl. Soc. 14:233-237.

125. Ziegenbein, G. 1976. New experimental results on growth retardation in turf. I. The responses of ornamental lawn grasses to growth regulators. Rasen. Grunflachen. Begrunungen. 72(2):42-46.

APPENDIX A

Table 5. Herbicides used for control of annual bluegrass

Common name	Chemical Name
benefin	N-butyl-N-ethyl-ααα-trifluoro-2,6-dinitro-p-toluidine
bensulide	O,O-diisopropylphosphorodithioate S-esterwithN-(2-mercaptoethyl)
bromacil	5-bromo-6-methyl-3-(1-methylpropyl)-uracil
calcium arsenate	
chlorflurenol	methylhydroxyfluorene-9-carboxylate
chloropropham	isopropyl m-chlorocarbanilate
DCPA	dimethyl tetrachloroterephthalate
dichlobenil	2,6-dichlorobenzonitrile
DMPA	O-(2,4-dichlorophenyl) O-methyl isopropylphosphoramidothioate
DSMA	disodium methanearsonate
endothall	7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
lead arsenate	

Table 5. Herbicides used for control of annual bluegrass (con't)

Common name	Chemical Name
linuron	3-(3,4-dichlorphenyl)-1-methoxy-1-methylurea
maleic hydrazide	1,2-dihydro-3,6-pyridazinedione
mefluidide	N-[2,4-dimethyl-5-[[(trifluoromethyl)sulfonyl] amino] phenyl] acetamide
neburon	1-butyl-3-(3,4-dichlorophenyl)-1-methylurea
oxadiazon	2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)- -1,3,4-oxadiazolin-5-one
pronamide	3,5-dichloro-(N-1,1-dimethyl-2-propynyl)benzamide
sodium arsenite	
terbacil	3-tert-butyl-5-chloro-6-methyluracil
terbutol	2,6-di-tert-butyl-p-tolyl methylcarbamate
trifluralin	$\alpha\alpha\alpha$,-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine

APPENDIX B

Tables 6 - 18.

[a] Values based on a 1 - 9 scale, 1 = no live turf, 6 = acceptable, 9 = ideal

[b] * Means within a column significantly different than the 0.0 rate according to LSD (P >0.05)

Table 6. Effect of formulation and rate of ethofumesate on established perennial ryegrass. Summer, 1980.

Formulation	Rate (kg/ha)	Weeks after application: 3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	8.0	7.7	8.6	8.0	7.7	8.0	8.0	7.0	7.3
	0.3	7.0	7.0	7.3	8.0	7.0	7.7	7.7	7.0	7.0
	0.6	7.3	7.0	7.3	8.0	7.0	8.0	8.0	7.0	7.3
	1.0	7.3	7.3	7.7	8.0	7.0	8.0	8.0	7.0	7.7
	1.5	8.0	7.3	8.0	8.0	7.0	8.0	8.0	7.0	7.3
Flowable	0.0	8.0	7.7	8.0	8.0	7.3	8.0	8.0	7.0	7.3
	0.3	7.7	6.7	7.7	8.0	7.0	8.0	8.0	7.0	7.7
	0.6	8.0	7.0	7.7	8.0	7.0	8.0	8.0	7.0	7.3
	1.0	7.3	7.0	7.0	8.0	7.0	8.0	8.0	7.0	7.0
	1.5	7.7	7.0	7.3	8.0	7.0	7.3	8.0	7.0	7.3
Granular	0.0	8.0	7.7	8.0	8.0	7.7	8.0	8.0	7.0	7.3
	0.3	8.0	7.0	8.0	8.0	7.0	8.0	8.0	7.0	7.0
	0.6	8.0	7.3	7.3	8.0	7.0	7.7	8.0	7.0	7.0
	1.0	7.7	7.0	7.7	8.0	7.0	7.7	8.0	7.0	7.0
	1.5	7.7	7.0	7.7	8.0	7.0	7.3	8.0	7.0	7.3

Table 7. Effect of formulation and rate of ethofumesate on established perennial ryegrass. Fall, 1980.

