AN ABSTRACT OF THE THESIS OF

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Title: Annual Bluegrass (Poa annua L.) Control with Ethofumesate During Turfgrass Establishment

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Thomas W. Cook

Temperate climates are particularly conducive to growth of annual bluegrass which readily invades and dominates most cool-season turfgrasses. Ethofumesate (2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate) is one herbicide available which will selectively control annual bluegrass.

The primary objectives of this research were to determine optimum application rates and timing of ethofumesate for control of annual bluegrass on sites renovated by three different techniques. In addition, tolerance of common turfgrass cultivars was determined. Ethofumesate rates of 0.5, 1.0, 1.5 kg ai/ha, and split repeat treatments of 0.5 kg ai/ha applied twice or three times, applied preemergence, or early postemergence at the one and two leaf stage relative to perennial ryegrass were tested. Protected Least Significant Difference mean separation statistical analysis was used to

determine differences at the 5% level.

Differences were observed between ryegrass and tall fescue cultivars in greenhouse ethofumesate tolerance studies but not in field trials. Ethofumesate greenhouse cultivar tolerance differences did not correlate to results of field trials. All perennial ryegrass and tall fescue cultivars tested in field trials tolerated ethofumesate well at all rates. There was an initial 1 month period of growth suppression following ethofumesate application which perennial ryegrass and tall fescue appeared able to recover and annual bluegrass was not. Annual bluegrass was controlled in all trials at 0.5, 0.5 X 2, 0.5 X 3, 1.0, and 1.5 kg ai/ha ethofumesate rates and at all stages of application. Annual bluegrass reduction ranged between 83% to 100%.

Perennial ryegrass cultivars Palmer, Blazer, Loretta, Dasher, and Regal, tall fescue cultivar Mustang, and `America' Kentucky bluegrass tolerated ethofumesate. Red fescue, hard fescue, chewings fescue, roughstalk bluegrass, colonial bentgrass, and annual bluegrass did not tolerate ethofumesate.

In the three establishment methods studied, annual bluegrass control was 100% in the no-till followed by surface scarification and broadcast seeding, 97.3% in

the till trials with broadcast seeding, and 83% in the no till slicer seeder method.

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

by

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INTRODUCTION

Annual bluegrass, (ie. *Poa annua* L.), is a cool-season grass found growing in most areas of the world as an opportunistic colonist. Annual bluegrass generally is found in one or both of the following habitats: a) disturbed, (ie. open habitat), exhibiting typical Ruderal characteristics, b) as a component of a stable, (ie. closed habitat), fertile environment such as a pasture or lawn. Varieties found in different habitats worldwide exist as annuals or modified perennials with as many as 48 different biotypes, ecotypes, races, and subspecies (Tutin, 1957; Arber, 1965; Ellis et al., 1970; Gibeault, 1971; Hitchcock, 1971; Gould, 1975; Cordukes, 1977; Beard et al., 1978; Couch, 1979; Peel, 1982; Tsvelev, 1984).

Controversy continues regarding the agronomic and horticultural status of annual bluegrass. Classical turf culture deals with cultivated species often in monoculture. In this context, annual bluegrass is an unwanted grass because its texture and color do not blend with planted grasses, its prolific flowering at all cutting heights, and its alleged poor tolerance to drought, wear, and disease. Annual bluegrass is per-

ceived to be a weed in what turf managers believe to be a stable environment.

Conversely, practical turfgrass ecology acknowledges that pure stands of cultivated grasses are quite rare. The natural fate of all turf is to increase species diversity until ecological balance is achieved. Annual bluegrass is uniquely able to invade and compete in established monostands of other grasses. Research shows that annual bluegrass wear tolerance, disease resistance, and rooting potential is equal to desireable turf grass species (Sprague and Burton, 1937; Tutin, 1957; Wilkinson and Duff, 1972; Grime and Hunt, 1975; Cordukes, 1977; Beard et al., 1978; Karnok and Kucharski, 1980; McNeilly, 1981; Wehner and Watschke, 1981; Fitter, 1982; Peel, 1982). For these reasons annual bluegrass is often accepted as a component of a mature turf.

Any attempt to control annual bluegrass is done with the goal of maintaining pure stands of cultivated species, thus countering the natural ecological trend toward species diversification.

Successful selective annual bluegrass control attempts to reduce this ecological trend by removing the weed and increasing competition from cultivated cool season species in the stand.

Ethofumesate has unique preemergence and postemergence selectivity in perennial ryegrass (Lolium perenne L.), for control of annual bluegrass in seed fields, pastures, athletic turf, and lawns. Ethofumesate has been used to control annual bluegrass in Kentucky bluegrass (Poa pratensis L.), tall fescue (Festuca arundinacea Schreb.), bentgrass (Agrostis tenuis Sibth. and Agrostis palustris Huds.), and Bermudagrass (Cynodon L. sp.) turfs (Haggar and Bastian, 1976; Lee, 1977; Ekins and Day, 1978; Griffiths et al., 1978; Dickens, 1979; Kamp, 1981).

The influence of planting techniques on ethofumesate effectiveness has not been determined. Likewise, optimum timing and rates for ethofumesate and cool season grass tolerance have not been determined.

The objectives of this study were to: (a) determine tolerance of perennial ryegrass, tall fescue, Kentucky bluegrass, annual bluegrass, colonial bentgrass (Agrostis tenuis Sibth.), roughstalk bluegrass (Poa trivialis L.), red fescue (Festuca rubra var. rubra L.), Chewings fescue (Festuca rubra var. commutata Gaud.), and hard fescue (Festuca ovina var.duriscula L. Koch) to ethofumesate; (b) determine perennial ryegrass cultivar tolerance to ethofumesate; (c) determine optimum ethofumesate rates and application timing rela-

tive to growth stages of cultivated grasses; and (d) determine the effects of seedbed preparation techniques on annual bluegrass control with ethofumesate.

LITERATURE REVIEW

Annual Bluegrass (Poa annua L.) Origin

Annual bluegrass is believed to have originated in Europe in the relatively recent past (Beard et al., 1978; Gould, 1975; Hitchcock, 1971; Holtzner and Numata, 1982; Peel, 1982; Tutin, 1957; Warwick, 1979). Annual bluegrass is believed to have arisen as a hybrid tetraploid from a chance cross between Poa infirma (H.B.K.) which now grows in the Mediterannean region, and Poa supina (Schrad.) which presently is found as a cool-temperature creeping perennial in northern and central Europe (Tutin, 1952, 1957).

Annual bluegrass probably formed on the north shore of the Mediterranean during late Quaternary glaciation (approximately 10,000 B.C.) when a compression of climate zones gave overlap of distribution between Poa supina and Poa infirma (Tutin, 1952, 1957).

The chromosome number of annual bluegrass was first determined to be 2N=28 in 1937 (Hovin, 1958; Ellis et al., 1970). Annual bluegrass is believed to be an allotetraploid (Ellis et al., 1970; Gibeault, 1971; Hovin, 1958; Tutin, 1957; Warwick and Briggs, 1978a).

Annual bluegrass is also reported to have 2N=14 chromosomes (Ellis et al., 1970; Hovin, 1958). More cytological research is required to resolve this discrepancy. It is possible the taxonomic confusion is due to misidentification of Poa annua L. biotypes and other Poa taxa. As an example, Poa infirma (Murb.) has been treated as Poa annua L. subsp. exilis (Tomm.) and Poa supina as Poa annua subsp. supina (Schrader) Link) (Peel, 1982).

Two diploid species (2N=14) have been described as Poa infirma and Poa supina (Tutin, 1957). These two diploid Poa "species" are included in a small section of Ochlopoa (Aschers and Graebn.) which contains six known species found in Europe and North America, all of which are morphologically similar. The four remaining "species" of Ochlopoa are: Poa annua L., Poa dimorphanta (Murbeck), Poa moroccana (Nannfeldt), and Poa rivulorum (Maire and Trabut), all of which are felt to be tetraploids (2N=28). A key for distinguishing and accounting for these "species" was published by Nannfeld in 1938 (Tutin, 1952, 1957). Recent discovery of a diploid population (2N=14) of annual bluegrass (Poa annua L.) in Australia with regular bivalent formation may indicate that evolutionary association is more complex than previously recognized (Ellis et al., 1970).

Taxonomic disagreement about annual bluegrass (Poa annua L.) may be due to genetic inconsistencies associated with the rapid evolutionary pace of the species (Ellis et al., 1970). More cytological study such as genome analysis may be needed to sort out the actual evolutionary and taxonomic status of this species. Genomic analysis (1 haploid set of chromosomes including the genes they contain is defined as a genome) has provided satisfactory proof of evolutionary ancestry of plant species with the classic example being Viola (Ellis et al., 1970).

Annual bluegrass chromosome number inconsistencies indicate either the two parent genomes have become homologous for long regions of the chromosome or annual bluegrass did not arise as an allotetraploid but in fact is an autotetraploid (Ellis et al., 1970).

Ecological studies show disturbances tend to accelerate natural evolutionary processes. Cultivation in lawns is an example of disturbance. Human disturbance has increased in intensity through time and the cumulative effects are reflected in the taxonomy of Poaceae (Gramineae) (Estes et al., 1982).

Taxonomic differentiation is clearly not resolved for this species. The issue of subspecies classification may not be warranted in North America since

varieties are not geographically isolated. From this perspective of view, varieties simply reflect intra-population differences resulting from different selective pressures on a genetically heterogeneous population (Warwick, 1979).

Taxonomy

Annual bluegrass (*Poa annua* L.) was first described by Linnaeus in 1753. The name is from the Greek word "Poa" meaning grass and "annua" referring to annual growth habit (Hitchcock, 1971). The plant is most often described as a tufted, bright green, bunch-type annual which will persist under close cut, irrigated situations as a prostrate creeping perennial that roots at the nodes (Beard et al., 1978). Plant height is generally 5-20 cm. A wide range of vegetative characteristics and habitats have been described for annual bluegrass. Varieties fit on a continuum from noncreeping bunch type annuals usually light green in color with upright growth habit, to stoloniferous prostrate perennials with creeping growth habit and dark green color. Intermediate growth habits and vegetative characteristics have been described between these extremes (Beard et al., 1978; Cordukes, 1977; Ellis et al., 1971; Gibeault, 1971; Hitchcock, 1971; Tutin, 1957; Warwick et al., 1980).

Characteristics commonly used in identifying annual bluegrass (Poa annua L.) include the following:

Inflorescence Characteristics

> "Panicle pyramidal, open, 3-7 cm long, spikelets crowded, 3-6 flowered, about 4 mm long, First bloom 1.5-2.0 mm, the second 2.0-2.5 mm, lemma not webbed at base, distinctly 5 nerved, more or less pubescent on lower part of the keel sometimes simulating a web, anthers 0.5-1.0 mm long" (Beard et al., 1978).

Vegetative Characteristics

> "Vernation folded, sheath distinctly compressed, glabrous, whitish at base, keeled, split with over lapping hyaline margins..." (Beard, 1973).

Poa annua L. vegetative characteristics as found under turf conditions include:

> "vernation folded in the bud shoot, long transparent ligule, V shaped cross section of leaf blade, and boat shaped leaf tip. Supporting characteristics that may occasionally be helpful include the presence of seedheads and a turf which tends to be somewhat yellow green to light green" (Beard et al., 1978).

Annual bluegrass descriptions often identify varieties as biotypes, ecotypes, races, species, or subspecies. Biotypes are naturally occurring groups of individuals having the same genetic composition. Biotypes are a physiologic race. Ecotypes are a group of plants within a species adapted genetically to a particular habitat but able to cross freely with other ecotypes of the same species. Biotypes and ecotypes

are examples of physiologic specialization defined as the existence within a species of genetically different races or forms indistinguishable in structure, that show differences in physiological, biochemical, or pathogenic characters (Abercrombie et al., 1980). A race is an interbreeding group within a species also referred to as a taxonomic category (subspecies) representing such a group (Webster's New Collegiate Dictionary, 1979). Subspecies are subdivisions of a species forming a group whose members differ from other members of the species in certain characteristics though there may be no sharp dividing line. While breeding is possible and in many cases occurs between different subspecies it does not occur as freely as within each subspecies. Because isolation is incomplete, subspecies nearly always grade into each other. The partial reproductive isolation is commonly due to the occupation of different geographical areas. Some subspecies are probably new species in the making. Species are defined by the binomial system of classification first applied by Linnaeus in the Species Plantarum in 1753 and in the tenth edition of Systema Naturae in 1758. Subspecies and varieties where described are classified using a trinomial system where the third term names the variety or subspecies (Abercrombie et al., 1980).

Annual and perennial "biotypes" are described for Poa annua L. Tutin (1957) describes three stock types as follows:

Poa annua var. annua (Var. typica Beck) (Tutin, 1957)
Poa annua var. reptans (Hausskn.) " "
Poa annua var. aquatica (Aschers) " "

Gibeault (1971) separates Poa annua L. taxonomy into "annual biotypes and perennial biotypes". Gibeault lists 21 annual varieties of Poa annua L. and 10 perennial varieties. Gibeault (1971) suggests that subspecies classification is warranted for the following:

Poa annua ssp annua(var.typica Beck)Timm (Gibeault,1971)
Poa annua ssp. reptans (var.reptans Hasskn.)Timm " "
Poa annua ssp. aquatica (var.aquatica Aschers)Timm" "

Hitchcock (1971) lists 10 separate descriptions for Poa annua L.:

Poa annua var. acquatica (Aschers) (Hitchcock, 1971)
Poa annua var. erecta " "
" " var.praecox " "
" " var. perennans " "
" " var. typica " "
" " var. pauciflora " "
" " var. serotinia " "

Poa annua var. tenuis (Hitchcock, 1971)

" " var. caespitosa " "

Poa chapmaniana(Scribn.) is listed as an "ecotype" of Poa annua possibly evolving into a new species (Arber, 1965; Gould, 1975).

Several "ecotypes" specific to the U.S.S.R. are described by Tsvelev (1984) for Poa annua. L.

Poa annua ssp. subpina (Schrad.) Husn. (Tsvelev, 1984)

Poa infirma (P. annua ssp. exilis) " "

Poa hohenackeri " "

Couch (1979) describes 48 distinct "subspecies" worldwide which include:

Poa supina (Described as a Poa annua L. hybrid which is a creeping perennial found in the mountains of northern Europe.) (Couch, 1979)

Poa infirma (Described as an upright annual found in the Mediterannean) " "

Although there is disagreement on the taxonomy of different varieties, there is agreement that annual and perennial varieties are found. Evidence for population differentiation depending on temperature, moisture level, soil type, soil fertility, site culture, and degree of site disruption is documented (Cordukes, 1977; Ellis et al., 1971; Tutin, 1957; Warwick and Briggs,

1978 b; Warwick, 1979).

Distribution

The geographic range of annual bluegrass is nearly worldwide in areas of human habitation. The northern range of the plant extends from Newfoundland and Labrador, west to Alaska (Hitchcock, 1971) throughout both Asian and European parts of the U.S.S.R. except arctic regions (Tsvelev, 1984) and through Finland, Norway, Sweden, Iceland, and Denmark (Holm et al., 1979) and Greenland (King, 1966). The southern range of this grass species is from Chile and Argentina to South Africa, Australia, and New Zealand (Holm et al., 1979). Annual bluegrass has been found growing at elevations as high as 3,658 meters above sea level in the Himalayas (Arber, 1965) and in tropical America (Hichcock, 1971). Annual bluegrass is absent from only: a) areas of high temperature and low rainfall, b) areas of highly competitive plant communities such as tall grass lands, and c) areas having highly acid soils (Peel, 1982).

Annual bluegrass is postulated to have been introduced to America from Europe by Spanish explorers (Beard et al., 1978). Annual bluegrass seed has been found in adobe bricks from the mission period (1769-1824) (King, 1966). Annual bluegrass is thought to

have been naturalized in China, Korea, and Japan by human travel in prehistoric times (Holzner and Numata, 1982) and introduced and naturalized in Australia by 1878 (Ellis et al., 1971). The majority of annual bluegrass dispersal to present world-wide distribution appears to be due to human travel and agriculture (Ellis et al., 1971; Holm et al., 1977; Peel, 1982).

Habitat

Annual bluegrass is native to wasteplaces, flower beds and gardens, cultivated land, grasslands, mountains, and areas adjacent to water in temperate climates (Beard, 1973; Clapham et al., 1962; Hitchcock, 1971; Warwick and Briggs, 1978 a).

Based on field surveys of natural habitat locations, annual bluegrass is termed ubiquitous (Cadbury et al., 1971; Grime et al., 1981). It is found in arctic, boreal, temperate, and sub-Mediterranean climatic habitats (Holzner and Numata, 1982).

Annual bluegrass develops highest populations in areas where soil is loose, well cultivated, or disturbed routinely (Ruderal) (Arber, 1965; Cadbury et al., 1971). Ruderal (from the Latin `rudus' meaning debris) describes habitats of disturbance. Ruderal characteristics include: precocious flowering, potentially fast

growing habit, and having an annual life cycle (Grime, 1979; Holzner and Numata, 1982). Ruderal sites where annual bluegrass is found include: roadsides, railways, farmyards, pathsides, canal towpaths, manufacturing, sewerage, mining waste sites, industrial yards, and old housing sites (Arber, 1965; Cadbury et al., 1971; Clapham et al., 1962; Grime et al., 1981). It also is found between flagstones and cobblestones of roadways and courtyards (Arber, 1965; King, 1966), on roof tops, on top of walls (Arber, 1965), on marshland (Thompson and Grime, 1979), in orchards (Harper, 1977), and in forest and woodlands (Thompson and Grime, 1979).

Annual bluegrass is successful as a Competitive Ruderal (Grime, 1979) in areas which include: tilled crop land and gardens, grasslands, rangelands, pastures, lawns, bowling greens, golf greens, lawn borders, athletic fields, and public parks (Beard et al., 1978; Cadbury et al., 1971; Gould, 1975; Kamp, 1981; Tothill and Hacker, 1983; Tsvelev, 1984; Warwick and Briggs, 1978 b). Competitive Ruderal characteristics include: delayed flowering, potentially rapid growth and spread, biennial or perennial life cycle, rapid proliferation, fragmentation of shoots, rapid leaf turnover, and lack of seasonal flowering (Grime, 1979).

Annual bluegrass population increase is positively

correlated with amount of site disturbance and/or increase in human activity near the site (Arber, 1965; Harper, 1977; Holzner and Numata, 1982; Tutin, 1957; Warwick and Briggs, 1978 b).

Dispersal

Annual bluegrass has two natural dispersal mechanisms depending upon variety. Annual types disperse primarily by seed. Perennial types produce less seed but compensate with vegetative spread by stolons (Law, 1979).

Natural seed dispersal of annual bluegrass seed is calculated to be 0.5 meters from isolated parent plants (Arber, 1965). Annual bluegrass seed does not possess special dispersal mechanisms for clinging, floating, or flying (Grime et al., 1981). Viable annual bluegrass seed has survived gut passage in cows and other forage animals, birds, and rodents (Dirzo and Sarukhan, 1984; Harper, 1977). Seeds may be dispersed with soil or plant debris by wind and water (Arber, 1965; Harper, 1977).

Perennial types form secondary tillers after flowering. These tillers develop adventitious roots at nodes assisting vegetative spread of the plant (Gibeault, 1971; Grime, 1979; Law et al., 1977; Warwick

and Briggs, 1978 b). Grazing or mowing tends to stimulate lateral vegetative spread of the plant (Law, 1979).

Seed numbers tend to decrease as plants age and population density increases, resulting in additional vegetative spread (Arber, 1965).

Pollination/Fertilization

Annual bluegrass is capable of both self pollination and cross pollination. Cross pollination is extremely rare in nature, however (Arber, 1965; Tutin, 1957).

Anthesis begins from the top of the panicle and proceeds downward. The same order is followed in the individual spikelets. The uppermost floret, or in larger spikelets the two upper florets, are always female, the remainder being hermaphroditic. The female florets open in the early morning, and remain partially open with protruding stigmas during the following day. This may be repeated for three to four days although repetition is unusual. The behavior of the hermaphrodite florets varies with humidity and temperature. Annual bluegrass exhibits an unusual adaptation of monoecism termed gynomonoecism (having female and hermaphroditic flowers in the same spikelet) (Arber,

1965).

Annual bluegrass is classified as chasmogamic (Arber, 1965) which means it produces flowers that open to expose the reproductive organs. Chasmogamy allows cross pollination but does not preclude self pollination. The production of annual bluegrass flowers that do not open to expose reproductive organs (termed cleistogamy) thus preventing cross pollination is also common in winter (Tutin, 1957). Cleistogamy may be significant in evolution because of reduced cross pollination between plant varieties.

Annual bluegrass tends to self pollinate because of floral size, orientation, and proximity on the plant. The chance of outbreeding by cross pollination appears remote in nature (Tutin, 1957). These facts may account for the many annual bluegrass varieties described worldwide. In one example, four different annual bluegrass ecotype populations remained genetically distinct when grown adjacent to each other in field trials for a 6 year period (Tutin, 1957).

Annual bluegrass is fully self compatible with high pollen fertility (82-99%) (Beard et al., 1978). High seed sets are common for annual bluegrass (86-98%) in both selfed and open pollinated panicles (Ellis et al., 1970, 1971).

Strict annual Poa annua L. populations do occur. A strictly annual and seasonal flowering Australian annual bluegrass population was found in a dry area adjacent to a mountain range (Ellis et al., 1971). Annual varieties flowered in 42-50 days compared to 55-93 days for perennial types (Peel, 1982).

The photosynthetic efficiency of annual bluegrass is unaffected by initiation of flowering (Warwick, 1979). Inflorescences of annual bluegrass are important photosynthetic organs right through grain ripening. Anthesis patterns of annual bluegrass are affected by photoperiod and light intensity. Annual bluegrass plants acclimatized by a 12 hour photoperiod have one burst of anther dehiscence during the dark period each day. Nonacclimatized plants exhibited two bursts of dehiscence per day, both occurring during the light period (Warwick, 1979).

Temperature and light influence anther development. Anther development was stopped in one annual bluegrass population at temperatures above 25 degrees Celsius (Ellis, et al, 1970). Alternating day/night temperatures of 24 degrees Celsius and 10 degrees Celsius had no effect on fertilization but reduced seed dormancy (Warwick, 1979; Wells, 1974).

The Seed

Annual bluegrass seed characteristics described from field sampling studies (Grime et al., 1981) include the following:

Seed length: 2.60 mm
Seed width: 0.85 mm
Seed weight: 0.26 mg
Seed shape: Ovoid, rhomboidal, turbinate
Seed appendages: Absent
Seed hairs, teeth: Absent or inconspicuous
Seed surface area: 0.009 sq cm (King, 1966)
Seed colors: Hue 5 YR, value 8, chroma 3(Munsell, 1954)
Germinule surface texture: Smooth

(Grime et al., 1981)

Dehiscence is passive in annual bluegrass seed. Mean height of inflorescence is 15 cm (Clapham et al., 1962; Grime et al., 1981).

Annual bluegrass, like all grasses, produces one seed per fruit. Predicted seed production per inflorescence ranges between 60-80 viable seeds depending on habit and population density (Arber, 1965; Law, 1981).

Seed numbers per inflorescence are generally greater in annual varieties and at low plant population densities (Law et al., 1977). One annual bluegrass plant produced 360 seeds between May and August (4 months) (Beard et al., 1978). Annual bluegrass surface soil seed bank estimates range from 12.27 million

viable seeds per acre in grasslands to 30 million viable seeds per acre in disturbed arable soil (Champness and Morris, 1948; Chippendale and Milton, 1934).

Germination Parameters

All annual bluegrass seeds do not germinate immediately. Some varieties have a post harvest dormancy factor (Ellis et al., 1970; Gibeault, 1971; Hovin, 1957; Law et al., 1977; Tutin, 1957). Disturbance of the soil/seed bed, alternate temperatures (cool/warm), alternate dark/light periods, increasing soil moisture content from 20% to 40% of field capacity, and low oxygen partial pressures (3.3-8.5% molecular oxygen) break dormancy and increase annual bluegrass seed germination rate (Beard et al., 1978; Bewley and Black, 1985; Bogart and Beard, 1973; Wells, 1974).

Annual bluegrass seed germination occurs from 4 degrees Celsius to 31 degrees Celsius (Beard et al., 1978; Bogart and Beard, 1973; Grime et al., 1981). Based upon time to reach 50% germination, the optimum range appears to be from 8 degrees Celsius to 19 degrees Celsius (At 8 degrees Celsius the plant took 8 days to reach 50% germination, 6 days at 9 degrees

Celsius, 5 days at 10 degrees Celsius, 4 days at 11 degrees Celsius, 3 days at 16 degrees Celsius, 2 days at 19 degrees Celsius. Time to reach 50% germination ranged from 12-14 days at 6 degrees Celsius and between 2-14 days at 31 degrees Celsius) (Grime et al., 1981).

Alternating temperatures of 30 degree Celsius days and 20 degrees Celsius nights resulted in higher germination than constant temperature at 20 degrees Celsius and 30 degrees Celsius respectively (Beard et al., 1978).

Germination is increased by light (Wells, 1974). Germination in dark is generally less than germination in light (100% germination in light compared to 81% germination in dark) (Grime et al., 1981).