Formulation	Rate (kg/ha)	Weeks after application								
		3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	8.0	7.0	8.0	8.0	7.7	8.0	8.7	8.0	8.0
	0.3	8.0	7.0	8.0	8.0	7.7	8.0	8.7	8.0	8.0
	0.6	8.0	7.3	8.0	8.0	7.7	8.0	8.0	8.0	8.0
	1.0	8.0	7.3	8.0	8.0	7.3	8.0	8.3	8.0	8.0
	1.5	8.0	7.0	8.0	8.0	7.3	8.0	8.0	8.0	8.0
Flowable	0.0	8.0	7.0	8.0	8.0	7.7	8.0	8.3	8.0	8.0
	0.3	8.0	7.0	8.0	8.0	7.3	8.0	8.0	8.0	8.0
	0.6	8.0	7.3	8.0	8.0	7.3	8.0	8.0	8.0	8.0
	1.0	8.0	7.7	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.5	8.0	7.3	8.0	8.0	7.3	8.0	8.0	8.0	8.0
Granular	0.0	8.0	7.0	8.0	8.0	7.7	8.0	8.7	8.0	8.0
	0.3	8.0	7.0	8.0	8.0	7.7	8.0	8.3	8.0	8.0
	0.6	8.0	7.0	8.0	8.0	7.3	8.0	8.0	8.0	8.0
	1.0	8.0	7.3	8.0	8.0	7.3	8.0	8.3	8.0	8.0
	1.5	8.0	7.0	8.0	8.0	7.0	8.0	8.0	8.0	8.0

Table 8. Effect of formulation and rate of ethofumesate on established perennial ryegrass. Spring, 1981.

Formulation	Rate (kg/ha)	Weeks after application: 3			5			7		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Flowable	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Granular	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0

Table 9. Effect of formulation and rate of ethofumesate on established perennial ryegrass. Summer, 1981.

Formulation	Rate (kg/ha)	Weeks after application: 3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	9.0	8.0	8.7	9.0	8.0	8.7	9.0	8.3	9.0
	0.3	9.0	8.0	8.7	9.0	8.0	8.7	9.0	8.0	8.7
	0.6	9.0	8.7	9.0	9.0	8.0	9.0	9.0	8.0	8.7
	1.0	9.0	8.3	9.0	9.0	8.3	9.0	9.0	8.3	8.3
	1.5	9.0	8.3	9.0	9.0	8.3	9.0	9.0	8.3	9.0
Flowable	0.0	9.0	8.3	9.0	9.0	8.0	9.0	9.0	8.3	9.3
	0.3	9.0	8.3	9.0	9.0	8.0	9.0	9.0	8.3	9.3
	0.6	9.0	8.3	9.0	9.0	8.0	8.7	9.0	8.3	8.3
	1.0	9.0	8.0	9.0	9.0	8.0	8.7	9.0	8.0	8.7
	1.5	9.0	8.0	9.0	9.0	8.0	9.0	9.0	8.0	9.0
Granular	0.0	9.0	8.0	8.7	9.0	8.0	8.7	9.0	8.3	9.0
	0.3	9.0	9.0	9.0	9.0	8.0	8.7	9.0	8.7	9.0
	0.6	9.0	8.3	9.0	9.0	8.0	9.0	9.0	8.0	9.0
	1.0	9.0	8.0	9.0	9.0	8.3	8.7	9.0	8.0	8.3
	1.5	9.0	8.0	9.0	9.0	8.3	9.0	9.0	8.0	8.7

Table 10. Effect of formulation and rate of ethofumesate on established perennial ryegrass. Fall, 1981.