Annual bluegrass seed dormancy and light requirements for germination result in a large buildup in soil profiles of potentially viable seed. Seed has been found to remain viable for as long as 6 years in these soil banks (Beard et al., 1978; Grime et al., 1981).

Measurements of seed dimensions, actuarial tables, and seed bank data have shown that annual bluegrass is able to survive in nature without special seed dispersal mechanisms by compensating with high seed numbers, dormancy mechanisms, and small seed size which allow dispersal in soil and frass by humans, animals,

water and wind (King, 1966; Wells, 1974). Opportunistic colonization occurs readily in disrupted areas (Grime et al., 1981).

Stand Development

Typical germination times for freshly collected seeds under field conditions is 11 days (Grime et al., 1981). All varieties exhibit one seminal root per plant. Annual types produce fewer adventitious roots than perennial types. Optimal growth conditions for annual bluegrass include a 16-hour photoperiod with 130 K lx of light and alternating diurnal temperature of 26/17 degrees Celsius. Adequate water levels are also required (Warwick, 1979). Plant life spans range from 42-60 days for the annual type and from 13-19 months (Wells, 1975) to 2-3 years (Tutin, 1957) for the perennial type when grown under optimal conditions (Warwick, 1979).

Annual bluegrass readily invades and often dominates planted cool season turfgrasses. Initial invasion is slow and may take 5 to 10 years to make up 25% of the stand. Once established, annual bluegrass increase is rapid, often dominating turf 2 to 3 years after reaching the 25% mark (Cook, 1987)

Herbicidal Control

Herbicidal control of Poa annua L. may be grouped into four categories: a) flower suppression/growth regulation, b) selective postemergent control, c) selective preemergent control, and d) selective preemergent and postemergent control.

Flower Suppression/Growth Regulation

Annual bluegrass (Poa annua L.) produces an abundance of seed and quickly invades and dominates bentgrass (Agrostis sp. L.), Kentucky bluegrass (Poa pratensis L.), and perennial ryegrass (Lolium perenne L.) turf. Preventing seed set, reducing seed fertility, or reducing seed production could eliminate the primary means of invasion for annual bluegrass. Many chemicals have been evaluated for the purpose of flower suppression.

Fluorophenoxyacetic acid induces sterility in annual bluegrass for 4 to 6 weeks. Selectivity between desirable and weed plants with this chemical has not been reported (Engel and Aldrich, 1960).

Maleic hydrazide (MH) at a rate of 1.12 kg ai/ha caused a 29% reduction in bentgrass (Agrostis sp. L.) and a 12% reduction in annual bluegrass compared to the

check. The production of annual bluegrass seedheads was greatly reduced in this golf course fairway test by the maleic hydrazide treatment. However, an associated 142% increase in clovers (Trifolium sp. L.) in treated versus untreated plots suggests the grasses were less competitive or inhibited more than clover as a result of the MH treatment. The turf quality of the MH plots was reduced so severely that treatment with MH was discontinued (Engel and Aldrich, 1960).

MH mixed with chlorflurenol on Kentucky bluegrass (Poa pratensis L. `Merion') resulted in substantial inhibition of annual bluegrass seedheads. Temporary discoloration of the Kentucky bluegrass and bentgrass was observed. Other effects included: reduction of the mowing requirement, control of some broadleaf weeds, reduction of annual bluegrass stands with some increase in density of perennial turfgrasses, and reduced viability in annual bluegrass seed. Young seedlings of annual bluegrass were killed by fall applications. Overseeding with desireable turfgrasses in conjunction with autumn applications of MH and chlorflurenol was recommended (Beard et al, 1978).

Chlorflurenol stops annual bluegrass seedhead formation by retarding growth and affecting reproduction. Best results come from treatments between 15 March and

15 April. A second application between 15 September and 1 October will inhibit seedheads in the fall and kill young annual bluegrass seedlings. A short period of chlorosis or discoloration may occur, but following recovery the turfgrass will become a darker green than observed prior to treatment (Goss et al., 1980).

Mefluidide (Embark) suppressed annual bluegrass flowering from March, April, and May treatments when applied at 0.4 and 0.8 kg ai/ha rates. Initial discoloration as a result of treatments was observed followed by recovery and subsequent color enhancement of the turf. Flower suppression was excellent as long as the chemical remained active. Once activity diminished, flowering proceeded as if no treatment had been made. These results were observed on weedy grass stands which included Holcus lanatus L., Poa trivialis L., Poa annua L., Trifolium sp. L., Hypochaeris radicata L., and Medicago lupulina L. as well as a 2 year old stand of 50% `Diplomat' and 50% `Regal' perennial ryegrass. Spring applications caused no turf injury to bentgrasses. Growth inhibition was nearly complete for 4 to 6 weeks following treatment (Cook, 1981).

Fenarimol (Rubigan) can reduce annual bluegrass populations in turf. The herbicidal activity is ap-

parently due to inhibition of gibberellic acid synthesis in sensitive plants. Poor selectivity between creeping bentgrass (Agrostis palustris Huds.) and annual bluegrass has resulted in significant injury to both grasses (Guillikson and Johnston, 1986).

Fenarimol controlled the erect annual type of annual bluegrass when applied 2 weeks prior to ryegrass overseeding in warm season turf. Fenarimol has not controlled the prostrate perennial type in mild climate areas (Elmore, 1988).

Selective Postemergence Control

Although typically applied premergence for annual grasses, chloropropham, neburon, and DSMA have each shown fair to moderate postemergence annual bluegrass control in athletic field turf. Weakened stands of desireable turf following two years of use of these chemicals was an undesireable effect of these treatments. Annual bluegrass was reduced 20-40% (Beard et al., 1978).

Annual bluegrass was reduced 62% in colonial bentgrass (Agrostis tenuis Sibth.) fairways following four consecutive years of postemergence applications with endothall in the spring (April-May) at 0.56 kg ai/ha rates (Engel and Aldrich, 1960).

Endothall reduced annual bluegrass 28% in Kentucky bluegrass following three repeat applications of 1.1 kg ai/ha, applied in September. Repeat applications at 2 week intervals gave best annual bluegrass control (Turgeon et al., 1972).

Endothall may discolor desireable turfgrasses. Selective recovery of Kentucky bluegrass occurs within 4 weeks of endothall applications. Kentucky bluegrass composed 93% of the stand 6 months after endothall treatment compared to 65% of the stand in untreated turf (Turgeon et al., 1972). Endothall gave good to excellent control of annual bluegrass in Kentucky bluegrass sod at 1.68-3.36 kg ai/ha (Elmore et al, 1972).

Annual bluegrass readily reinfests endothall treated areas unless endothall is reapplied or a preemergence herbicide for annual bluegrass control is used to inhibit germination of annual bluegrass seed (Turgeon et al., 1972). Annual bluegrass recovery after postemergence endothall treatments may occur 3 weeks after treatment (Cook, 1977 b).

Selective control of annual bluegrass in Kentucky bluegrass and bentgrass with endothall can be achieved if bensulide is used as a preemergence herbicide after endothall applications. Endothall treatments in early

spring are unpredictable in Kentucky bluegrass. Mid-summer endothall treatments cause unacceptable discoloration of bentgrass turf. Application of nitrogen and water are required to stimulate recovery of Kentucky bluegrass and bentgrass following endothall application (Cook, 1977 b).

Granular formulations of endothall reduced annual bluegrass populations by 75%. An associated 78% increase in Kentucky bluegrass was observed May to October following granular endothall application. Objectional discoloration of Kentucky bluegrass occurred following May and August applications. Endothall was more effective than diuron, linuron, and terbacil (Jagschitz, 1979).

Endothall controls annual bluegrass by selective desiccation. Annual bluegrass has a more open and less organized leaf structure than most festucoid grasses. Panicoid species are generally more highly organized than the festucoids and have thicker epidermal layers which are less subject to water loss. Kentucky bluegrass is much less suceptible to phytotoxicity from endothall than bentgrasses. The highest endothall application rate tolerated by colonial bentgrass and creeping bentgrass was 0.28 kg ai/ha (McMaugh, 1970). Rates as high as 1.12-1.68 kg ai/ha are reported in

other studies (Cook, 1977a). Kentucky bluegrass survives endothall from 1.68-3.36 kg ai/ha, but phytotoxicity is observed from endothall applications above 1.68 kg ai/ha (Elmore et al., 1972).

Endothall selectivity also is related to differential chemical absorption, translocation, and retention between species. Glasshouse pot studies comparing foliar absorption and spray retention of endothall showed that annual bluegrass retained more endothall in its tissue than `Merion' Kentucky bluegrass, and `Penncross' creeping bentgrass (Agrostis palustris Huds. `Penncross'). Annual bluegrass retained 720 dpm/sq cm, bentgrass 396 dpm/sq cm, and Kentucky bluegrass 487 dpm/sq cm endothall in this study. Rates of foliar absorption in these species were not significantly different (Turgeon et al., 1972).

Analysis of plant tissue treated with (carbon-14) labeled endothall indicated greater translocation of endothall in annual bluegrass than in Kentucky bluegrass and creeping bentgrass. Annual bluegrass root tissue contained twice as much endothall as Kentucky bluegrass and creeping bentgrass root tissue. Endothall concentrations in foliage of these three species were not significantly different (Turgeon et al., 1972).

An important problem in herbicidal control of an-

nual bluegrass is genetic heterogeneity. Under laboratory conditions, erect types were killed at 2.7 X 10 -4 M and 5.4 X 10 -4 M endothall rates while prostrate types were only stunted at these rates (Turgeon et al., 1972).

Erect and prostrate types of annual bluegrass respond differently to endothall treatments in field trials on colonial bentgrass and creeping bentgrass. The upright, truly annual types of annual bluegrass, were very susceptible and showed a high percentage of kill after the first endothall application. The more prostrate, short term perennials were less susceptible and required at least two applications for control. Regrowth was apparent thirty days following endothall treatments in prostrate types even after apparent death (McMaugh, 1970).

Endothall effectiveness increases as annual bluegrass leaf area increases. Erect types have greater leaf areas combined with differences in arrangement of meristematic zones which might explain sensitivity differences among biotypes (McMaugh, 1970).

A glasshouse study using erect annual bluegrass type seed collected from flower beds and prostrate type seed collected from bowling greens showed no differences in biotype sensitivity from pre and post emergence ap-

plications of bensulide and endothall (Warwick et al., 1980).

Terbutol, benefin, MSMA, and endothall were compared for postemergence annual bluegrass control on a `Merion'- `Newport' Kentucky bluegrass sod. Terbutol, benefin, and MSMA did not control annual bluegrass. In addition terbutol damaged the Kentucky bluegrass at 16.8 kg ai/ha (Elmore et al., 1972).

Effective control of annual bluegrass in dormant common Bermudagrass (Cynodon sp. L.) turf has been achieved with glyphosate or paraquat at 0.56 kg ai/ha. Treatments showed no injury to Bermudagrass (Beard et al., 1978).

Used as a postemergent herbicide, pronamide effectively controls annual bluegrass and crabgrass (Digitaria sp. L.) in `Tifgreen' Bermudagrass. Pronamide at 1.68 kg ai/ha postemergence and bensulide at 16.8 kg ai/ha premergence are good herbicide combinations for annual bluegrass control in Bermudagrass. Pronamide is phytotoxic to desireable cool season turfgrasses (Elmore et al., 1972), (Gibeault, 1974).

Ethofumesate, NC 20484, cyanazine, asulam, and metamitron were tested for selective early postemergence annual bluegrass control at the three to four leaf stage of perennial ryegrass. Based on annual

bluegrass control and perennial ryegrass tolerance, ethofumesate was the most effective herbicide in this test. Ethofumesate at 1.0 kg ai/ha reduced annual bluegrass to 2% without injuring the perennial ryegrass stand. In contrast, NC 20484, at 1.5 kg ai/ha severely thinned the perennial ryegrass (Kirkham and Richardson, 1983).

Herbicides labeled in 1988 for selective postemergence control of annual bluegrass in turf include: endothall, ethofumesate, metribuzin, and pronamide. Metribuzin and pronamide are specifically for use in warm season turfgrasses (Beard, 1988).

Selective Preemergence Control

Bensulide is a very effective preemergent herbicide on established cool season turfgrasses. Bensulide provided good preemergent annual bluegrass control in bentgrass greens at 33.6 kg ai/ha and 22.4 kg ai/ha thereafter. Residual activity was longest in heavy clay soils and variable in light soils. Based on root volume analysis bensulide inhibits rooting of bentgrass, Bermudagrass, and crabgrass when used preemergent. Damage to desireable grasses was reduced to an acceptable level by keeping bensulide applications at 16.8 kg ai/ha (McMaugh, 1970).