Formulation	Rate (kg/ha)	Weeks after application 3 Color	3 Density	3 Quality	5 Color	5 Density	5 Quality	9 Color	9 Density	9 Quality
Emulsifiable concentrate	0.0	7.0	6.3	6.3	7.0	6.0	7.0	7.0	6.0	7.0
	0.3	7.0	6.0	6.3	7.0	6.0	6.7	7.0	6.0	6.7
	0.6	7.0	6.0	6.5	7.0	5.7	6.7	7.0	6.0	7.0
	1.0	7.0	6.3	6.2	7.0	6.0	7.0	7.0	6.0	6.7
	1.5	7.0	6.0	6.3	7.0	5.7	6.7	7.0	6.0	7.0
Flowable	0.0	7.0	6.3	6.5	7.0	6.0	7.0	7.0	6.0	7.0
	0.3	7.0	6.0	6.0	7.0	6.0	6.7	7.0	6.0	7.0
	0.6	7.0	6.0	6.0	7.0	6.0	6.3	7.0	6.0	7.0
	1.0	7.0	6.0	6.0	7.0	6.0	6.3	7.0	6.0	7.0
	1.5	7.0	6.3	6.3	7.0	6.3	6.3	7.0	6.0	6.7
Granular	7.0	7.0	6.3	6.5	7.0	6.0	7.0	7.0	6.0	7.0
	0.3	7.0	6.3	6.7	7.0	7.0	6.0	6.7	6.3	7.0
	0.6	7.0	6.0	6.3	7.0	6.0	6.7	7.0	6.0	7.0
	1.0	7.0	6.0	6.2	7.0	6.0	6.7	7.0	6.0	7.0
	1.5	7.0	6.0	6.5	7.0	6.0	6.7	7.0	6.0	7.0

Table 11. Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Fall, 1980.

Formulation	Rate (kg/ha)	Weeks after application: 3 Color	3 Density	3 Quality	5 Color	5 Density	5 Quality	9 Color	9 Density	9 Quality
Emulsifiable concentrate	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	0.3	7.3	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	0.6	7.3	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	1.0	6.7	7.0	7.0	7.0	7.0	7.0	6.3*	6.7	6.3
	1.5	7.0	7.0	7.0	6.7	7.0	7.0	6.3*	7.0	6.7
Flowable	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	0.3	7.0	7.0	7.0	7.0	7.0	7.0	6.7	7.0	7.0
	0.6	7.3	7.0	7.0	7.3	7.0	7.0	7.0	7.0	7.0
	1.0	7.3	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	1.5	7.0	7.0	7.0	7.0	7.0	7.0	6.7	7.0	7.0
Granular	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	0.3	7.7	7.0	7.0	7.0	7.3	7.0	7.0	7.0	7.0
	0.6	7.7	7.3	7.3	7.3	7.0	7.0	7.0	7.0	7.0
	1.0	7.3	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
	1.5	7.0	7.0	7.0	7.0	7.0	7.0	6.3*	7.0	6.7

Table 12. Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Spring, 1981.

Formulation	Rate (kg/ha)	Weeks after application								
		3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.0	8.0	8.0	8.0	8.0	8.0	7.7	8.0	8.0	8.0
	1.5	8.7*	8.0	8.0	8.0	7.7	7.7	8.0	8.0	8.0
Flowable	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	1.5	8.0	8.0	8.0	8.0	8.0	7.3*	8.0	8.0	8.0
Granular	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	0.6	8.3	8.0	8.0	8.0	8.0	7.7	8.0	8.0	8.0
	1.0	8.0	8.0	8.0	8.0	8.0	7.7	8.0	8.0	8.0
	1.5	8.7*	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0

Table 13. Effect of rate and formulation of ethofumesate on established Kentucky bluegrass. Summer, 1981.

Formulation	Rate (kg/ha)	Weeks after application: 3 Color	3 Density	3 Quality	5 Color	5 Density	5 Quality	9 Color	9 Density	9 Quality
Emulsifiable concentrate	0.0	9.0	8.0	8.0	9.0	8.0	8.7	8.0	8.0	8.0
	0.3	9.0	8.0	8.3	8.3	8.3	9.0	8.0	8.0	8.0
	0.6	9.0	8.0	8.3	9.0	8.3	8.3	8.0	8.0	8.0
	1.0	9.0	8.0	8.3	9.0	8.0	8.3	8.0	8.0	8.0
	1.5	9.0	8.0	8.3	9.0	8.0	8.0	8.0	8.0	8.0
Flowable	0.0	9.0	8.0	8.0	9.0	8.0	8.7	8.0	8.0	8.0
	0.3	9.0	8.0	8.7	9.0	8.0	9.0	8.0	8.0	8.0
	0.6	9.0	8.0	8.3	9.0	8.0	9.0	8.0	8.0	8.0
	1.0	9.0	8.0	8.3	9.0	8.0	9.0	8.0	8.0	8.0
	1.5	9.0	8.0	8.7	9.0	8.0	8.3	8.0	8.0	8.0
Granular	0.0	9.0	8.0	8.0	9.0	8.0	8.7	8.0	8.0	8.0
	0.3	9.0	8.0	9.0*	8.7	8.0	8.7	8.0	8.0	8.0
	0.6	9.0	8.0	8.7	9.0	8.0	8.7	8.0	8.0	8.0
	1.0	9.0	8.0	8.0	9.0	8.0	8.3	8.0	8.0	8.0
	1.5	9.0	8.0	8.3	9.0	8.0	8.0	8.0	8.0	8.0