Fall applications (30 August) of bensulide at 33.6 kg ai/ha gave the most effective preemergent annual bluegrass control with the least injury to bentgrass of all herbicides tested. Siduron was injurious to some bentgrasses and had no effect on annual bluegrass. `Seaside' creeping bentgrass tolerated neburon only at the 1.12 kg ai/ha rate. This rate resulted in poor annual bluegrass control. DCPA and diphenamid were too phytotoxic to use on `Seaside' creeping bentgrass except at very low rates (Duich and Perkins, 1967).

In addition to bensulide and DCPA, DMPA and trifluralin are effective for preemergent control of annual bluegrass in a polystand of colonial bentgrass and red fescue (Festuca rubra var. rubra L.) (Gibeault, 1971). Fine leaf fescues and bentgrasses are injured by DCPA while Kentucky bluegrass and perennial ryegrass are tolerant (Brauen, 1986). No turf injury following bensulide treatments was observed on Kentucky bluegrass, perennial ryegrass, bentgrass, or fine fescue turf (Brauen, 1986).

DCPA prevents annual bluegrass germination for 3 to 4 months compared to 6 to 8 months with bensulide (Goss et al., 1980). Annual bluegrass reduction of 36% was observed following 4 years of preemergent DCPA applications in Kentucky bluegrass turf (Jagschitz,

1970, 1979). Annual bluegrass population reduction by DCPA typically takes two seasons (Brauen, 1986; Warwick et al., 1980). Annual bluegrass control with bensulide is effective in bentgrass and Kentucky bluegrass when rates are matched to desireable grass tolerance levels (Jagschitz, 1979).

Bensulide reduces root growth and prevents seed germination in high concentrations. DCPA also affects roots, but uptake in grasses occurs primarily through the hypocotyl which accounts for the delayed response to DCPA (Warwick et al., 1980). Trifluralin and DMPA also inhibit seed germination and subsequent growth of annual bluegrass (Gibeault, 1971).

Elmore et al. (1972) tested bensulide, benefin, DCPA, EPTC, and dichlobenil for annual bluegrass control. Dichlobenil at 2.24 and 4.48 kg ai/ha and EPTC at 3.36 kg ai/ha controlled annual bluegrass but were phytotoxic to established Bermudagrass. Bensulide at 22.4 kg ai/ha controlled annual bluegrass and caused the least apparent injury to existing Bermudagrass turf (Downing et al., 1970; Elmore et al., 1972).

Benefin provides preemergence annual bluegrass control in warm season turfgrass for less than 45 days when applied in August and March. Ryegrass may be seeded 45 days after benefin treatment without herbicide damage.

Bensulide has stunted ryegrass overseeded 45 days after treatment. The residual of bensulide is usually two to three times longer than benefin (Elmore, 1988).

Oxadiazon applied in September at 3.36 kg ai/ha and 1.68 kg ai/ha in April for 4 years resulted in 29% annual bluegrass control in Kentucky bluegrass turf. Bensulide gave 91% control, butralin 85% control, prosulfalin 83% control, benefin 59% control, DCPA 36% control, and siduron 19% control (Jagschitz, 1979).

Oxadiazon applied to Kentucky bluegrass at 4.5 kg ai/ha in the spring resulted in a 28% annual bluegrass reduction and a 32% reduction when applied both spring and fall. Applications made in the spring still had preemergence activity the following winter. Annual bluegrass populations increased to unacceptable levels as soon as the treatments were discontinued (Johnson, 1982).

Preemergence herbicides labeled in 1988 for selective annual bluegrass control in turfgrass include: benefin, benefin + oryzalin, benefin + trifluralin, bensulide, DCPA, ethofumesate, metribuzin, napropamide, oryzalin, oxadiazon, pendimethalin, and pronamide (Beard, 1988).

Recent research shows prodiamine, and cinmethylin also may be used for control of annual bluegrass in

turf, although more research is necessary to define tolerance and selectivity. Phytotoxicity to turfgrass was highest in fine leaf fescues such as red fescue (Festuca rubra L.) and chewings fescue (Festuca rubra var. commutata Gaud.) and lowest in Kentucky bluegrass sod when using prodiamine. Annual bluegrass was reduced by treatments, with prodiamine, DCPA, bensulide, pendimethalin, and cinmethylin (Brauen, 1986).

Selective Pre/Post Emergence Control

Preemergent and postemergent herbicides can be utilized together to achieve long term reduction of annual bluegrass populations. (Warwick, 1979). Attempts at preemergent/postemergent annual bluegrass control date back to the 1930's when lead arsenate was found to discourage annual bluegrass in turf (Sprague and Burton, 1937). Calcium arsenate, sodium arsenite, and tri-calcium arsenate were also used for annual bluegrass control (Beard et al., 1978). After several seasons use of inorganic arsenicals, nontarget turfgrass injury problems were observed. Less turfgrass injury was observed when tri-calcium arsenate was applied in granular form at 140-234 kg ai/ha in spring and/or autumn (Kerr, 1963). Nontarget toxicity is most apparent in poorly drained areas and appears to be caused

by decreased phosphorous uptake by turfgrass roots. Arsenical toxicity is inversely related to soil phosphorus level (Daniel, 1972).

Calcium arsenate effectively removed annual bluegrass from Kentucky bluegrass, colonial bentgrass, and Bermudagrass turfs (Daniel, 1972; Gibeault, 1974; Kerr, 1963). Lead arsenate and sodium arsenite applications resulted in similar annual bluegrass reductions from Kentucky bluegrass and colonial bentgrass turfs (Beard et al., 1978; Engel and Aldrich, 1960; Turgeon, 1974). Decreased vigor of nontarget species was observed in most applications if treatments continued for more than 1 year. The narrow tolerance range between weed seedlings and desireable turfgrasses, and the development of new herbicides, led to a gradual switch from inorganic arsenicals to other herbicides better suited for selective annual bluegrass control (Beard et al., 1978).

Organic arsenicals have also been tested for annual bluegrass control. Disodium methanearsonate (DSMA) applied postemergence gave fair to moderate annual bluegrass control in athletic turf (Beard et al., 1978). Monosodium methanearsonate (MSMA) did not control annual bluegrass in Kentucky bluegrass sod (Elmore et al., 1972). DSMA or MSMA are most effective applied post-

emergence in two treatments 10 to 14 days apart preferably when weeds are young. DSMA and MSMA are not currently registered for annual bluegrass control in turfgrass (Beard, 1988).

Bromacil provided selective preemergence annual bluegrass control when applied to Kentucky bluegrass seedfields at 0.22 and 0.45 kg ai/ha. Selectivity was inadequate when applied postemergence (Neidlinger, 1965).

An application of bromacil at 0.56 kg ai/ha provided complete preemergence control of annual bluegrass. Good germination of colonial bentgrass and red fescue seeded 1 week following bromacil application was achieved (Beard et al., 1978).

Atrazine and simazine at 0.56 kg ai/ha gave effective pre and post emergence control of annual bluegrass in Kentucky bluegrass and velvet bentgrass (Agrostis canina L.) turf but severely injured both turfgrasses (Jagschitz, 1970). Annual bluegrass resistance to atrazine has been reported in France (Warwick, 1979).

Atrazine at 1.4 kg ai/ha and simazine at 2.2 kg ai/ha, both applied in October, reduced annual bluegrass 90% and 94% respectively in established perennial ryegrass seed fields. Propham at 3.4 kg ai/ha and chloropropham at 2.2 kg ai/ha reduced annual bluegrass 99% and

86% respectively in the same test. October coincides with onset of fall rains in western Oregon which initiates germination of annual bluegrass in seed fields (Lee, 1981).

Diuron at 0.56-3.36 kg ai/ha and linuron at 2.52-4.7 kg ai/ha controlled annual bluegrass in Kentucky bluegrass turf. Post emergent applications of diuron on 22 May and 18 Aug completely eliminated annual bluegrass from the plots by 13 October. Linuron reduced annual bluegrass 60-95% during the same period. Both herbicides produced overall turf discoloration with associated thin areas of Kentucky bluegrass. Irrigation following the August application reduced Kentucky bluegrass discoloration (Jagschitz, 1979).

Linuron applied postemergent at 1.25, 2.50, and 5.00 kg ai/ha reduced vegetative biomass of annual bluegrass in glass house experiments. Dry weight of prostrate types was reduced more than that of erect types. Linuron reduced annual bluegrass biomass more than endothall in these tests. Differences may be due to the greater soil residual activity of linuron (Warwick et al., 1980).

Methabenzthiazuron at 1.57-3.14 kg ai/ha pre and postemergence controlled annual bluegrass in new sowings of perennial ryegrass, Italian ryegrass (Lolium

multiflorum Lam.), and meadow fescue (Festuca elatior L.). Poa trivialis L., Bromus sp. L., and colonial bentgrass were also controlled. Annual bluegrass reductions ranged from 43-100% depending on rate (Budd, 1970).

Methabenzthiazuron gave good annual bluegrass control in sports turf consisting of Kentucky bluegrass, perennial ryegrass, and red fescue. Annual bluegrass was reduced by 33% at the 4 kg ai/ha rate and 83% at 6 kg ai/ha. Herbicides were applied in September and May-June. Kentucky bluegrass was injured at 6 kg ai/ha (Kamp, 1981).

Methabenzthiazuron gave 100% annual bluegrass control in establishment trials with bentgrasses and chewings fescue when applied pre or post seeding at 2.35-7.05 kg ai/ha. Bentgrasses, and to a lesser extent red fescue, were thinned unacceptably by the methabenzthiazuron treatments (Woolhouse and Shildrick, 1971).

Terbacil has also been used for annual bluegrass control. Terbacil at 0.28 or 0.57 kg ai/ha on Kentucky bluegrass and colonial bentgrass reduced annual bluegrass 71%-91% depending on application rate. Colonial bentgrass did not tolerate terbacil well. The Kentucky bluegrass was injured but recovered (Jagschitz, 1982).

Ethofumesate was developed as a herbicide for

sugarbeet and grass seed crops for pre and postemergence control of Amaranthus retroflexus L., Polygonum hydropiper L., Setaria sp. L., Kochia sp. (L) Schrad., Salsola kali L., and others. Excellent control of annual bluegrass in established Kentucky bluegrass turf was reported at rates of 1.0-2.0 kg ai/ha (Ekins and Day, 1978).

Ethofumesate was tested for control of annual bluegrass (Poa annua L.), wild oats (Avena fatua L.), and chickweed (Stellaria media L.), in ryegrass seed crops. Applied preemergent at 0.8-1.7 kg ai/ha ethofumesate controlled wild oats, chickweed, and annual bluegrass. At 1-2 kg ai/ha ethofumesate gave postemergent control of annual bluegrass (Ekins, 1983).

Ethofumesate controlled annual bluegrass better, was cheaper to apply at equivalent rates, and resulted in higher ryegrass dry weight yields than other herbicides following 3 years of treatments, (eg. 1000 tillers per square meter in control, 3000 tillers per square meter with methabenzthiazuron, 7000 tillers per square meter with ethofumesate) (Haggar and Kirkham, 1981).

Ethofumesate gave preemergent control of annual bluegrass in perennial ryegrass overseeded in dormant Bermudagrass. Better than 95% control was achieved

with a single application of 2.2 kg ai/ha in 2 of 3 years. Multiple applications were required when ethofumesate was applied at 1.1 kg ai/ha or lower (Dickens, 1979).

Ethofumesate was selective in annual and perennial ryegrass seed crops when applied pre and post emergence. It was also selective in established stands of Kentucky bluegrass, fescues, and bentgrass. Annual bluegrass was 90-100% controlled at ethofumesate rates ranging from 0.75 to 1.5 kg ai/ha. Crop tolerance was satisfactory except under cold, wet conditions, where slight stand reduction and stunting was observed in new seedings of ryegrass (Ekins and Day, 1978).

Perennial ryegrass pastures normally are less than 50% of orignally sown species 5 years after sowing due to disruption caused by grazing. Annual bluegrass normally precedes bentgrass in botanical succession of a sward. Ethofumesate applied at 2 kg ai/ha gave excellent annual bluegrass control when applied at the two to three leaf stage in autumn plantings and in established pastures. Subsequent increase in ryegrass was observed based upon botanical analysis and dry weight tissue analysis (Griffiths et al., 1978).

Ethofumesate applied preemergent at 1 kg ai/ha to newly sown perennial ryegrass plots was effective in

controlling annual bluegrass. Best annual bluegrass control occurred when ethofumesate was applied prior to the two to three-leaf stage of annual bluegrass. Older plants required higher rates of ethofumesate to achieve the same degree of annual bluegrass control, (0.6 kg ai/ha applied preemergent to annual bluegrass, 1.1 kg ai/ha applied prior to two to three leaf stage, 3.0 kg ai/ha applied to fully tillered annual bluegrass plants to achieve 80% control). Tolerance to ethofumesate, applied at 1.9 kg ai/ha on fully tillered grass, ranked as follows: perennial ryegrass > Poa trivialis > Kentucky bluegrass > colonial bentgrass > Holcus lanatus > creeping bentgrass > annual bluegrass > red fescue. Ethofumesate applied preemergent, killed all grasses except perennial ryegrass. At the two to three leaf stage, tolerance to ethofumesate was: perennial ryegrass > Poa trivialis > Holcus lanatus > colonial bentgrass. Ethofumesate activity was significantly reduced when applied to dry soil, and in the presence of organic matter. With high organic matter, rates from 0.5-2.0 kg ai/ha failed to reduce annual bluegrass below 75% of original levels (Haggar and Bastian, 1976).

Ethofumesate activity was greater when applied to soil at 12% moisture content than in soil at 2% moisture

content 2 to 4 days prior to irrigation. In all field trials ethofumesate was less effective applied to dry soil than to wet soils (McAuliffe and Appleby, 1981). Ethofumesate applied at 2.0 kg ai/ha in October to newly seeded perennial ryegrass had a half life of just over 8 weeks in preventing annual bluegrass germination. After 7 months there was still sufficient herbicide present to cause a 50% reduction in annual bluegrass. Measurement of ethofumesate, in soil cores, over a 15 month period showed ethofumesate remained in the upper 2 cm of the soil profile (Haggar and Passman, 1978). Eighty to ninety percent of ethofumesate is broken down within the first 5 to 6 months following application if application occurs on moist soils with temperatures between 20-30 degrees Celsius (typical spring conditions). Ethofumesate applied in November persisted nearly twice as long in soil as that applied in March primarily due to lower soil microorganism populations present in autumn months (Schweizer, 1975).

Soil type, pH, and temperature also affect degradation rates of ethofumesate. Ethofumesate degradation products in a 0.5 ml aliquot of soil solution were approximately five to six times greater for Woodburn and Dayton soils than for Madras and Agency soils. Dayton

is a silty clay loam, Woodburn a silt loam, Madras a sandy loam, and Agency a sandy or gravelly loam. Where pH was raised to 8.0 or 9.0 from 7.0 ethofumesate degradation decreased 3-6 fold. Lowering pH to 4.9 increased herbicide loss slightly, while only 2.1% of applied ethofumesate was found as degradation products when the soil pH was decreased to 3.9. Ethofumesate degradation increases as temperature of soil increases. Increasing soil temperature from 20-50 degrees Celsius resulted in more than 6 fold increase in ethofumesate degradation (McAuliffe, 1983).

Both annual bluegrass and perennial ryegrass seed on the soil surface following ethofumesate spraying show highly significant germination reduction compared to seed not treated. The authors recommended drilling or harrowing in the perennial ryegrass seed to protect it from ethofumesate damage (Haggar and Passman, 1978).

Ethofumesate applied pre and early postemergence, at eight rates between 0.8 and 4.5 kg ai/ha, selectively removed annual bluegrass in perennial ryegrass, Italian ryegrass (Lolium multiflorum Lam.), and tall fescue (Festuca arundinaceae Schreb.) seed fields. Annual bluegrass control was 100% in preemergence experiments with rates of 0.8-4.5 kg ai/ha and postemergence with rates of 1.1-4.5 kg ai/ha. Perennial ryegrass and tall

fescue were tolerant to ethofumesate when applied at 1.1 kg ai/ha rates or less. Plants surviving at higher rates recovered quickly having vigor nearly equal to plants in untreated plots 6 weeks following treatments (Lee, 1977).

Ethofumesate applied postemergence in November at rates from 1.4 to 4.5 kg ai/ha eliminated all annual bluegrass which had survived application of diuron in fall carbon planted perennial ryegrass seed fields. Ethofumesate eliminated all annual bluegrass in established perennial ryegrass seed fields when applied in late October at rates from 1.1 to 3.4 kg ai/ha or when applied as sequential treatments with atrazine (1.4 kg ai/ha) or simazine (2.2 kg ai/ha) (Lee, 1981).

Annual bluegrass was controlled by ethofumesate applied in three sequential treatments of 2 kg ai/ha each 12 May, 7 June, and 7 July in perennial ryegrass soccer pitches. Annual bluegrass was reduced from 25% to 2.2% mean stand ground cover by mid August. No significant phytotoxicity to desireable grasses was observed (Peel, 1983).

Excellent annual bluegrass control was achieved using ethofumesate at 1.0, 1.5, and 2.0 kg ai/ha applied preemergence and early postemergence in established perennial ryegrass and Kentucky bluegrass.

Moderate annual bluegrass control was achieved when ethofumesate was applied to tillered plants. Tillered annual bluegrass plants damaged by ethofumesate treatment regained full growth 2 months after treatment. There was no significant difference between rates. This result is contrary to the postemergence control cited on the Prograss label (Maggard, 1983).

THE INVESTIGATION

Materials and Methods

Species/Tolerance to Ethofumesate

Greenhouse Studies

Greenhouse screening studies were conducted to determine the effects of ethofumesate on cool-season grass emergence from seed. Each experiment included 20 perennial ryegrass (Lolium perenne L.) cultivars, 4 tall fescue (Festuca arundinacea Schreb.) cultivars, and annual bluegrass (Poa annua L.) which had been field collected as seed (see Table 1). Each experiment was set up as a completely randomized design with four replications.

Trial #1 was initiated 3 April 1983. Eight planting flats 40 cm X 40 cm X 5 cm were filled with moistened sterilized sand (Table 2). The sand in each flat was packed firm and divided into 25 plots 8 cm X 8 cm. In each plot, one seed was placed in each of 25 holes, 5 mm deep, created by a planting template. Seed was covered to grade with sand and all plots were watered thoroughly. After planting, four flats were treated with ethofumesate at 0.6 kg ai/ha using a fixed boom carbon dioxide pressurized sprayer. The remaining

four flats were left untreated. Flats were placed in a greenhouse and mist irrigated as needed to encourage uniform germination. Seedlings were measured for percent emergence on 3 May 1983. Emergence was defined as seedlings $\geq$ 2 cm tall for perennial ryegrass and tall fescue cultivars and $\geq$ 1 cm tall for annual bluegrass seedlings.

Trial #2 was initiated 13 April 1983. This experiment was identical to trial #1 except that seeds were planted in sand loam soil (Table 2).

Data from greenhouse trials 1 and 2 were subjected to analysis of variance. Mean separations (LSD 0.05) were performed only if F ratios were significant (Table 3 and 4).

Field Studies

Field screening experiments were conducted to determine the effect of ethofumesate on cool season grass emergence of field collected seed of annual bluegrass, five perennial ryegrass cultivars, and one cultivar of tall fescue, red fescue (Festuca rubra L.), chewings fescue (Festuca rubra var. commutata Gaud.), roughstalk bluegrass (Poa trivialis L.), hard fescue (Festuca ovina var. duriscula L. Koch), colonial bentgrass (Agrostis tenuis Sibth.), and Kentucky blue-

grass (Poa pratensis L.) (Table 5 and 6). Each experiment was set up as a randomized complete block design with four replications.

Trial #3 was initiated 25 July 1985 at the Lewis Brown horticultural research farm near Corvallis, OR. Five perennial ryegrass cultivars (Table 5) were selected from the greenhouse studies to determine the effect of ethofumesate on emergence of perennial ryegrass cultivars when planted under field conditions. The test site was a Chehalis silt loam soil (Fine silty, mixed, mesic Cumulic Ultic Haploxeroll). The site was prepared by spraying out the existing turf with glyphosate applied at 4.5 kg acid equivalent/ha (25 July 1985) and rototilling to a 10-15 cm depth (9 August 1985). The tilled soil was then graded, raked smooth and free of debris, rolled and planted. All ryegrasses were planted at 25 g/sq meter with a calibrated drop spreader (Scotts Model PF-1). The entire area was overseeded with annual bluegrass at 5 g/ sq meter. The soil was then raked to cover the seeds, and nitrogen was applied as (25-2-4-12.6 S) at 5 g N/sq meter rate via drop spreader. The area was uniformly irrigated with repeated light applications to ensure uniform germination. After planting, preemergent ethofumesate applications were made to moist soil 9

August 1985 at 1.0 kg ai/ha. Postemergent treatments at the one leaf stage of perennial ryegrass were made on 19 August 1985. Check plots were not sprayed (Table 7). All sprays were made to 1.5 X 1.5 meter plots with a fixed boom carbon dioxide pressurized sprayer calibrated to deliver 800 liters of spray per hectare. The entire test area was irrigated following each ethofumesate application. Turf was maintained at 3 cm and mowed weekly during the experiment except following ethofumesate application. Perennial ryegrass and annual bluegrass plants were measured 1 month after planting (7 September 1985) and again 13 April 1986 by counting emerged plants found inside three 10 cm diameter rings randomly tossed into the plot (Table 7).

Trial #4 was initiated 9 August 1985. The experiment was similar to field trial #3 except cultivars of nine species were planted and ethofumesate was applied at three stages of growth (Table 6). Seeding was done using a drop spreader at 25 g/sq meter for `Palmer' perennial ryegrass, 49 g/sq meter for `Mustang' tall fescue, 25 g/sq meter for `Ensylva' red fescue, 25 g/sq meter for `Checker' chewings fescue, 15 g/sq meter for `Sabre' roughstalk bluegrass, 25 g/sq meter for `Scaldis' hard fescue, 10 g/sq meter for `Exeter'

colonial bentgrass, 20 g/sq meter for annual bluegrass, and 20 g/sq meter for `America' Kentucky bluegrass. Seed bed preparation, mowing, and irrigation management were the same as in experiment #3. Ethofumesate at 1.0 kg ai/ha was applied preemergent 9 August 1985, at the one-leaf stage for perennial ryegrass on 19 August 1985, and at the two leaf stage for perennial ryegrass 23 August 1985. Check plots remained untreated. Plant counts were made for cultivars and annual bluegrass by counting emerged plants found inside three 10 cm diameter rings randomly tossed into the plot 6 April 1986 (Table 8 and 9).

Data from field trials 3 and 4 was subjected to analysis of variance. Mean separations (LSD 0.05) were performed only if F ratios were significant (Table 8 and 9). Arcsine transformation was used for analysis of data in trial #4.

Planting/Establishment Methods

Ethofumesate Rate Studies

Three field studies were conducted to determine the effect of six ethofumesate rates on annual bluegrass and perennial ryegrass planted in tilled seedbeds. Each experiment was set up as a randomized

complete block design with four replications.

Trial # 5 was initiated 7 September 1983 at the Lewis Brown horticultural research farm near Corvallis, OR. The test site was a Chehalis silt loam soil (Fine silty, mixed, mesic Cumulic Ultic Haploxeroll). The site was prepared by spraying out the existing turf with glyphosate applied at 4.5 kg acid equivalent/ha (24 August 1983) and rototilling to a 10-15 cm depth (7 September 1983). The tilled soil was then graded, raked smooth and free of debris, rolled and planted. `Palmer' perennial ryegrass was planted at 25 g/sq meter with a calibrated drop spreader (Scotts Model PF-1). The entire area was overseeded with annual bluegrass at 5 g/sq meter. The soil was then raked to cover the seeds, and nitrogen was applied as (21-0-0-19 S) at 5 g N/sq meter rate via drop spreader. The area was uniformly irrigated with repeated light applications to ensure uniform germination. After planting, preemergent ethofumesate applications were made to moist soil 7 September 1983 at 0.5, 1.0, 1.5, 0.5 applied twice at 10 day intervals, and 0.5 applied three times at 10 day intervals kg ai/ha rates. Post-emergent treatments at the one-leaf stage of perennial ryegrass were made on 17 September 1983 at 0.5, 0.5 X 2, 0.5 X 3, 1.0, and 1.5 kg ai/ha or at the two-leaf

stage of perennial ryegrass 21 September 1983 at 0.5, 0.5 X 2, 0.5 X 3, 1.0, and 1.5 kg ai/ha. Repeat treatments (0.5 X 2, 0.5 X 3) were applied at 10 day intervals. A total of six ethofumesate applications were made at 10 day intervals between 7 September 1983 and 9 October 1983. Check plots were left untreated (Table 10). All sprays were made with a fixed boom carbon dioxide pressurized sprayer calibrated to deliver 800 liters of spray per hectare. The entire test was irrigated following ethofumesate application. Turf was maintained at 3 cm and mowed weekly during the experiment except following ethofumesate application. Annual bluegrass plants were measured 8 April 1984 by counting emerged plants found inside three 10 cm diameter rings randomly tossed into the plot (Fig. 1).

Trial # 6 was initiated 15 August 1984 and was identical to Trial 5 (Table 10, Fig. 2).