Table 14. Effect of formulation and rate of ethofumesate on established Kentucky bluegrass. Fall, 1981.

Formulation	Rate (kg/ha)	Weeks after application: 3 Color	3 Density	3 Quality	5 Color	5 Density	5 Quality	9 Color	9 Density	9 Quality
Emulsifiable concentrate	0.0	7.0	6.3	6.3	7.0	6.3	6.0	6.0	5.0	5.0
	0.3	7.0	6.0	6.3	6.0	6.0	6.0	5.0	6.0	5.0
	0.6	7.0	6.0	6.7	7.0	6.0	6.0	5.0	6.0	5.0
	1.0	7.0	6.0	6.5	7.0	6.0	6.0	5.0	6.0	5.0
	1.5	7.0	6.0	6.3	7.0	6.0	6.0	5.0	6.0	5.0
Flowable	0.0	7.0	6.3	6.3	7.0	6.3	6.0	6.0	5.0	5.0
	0.3	7.0	6.0	6.0	7.0	6.0	6.0	5.0	6.0	5.3
	0.6	7.0	6.0	6.0	7.0	6.0	6.0	5.0	6.0	5.0
	1.0	7.0	6.0	6.0	7.0	6.0	6.0	5.0	6.0	5.0
	1.5	7.0	6.3	6.3	7.0	6.0	6.0	5.0	5.7	5.0
Granular	0.0	7.0	6.3	6.3	7.0	6.3	6.0	6.0	5.0	5.0
	0.3	7.0	6.3	6.7	7.0	6.0	6.0	5.0	5.7	5.0
	0.6	7.0	6.0	6.3	7.0	6.0	6.0	5.0	5.3	5.0
	1.0	7.0	6.0	6.2	7.0	6.0	6.0	5.0	5.7	5.0
	1.5	7.0	6.0	6.5	7.0	6.0	6.0	5.0	6.0	5.0

Table 15. Effect of formulation and rate of ethofumesate on established colonial bentgrass. Summer, 1980.

Formulation	Rate (kg/ha)	Weeks after application: 3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	7.0	7.0	7.0	7.0	6.7	7.0	7.7	7.0	7.3
	0.6	7.0	6.0	7.0	7.3	7.0	7.0	7.7	7.0	7.0
	1.0	7.0	6.7	6.7	7.0	7.0	7.0	7.7	7.0	7.7
	1.5	7.0	6.3	6.3	7.0	6.0	7.0	7.7	7.0	7.0
Flowable	0.0	7.0	7.0	7.0	7.0	6.7	7.0	7.3	7.0	7.3
	0.6	7.0	6.7	7.0	7.3	7.0	7.0	7.3	7.0	7.3
	1.0	7.0	6.3	6.7	7.7	7.0	7.0	8.0	7.0	7.0
	1.5	6.7	6.3	6.0	7.0	6.7	7.0	7.7	7.0	7.3
Granular	0.0	7.0	7.0	7.0	7.0	6.7	7.0	7.7	7.0	7.3
	0.6	7.0	6.7	7.0	7.7	7.0	7.3	7.7	7.0	7.3
	1.0	7.0	7.0	7.0	7.3	7.0	7.0	8.0	7.0	7.3
	1.5	6.7	6.7	6.7	7.3	7.0	7.0	7.7	7.0	7.0

Table 16. Effect of formulation and rate of ethofumesate on colonial bentgrass. Fall, 1980.