Trial 7 was initiated 15 August, 1984 and was similar to trial 5 and 6 but included only two ethofumesate rates (Table 11). After planting, ethofumesate was applied preemergent at 1.0 and 1.5 kg ai/ha 16 August 1984 and postemergent at the one-leaf stage of perennial ryegrass (25 August 1984) at 1.0 and 1.5 kg ai/ha, or at the two-leaf stage of perennial ryegrass (28 August 1984) at 1.0 and 1.5 kg ai/ha. Check plots

remained untreated (Table 11). The entire test was irrigated following ethofumesate application. Plant counts of emerged annual bluegrass plants found inside three rings randomly tossed into the plot were made 6 April 1985 (Table 11). All ethofumesate field rate studies were maintained at 3 cm and mowed weekly during the experiment except following ethofumesate application.

Data from field trials 5, 6, and 7 was subjected to analysis of variance. Mean separations (LSD 0.05) were performed only if F ratios were significant.

Planting/Establishment Methods

Field studies were conducted to determine the effect of method of seed bed preparation on ethofumesate efficacy. Two no-till establishment procedures were studied. No-till establishment using non-selective herbicide sprays to kill existing turf followed by surface scarification via a flail mower and broadcast seeding was compared to non-selective herbicide sprays followed by direct seeding with a mechanical slicer/seeder. Both experiments were conducted to determine the effect of ethofumesate on `Palmer' perennial ryegrass and annual bluegrass (which had been field collected as seed) emergence from seed (Table 11

and 12). Each experiment was set up as a randomized complete block design with four replications.

Trial #8 was initiated 19 August 1984 at the Lewis Brown horticultural research farm near Corvallis, OR. The test site was a Chehalis silt loam soil (Fine silty, mixed, mesic Cumulic Ultic Haploxeroll). The site was prepared by spraying out the existing turf with glyphosate applied at 4.5 kg acid equivalent/ha (19 August 1984) and surface scarification using a flail mower (2 September 1984). Uniform sod surface scarification was achieved by operating the flail mower in two directions. Surface scarification was followed by rotary mowing to remove grass clippings and other organic matter debris (2 September 1984). `Palmer' perennial ryegrass was planted at 25 g/sq meter over the entire area with a calibrated drop spreader (Scotts Model PF-1). The entire area was overseeded with annual bluegrass at 5 g/sq meter. Nitrogen was applied as (21-0-0-19 S) at 5 g N/ sq meter via drop spreader. The area was uniformly irrigated with repeated light applications to ensure uniform germination. After planting, preemergent ethofumesate applications were made to moist soil 2 September 1984 at 1.0 and 1.5 kg ai/ha. Postemergent treatments at the one-leaf stage of perennial ryegrass

were made on 10 September 1984 and at the two-leaf stage 13 September 1984 at 1.0 and 1.5 kg ai/ha. Check plots were not sprayed (Table 11). All sprays were made with a fixed boom carbon dioxide pressurized sprayer calibrated to deliver 800 liters of spray per hectare. The entire test was irrigated following each ethofumesate application. Turf was maintained at 3 cm and mowed weekly during the experiment except following ethofumesate application. Perennial ryegrass and annual bluegrass plants were measured 6 April 1985 (Fig. 3) by counting emerged plants found inside three 10-cm diameter rings randomly tossed into the plot (Fig. 3).

Trial 9 was initiated 6 August 1985 at Eugene Country Club, Eugene, OR. The test site consisted of 70% perennial ryegrass and 30% annual bluegrass grown in Chehalis silt loam soil (Fine silty, mixed, mesic Cumulic Ultic Haploxeroll). The site was prepared by spraying out the existing turf with glyphosate applied at 4.5 kg acid equivalent/ha (6 August 1985) and mowing the area with a rotary mower at 3 cm. `Palmer' perennial ryegrass was planted 7 September 1985 at 5 g/sq meter using a tractor mounted Rogers slicer/seeder applied in two directions. The entire area was overseeded with annual bluegrass at 5 g/sq meter with a calibrated drop spreader (Scotts Model PF-1). Nitrogen

was applied as (25-2-4-12.6 S) at 5 g N/sq meter via drop spreader. The area was uniformly irrigated with repeated light applications to ensure uniform germination. After planting, preemergent ethofumesate applications were made to moist soil 7 September 1985 at 1.0 and 1.5 kg ai/ha. Postemergent ethofumesate applications were made at the one-leaf stage of perennial ryegrass 18 September 1985 at 1.0 and 1.5 kg ai/ha. Check plots were not sprayed (Table 12). All sprays were made with a fixed boom carbon dioxide pressurized sprayer calibrated to deliver 800 liters of spray per hectare. The entire test area was irrigated following each ethofumesate application. Turf was maintained at 3 cm and mowed every 2 weeks during the experiment except following each ethofumesate application. Emerged annual bluegrass plants were counted 27 April 1986 by counting plants found inside three 10-cm diameter rings randomly tossed into the plot (Table 12).

Data from field trials 8 and 9 were subjected to analysis of variance. Mean separations (LSD 0.05) were performed only if F ratios were significant.

Results and Discussion

Ethofumesate Species/Cultivar Tolerance

Annual bluegrass, cultivars of perennial ryegrass, and tall fescue differed in their response to ethofumesate ($P < 0.001$) in greenhouse emergence screening studies 4 weeks after planting (Trial 1 and 2). Dasher, Barry, Pennant, Palmer, Diplomat, Premier, Yorktown II, Elka, Prelude, Derby, Yorktown, Blazer, Birdie II, Loretta, Fiesta, Regal, Omega, Citation, Barclay, and Manhattan II perennial ryegrass cultivars were the most tolerant (LSD 0.05) to ethofumesate and Jaguar, Houndog, Rebel, and Mustang tall fescue cultivars were least tolerant when grown in sand (Table 3). Yorktown II, Pennant, Blazer, Palmer, Prelude, Barry, Diplomat, Premier, Omega, Yorktown, and Derby perennial ryegrass cultivars were most tolerant (LSD 0.05) to ethofumesate and Houndog, Jaguar, Mustang, and Rebel tall fescue cultivars; annual bluegrass; and Manhattan II, Regal, Dasher, Citation, Loretta, Fiesta, Birdie II, Elka, and Barclay ryegrass cultivars were least tolerant when grown in sand-loam soil (Table 4). Tolerance to ethofumesate in greenhouse sceening studies did not correlate to the results found in field trial #3 comparing Palmer, Regal, Dasher, Blazer, and Loretta perennial ryegrass cultivars

where no difference was found between cultivars 8 months after planting (Figure 4). These results suggest that greenhouse screening studies may not accurately predict grass tolerance to ethofumesate under field conditions. Annual bluegrass was 100% controlled in all ethofumesate-treated plots in this study (Table 7). Perennial ryegrass cultivar growth was suppressed 1 month after ethofumesate treatment, but this result was short lived (Fig. 4). Both ethofumesate rates were equally effective in annual bluegrass control ($P < 0.001$). Annual bluegrass was controlled at all stages of ethofumesate application (Pre, one-leaf). More annual bluegrass plants were found in Loretta and Blazer compared to that found in Regal, Palmer, and Dasher (LSD 0.05), suggesting that Loretta and Blazer were more competitive with annual bluegrass than the others (Fig. 5).

Differences were found among the nine grasses grown in field establishment trial #4 ($P < 0.001$) (Table 8). `Palmer' perennial ryegrass, `Mustang' tall fescue, and `America' Kentucky bluegrass were most tolerant (LSD 0.05) to ethofumesate and `Scaldis' hard fescue, `Ensylva' red fescue, `Checker' chewings fescue, `Sabre' roughstalk bluegrass, annual bluegrass, and `Exeter' colonial bentgrass were least tolerant (Fig. 6).

These results suggest Kentucky bluegrass may be more tolerant of ethofumesate in field trials than has been noted by previous studies. Ethofumesate application caused no observed effect in `Palmer' and `Mustang' compared to growth suppression observed for the others ($P < 0.001$). Annual bluegrass was controlled at all stages (Pre, one-leaf, two-leaf) of ethofumesate application. More annual bluegrass plants were found in untreated plots of `America', annual bluegrass, `Mustang', `Checker', and `Ensylva', than in `Exeter', `Scaldis', `Palmer', and `Sabre' (LSD 0.05) suggesting the possibility of cultivar/species competition (Table 9). Annual bluegrass was suppressed by ethofumesate in all cultivars (Fig. 7).

Planting/Establishment Methods

Annual bluegrass plant emergence differed ($P < 0.001$) in ethofumesate treated and untreated plots using the till method of establishment (Fig. 1). Annual bluegrass reduced by the 0.5, 0.5 X 2, 0.5 X 3, 1.0, and 1.5 kg ai/ha ethofumesate rates ($P<0.001$) compared to the untreated (0.0 kg ai/ha) rates. A similar result was observed in field till trial #6 where annual bluegrass was reduced by the 0.5, 0.5 X 2, 0.5 X 3, 1.0, and 1.5 kg ai/ha ethofumesate rates ($P < 0.001$) compared

to the untreated trials (Fig. 2). Annual bluegrass was controlled at all stages of ethofumesate application (Pre, one-leaf, two-leaf) in both trials (trial 5 and 6) (Table 10). Ethofumesate treatments had no visible effect on perennial ryegrass 7 months after planting and treatment.

In tilled field trial #7, annual bluegrass mean plant count differences were found among ethofumesate treated and untreated plots (LSD 0.05) (Fig. 8). Annual bluegrass was completely controlled in ethofumesate-treated plots at 1.0 and 1.5 kg ai/ha rates (Table 11). Ethofumesate had no visible effect on perennial ryegrass 8 months following planting. Similar results were observed in field trial #8 which was established using no-till surface scarification and broadcast seeding. Annual bluegrass was completely controlled by ethofumesate at 1.0 and 1.5 kg ai/ha rates (Fig. 8, Table 11). Annual bluegrass was controlled at all stages of ethofumesate application (Pre, one-leaf, two-leaf) in both trials (trial 7 and 8) (Table 11).

Perennial ryegrass and annual bluegrass mean plant counts were compared in trial #8 (Fig. 3). There were more perennial ryegrass plants in ethofumesate-treated plots compared to those in untreated plots ($P < 0.001$). These results suggest that ethofumesate control

of annual bluegrass is accompanied by perennial ryegrass plant growth enhancement (Fig. 3). Perennial ryegrass growth and development was enhanced in all plots where annual bluegrass was controlled by ethofumesate.

In trial #9, annual bluegrass was reduced by 83% from ethofumesate (no till/slicer seeder at 1.0 and 1.5 kg ai/ha). Annual bluegrass was controlled at all stages of ethofumesate application (Pre, one-leaf) (Table 12, Fig. 8). Ethofumesate treatments had no visible effect on perennial ryegrass turf 8 months following planting and treatment.

FIG. 1. EFFECTS OF ETHOFUMESATE RATES AND REPEAT TREATMENTS ON ANNUAL BLUEGRASS ESTABLISHED WHEN PLANTED ON A TILLED SEEDBED. DATA RECORDED 7 MONTHS AFTER PLANTING.