Formulation	Rate (kg/ha)	Weeks after application: 3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	8.0	8.0	8.0	8.0	7.7	8.0	8.0	8.0	8.0
	0.6	7.7	8.0	8.0	7.7	8.0	8.0	7.3	8.0	8.0
	1.0	7.3	8.0	7.3	7.3	8.0	7.7	7.3	8.0	7.3
	1.5	7.3	7.3	7.3	7.3	7.3	7.3	7.7	7.3	7.3
Flowable	0.0	8.0	8.0	8.0	8.0	7.7	8.0	8.0	8.0	8.0
	0.6	7.3	8.0	7.7	7.3	8.0	7.7	7.7	8.0	7.7
	1.0	7.7	8.0	7.7	7.3	8.0	7.3	8.0	8.0	8.0
	1.5	7.3	7.7	7.7	7.3	7.7	7.0*	7.7	7.7	8.0
Granular	0.0	8.0	8.0	8.0	8.0	7.7	8.0	8.0	8.0	8.0
	0.6	8.0	7.3	8.0	8.0	7.3	8.0	8.0	7.7	8.0
	1.0	7.7	7.3	7.7	7.7	7.0	7.7	8.0	8.0	8.0
	1.5	7.3	7.7	7.3	7.3	7.3	7.3	8.0	8.0	8.0

Table 17. Effect of formulation and rate of ethofumesate on established colonial bentgrass. Spring, 1981.

Formulation	Rate (kg/ha)	Weeks after application: 3			5			9		
		Color	Density	Quality	Color	Density	Quality	Color	Density	Quality
Emulsifiable concentrate	0.0	7.0	7.0	7.0	7.0	8.0	8.0	7.3	8.0	8.0
	0.6	7.0	7.0	7.0	7.0	8.0	8.0	7.0	8.0	8.0
	1.0	7.0	7.0	7.0	7.0	8.0	8.0	7.7	8.0	8.0
	1.5	7.0	7.0	7.0	7.0	7.7	7.3*	7.0	8.0	7.7
Flowable	0.0	7.0	7.0	7.0	7.0	8.0	8.0	7.3	8.0	8.0
	0.6	7.0	7.0	7.0	7.0	8.0	8.0	7.7	8.0	8.0
	1.0	7.0	7.0	7.0	7.0	8.0	8.0	7.0	8.0	8.0
	1.5	7.0	7.0	7.0	7.0	8.0	7.3*	7.0	8.0	7.0*
Granular	0.0	7.0	7.3	7.0	7.0	8.0	8.0	7.3	8.0	8.0
	0.6	7.0	7.0	7.0	7.0	8.0	8.0	7.0	8.0	8.0
	1.0	7.0	7.0	7.0	7.0	8.0	8.0	7.7	8.0	8.0
	1.5	7.0	7.0	7.0	7.0	8.0	8.0	7.3	8.0	8.0

Table 18. Effect of formulation and rate of ethofumesate on established colonial bentgrass. Summer, 1981.

Formulation	Rate (kg/ha)	Weeks after application: 3 Color	3 Density	3 Quality	5 Color	5 Density	5 Quality	9 Color	9 Density	9 Quality
Emulsifiable concentrate	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.7	7.0
	0.6	7.0	6.3*	7.0	7.0	6.7	7.0	7.0	6.0	7.0
	1.0	7.0	6.7	7.0	7.0	6.7	7.0	7.0	6.3	7.0
	1.5	7.0	6.0	6.3	7.0	6.7	7.0	7.0	6.7	7.0
Flowable	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.7	7.0
	0.6	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.7	7.0
	1.0	7.0	7.0	7.0	7.0	6.7	7.0	7.0	7.0	7.0
	1.5	7.0	6.0	6.3*	7.0	6.3	7.0	7.0	6.7	7.0
Granular	0.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.7	7.0
	0.6	7.0	6.7	7.0	7.0	6.3	6.7	7.0	6.3	7.0
	1.0	7.0	7.0	7.0	7.0	6.7	7.0	7.0	6.0	7.0
	1.5	7.0	6.0	6.7	7.0	6.0	7.0	7.0	6.3	7.0

Tables 19 - 21.