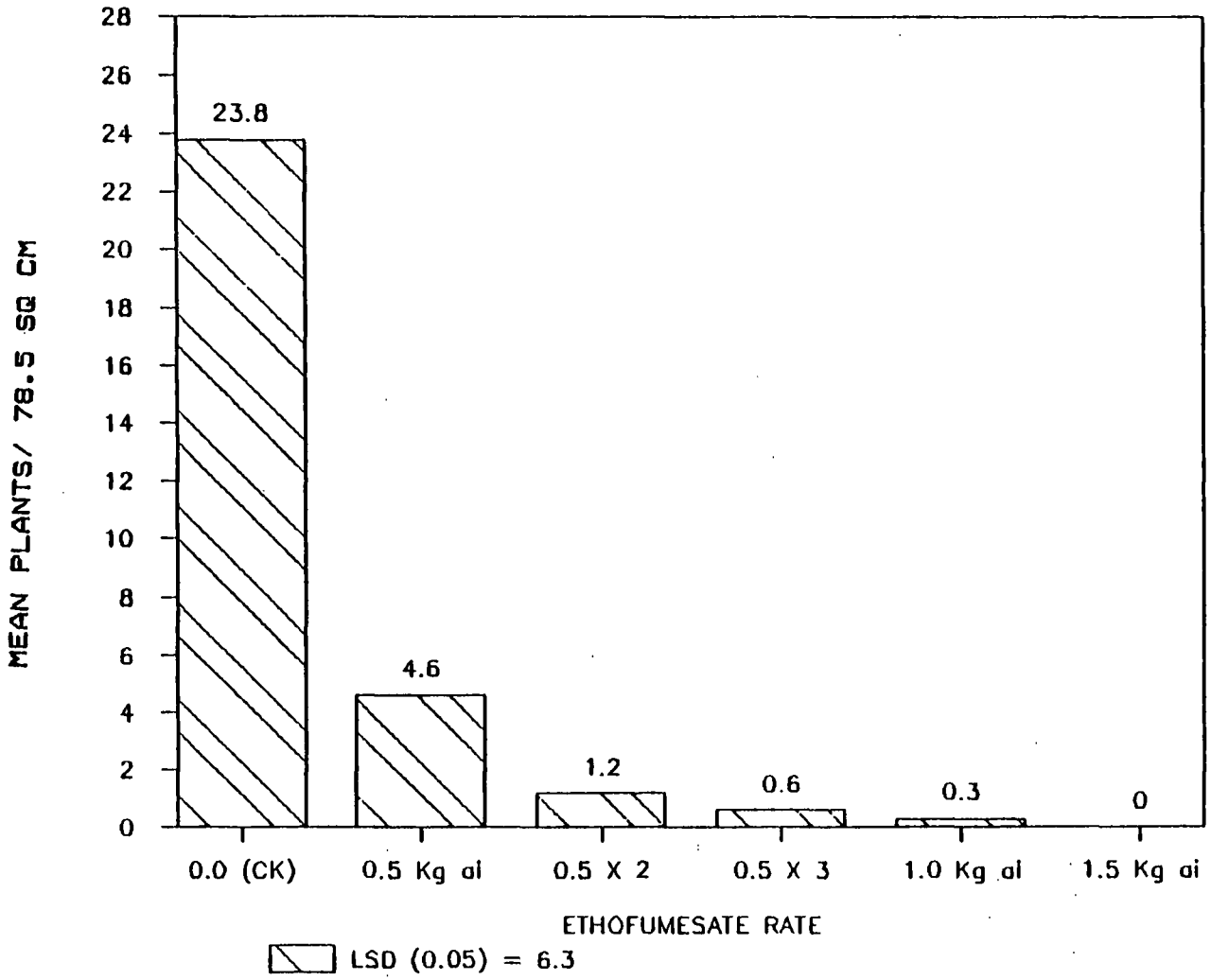

FIG. 2. EFFECTS OF ETHOFUMESATE RATES AND REPEAT TREATMENTS ON ANNUAL BLUEGRASS ESTABLISHMENT WHEN PLANTED ON A TILLED SEEDBED. DATA RECORDED 7 MONTHS AFTER PLANTING.

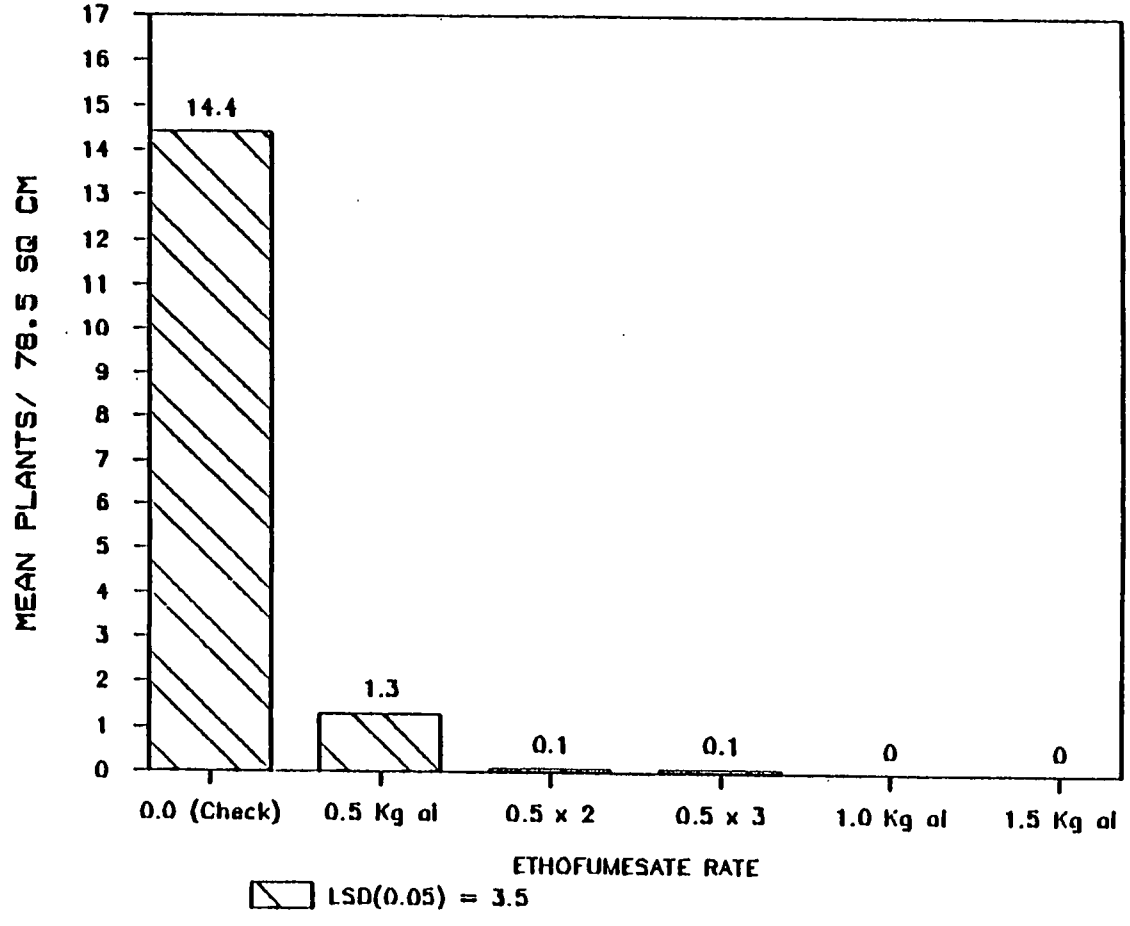

FIG. 3. EFFECTS OF ETHOFUMESATE RATES ON ESTABLISHMENT OF PERENNIAL RYEGRASS AND ANNUAL BLUEGRASS 7 MONTHS AFTER PLANTING ON A NO TILL SEEDBED.

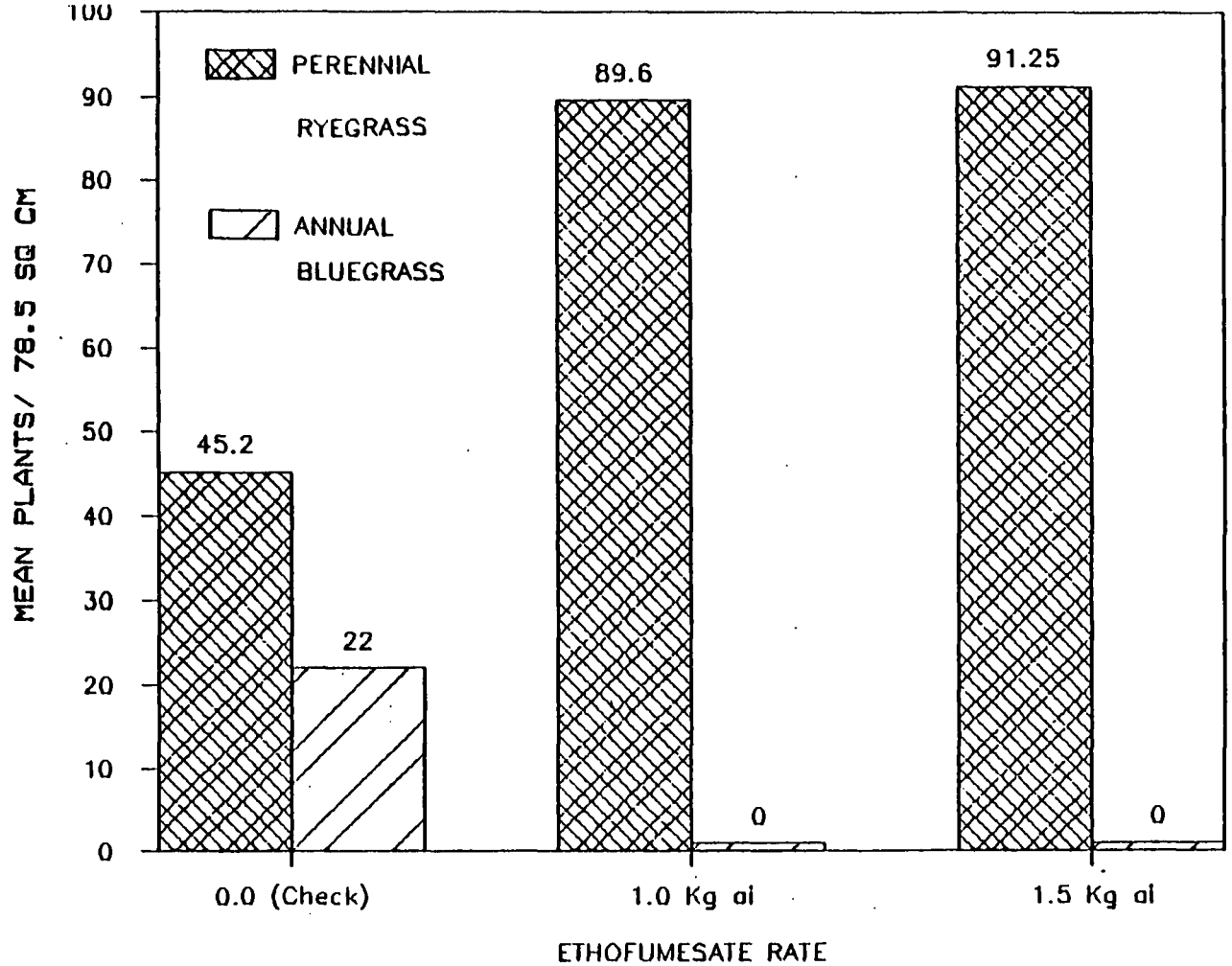

FIG. 4. EFFECTS OF ETHOFUMESATE ON STAND DEVELOPMENT OF FIVE CULTIVARS OF PERENNIAL RYEGRASS 1 AND 8 MONTHS AFTER PLANTING.

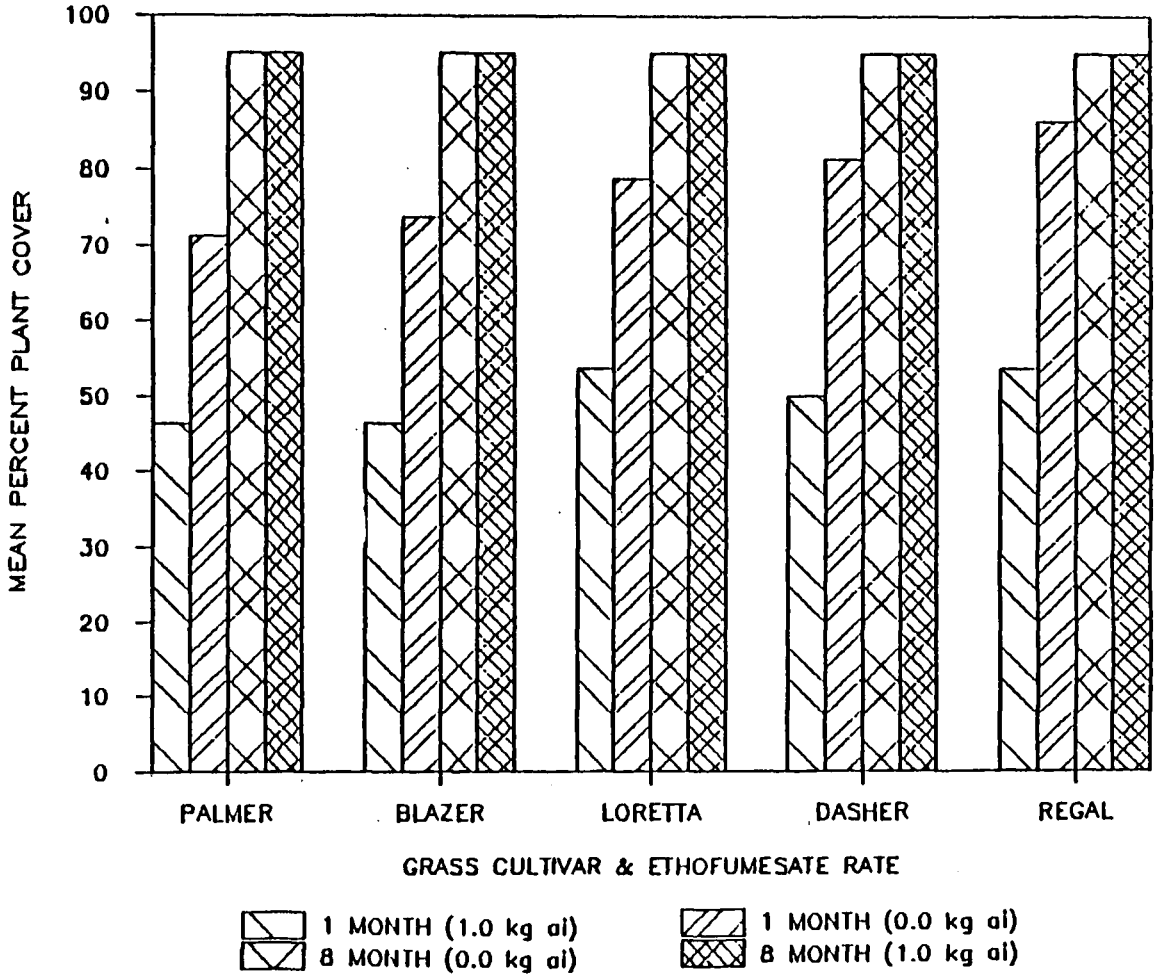

FIG. 5. ANNUAL BLUEGRASS DEVELOPMENT AS AFFECTED BY ETHOFUMESATE AND COMPETITION FROM FIVE CULTIVARS OF PERENNIAL RYEGRASS. PLANT COUNTS MADE 7 MONTHS AFTER PLANTING.