[a] Values based on a 1 - 9 scale, 1 = no live turf, 6 = acceptable, 9 = ideal

[b] Columns with the same letter(s) above are not significantly different at the 0.05 level by Duncan's multiple range.

Table 19. Effect of ethofumesate applied to several growth stages of annual bluegrass. Seeded March, 1981.

Weeks after application	Growth stage	Rate (kg/ha) 0.0	1.0	1.5	2.0
	Seeding	9.0a	1.0d	1.0c	1.0d
	1-leaf	9.0a	4.8b	3.5b	3.0c
3	3-leaf	9.0a	2.5c	2.8b	3.0c
	1-tiller	9.0a	7.5a	7.3a	7.5a
	3-tiller	9.0a	7.0a	7.3a	6.3b
	Seeding	9.0a	1.0c	1.0b	1.0b
	1-leaf	9.0a	4.0b	1.8b	1.5b
5	3-leaf	9.0a	1.0c	1.0b	1.0b
	1-tiller	9.0a	5.8a	6.3a	5.5a
	3-tiller	9.0a	6.3a	6.3a	6.3a
	Seeding	9.0a	1.0d	1.0c	1.0c
	1-leaf	9.0a	2.5c	1.0c	1.0c
7	3-leaf	9.0a	1.0d	1.0c	1.0c
	1-tiller	9.0a	5.3b	5.8b	5.3b
	3-tiller	9.0a	7.0a	7.0a	6.8a

Table 20. Effect of ethofumesate on several growth stages of annual bluegrass. Seeded June, 1981.

Weeks after application	Growth stage	Rate (kg/ha) 0.0	1.0	1.5	2.0
	Seeding	9.0a	1.0d	1.0d	1.0d
	1-leaf	9.0a	4.0b	4.0c	3.0c
3	3-leaf	9.0a	2.8c	3.3c	2.8c
	1-tiller	9.0a	6.8a	5.3b	4.5b
	3-tiller	9.0a	6.3a	6.8a	6.0a
	Seeding	9.0a	1.0d	1.0d	1.0d
	1-leaf	9.0a	2.3c	2.0c	1.8c
5	3-leaf	9.0a	1.0d	1.5cd	1.3cd
	1-tiller	9.0a	5.3b	6.0b	4.8b
	3-tiller	9.0a	6.0a	7.0a	6.5a
	Seeding	9.0a	1.0c	1.0c	1.0c
	1-leaf	9.0a	1.3c	1.0c	1.0c
7	3-leaf	9.0a	1.0c	1.0c	1.0c
	1-tiller	9.0a	5.3b	6.3b	5.5b
	3-tiller	9.0a	6.5a	7.3a	7.3a

Table 21. Effect of ethofumesate on several growth stages of annual bluegrass. Seeded October, 1981.

Weeks after application	Growth stage	Rate (kg/ha) 0.0	1.0	1.5	2.0
	Seeding	9.0a	1.0d	1.0d	1.0d
	1-leaf	9.0a	4.3c	4.3c	3.0c
3	3-leaf	9.0a	4.5bc	5.3b	4.5b
	1-tiller	9.0a	5.3b	5.8b	5.0b
	3-tiller	9.0a	9.0a	9.0a	9.0a
	Seeding	9.0a	1.0c	1.0c	1.0c
	1-leaf	9.0a	1.8c	2.0c	1.5c
5	3-leaf	9.0a	4.3b	4.0b	3.8b
	1-tiller	9.0a	4.0b	4.5b	4.3b
	3-tiller	9.0a	7.0a	6.8a	6.5a
	Seeding	9.0a	1.0c	1.0d	1.0d
	1-leaf	9.0a	1.0c	1.0d	1.0d
7	3-leaf	9.0a	3.3b	2.5c	2.8c
	1-tiller	9.0a	3.8b	4.0b	4.0b
	3-tiller	9.0a	8.0a	7.8a	7.3a