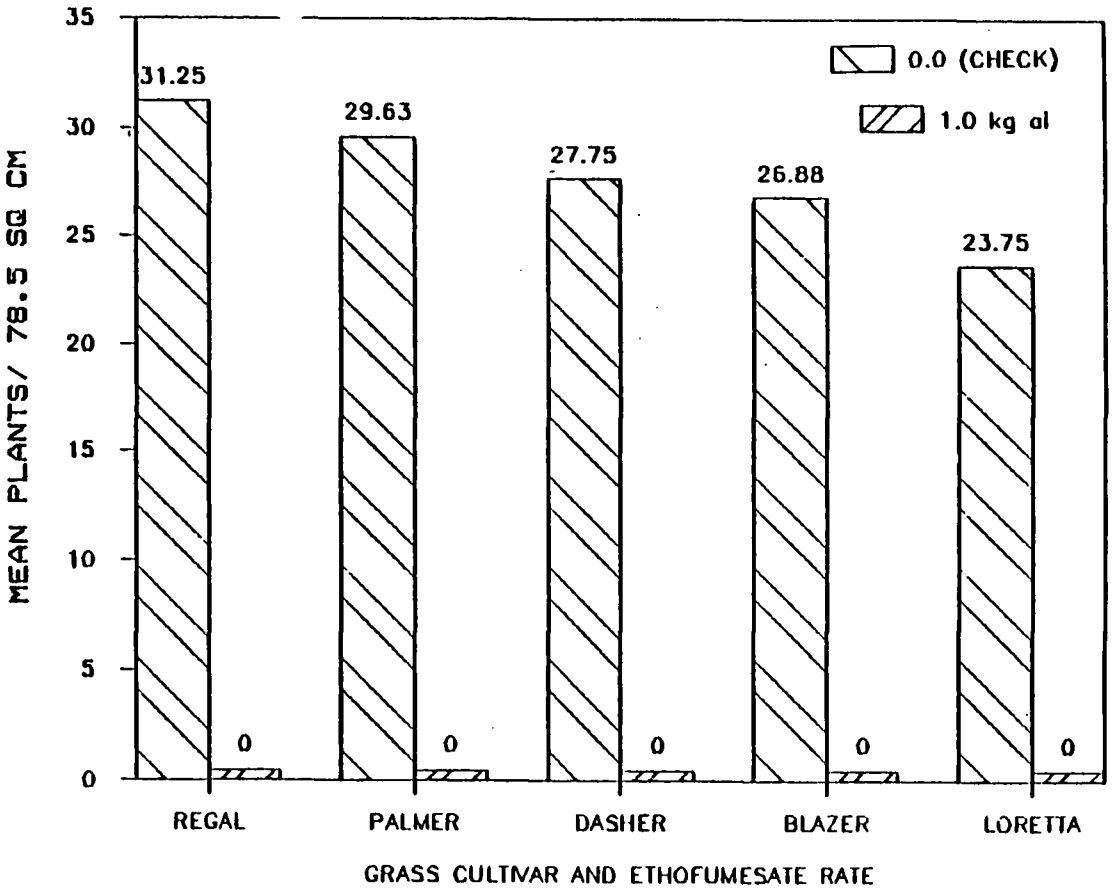

FIG. 6. EFFECTS OF ETHOFUMESATE ON ESTABLISHMENT OF NINE COOL SEASON GRASSES 7 MONTHS AFTER PLANTING.

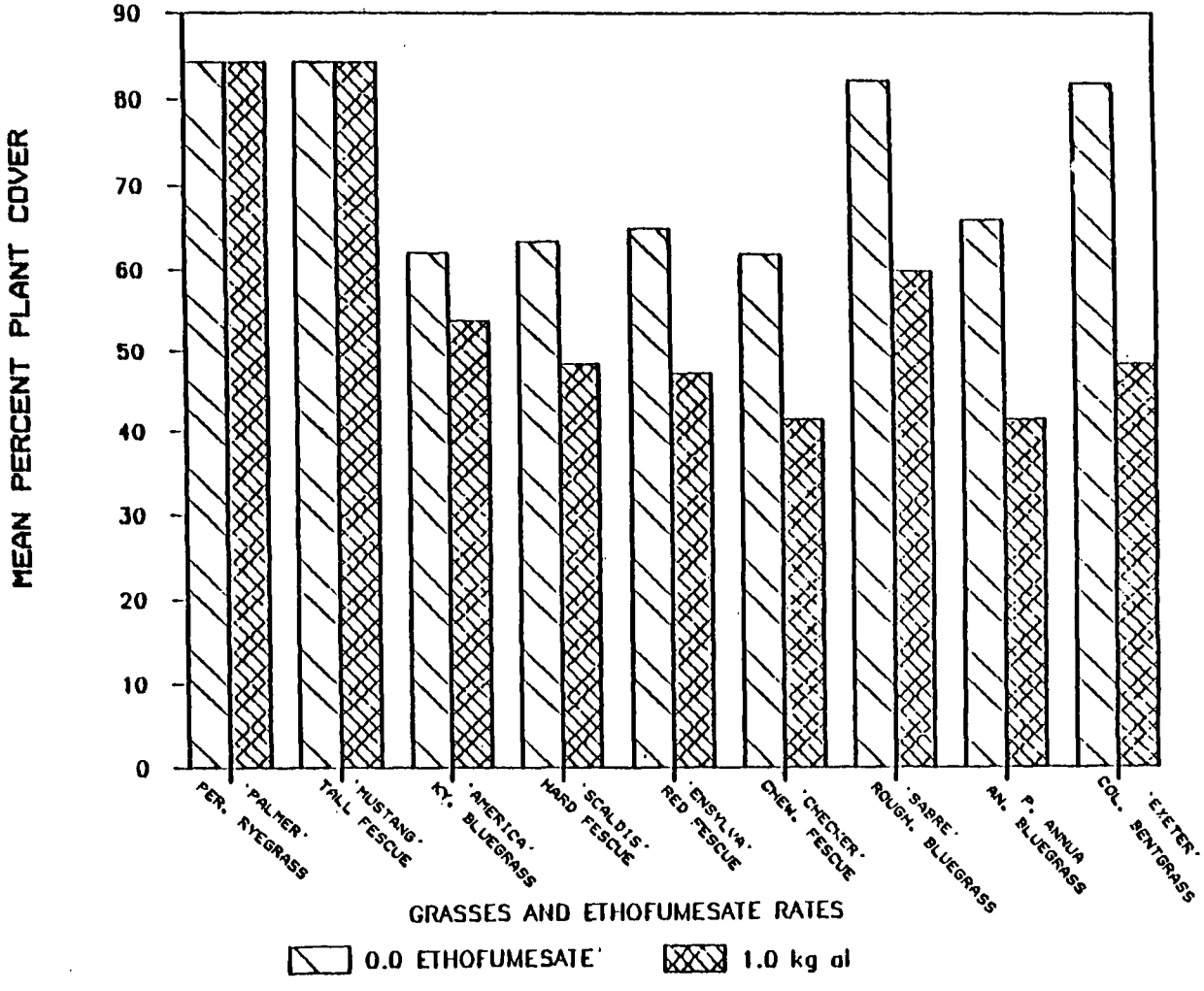

FIG. 7. EFFECTS OF ETHOFUMESATE ON CONTROL OF ANNUAL BLUEGRASS PLANTED WITH EACH OF NINE COOL SEASON GRASSES 7 MONTHS AFTER PLANTING.

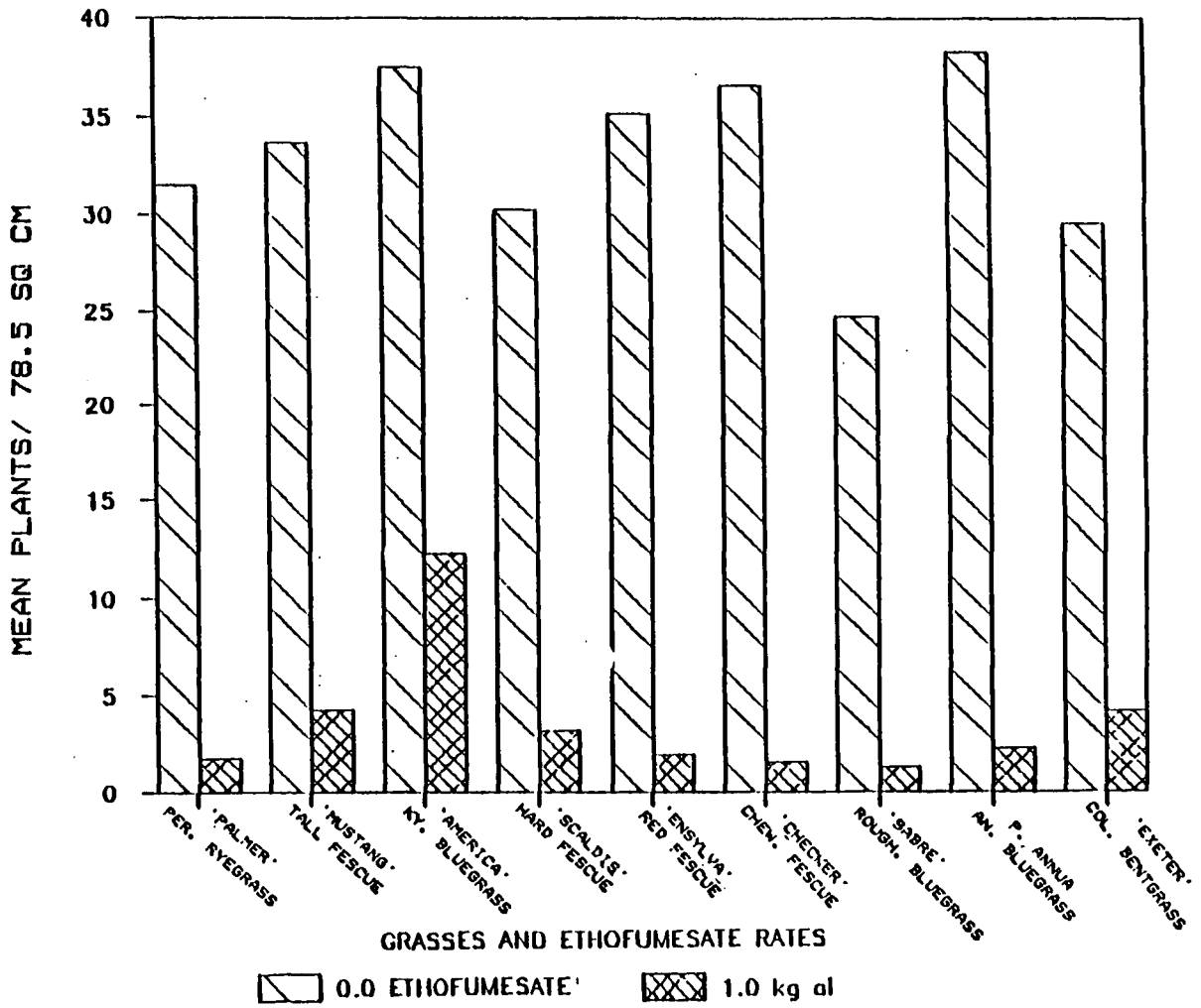

FIG. 8. EFFECT OF PLANTING METHOD AND ETHOFUMESATE RATE ON CONTROL OF ANNUAL BLUEGRASS PLANTED WITH PERENNIAL RYEGRASS.

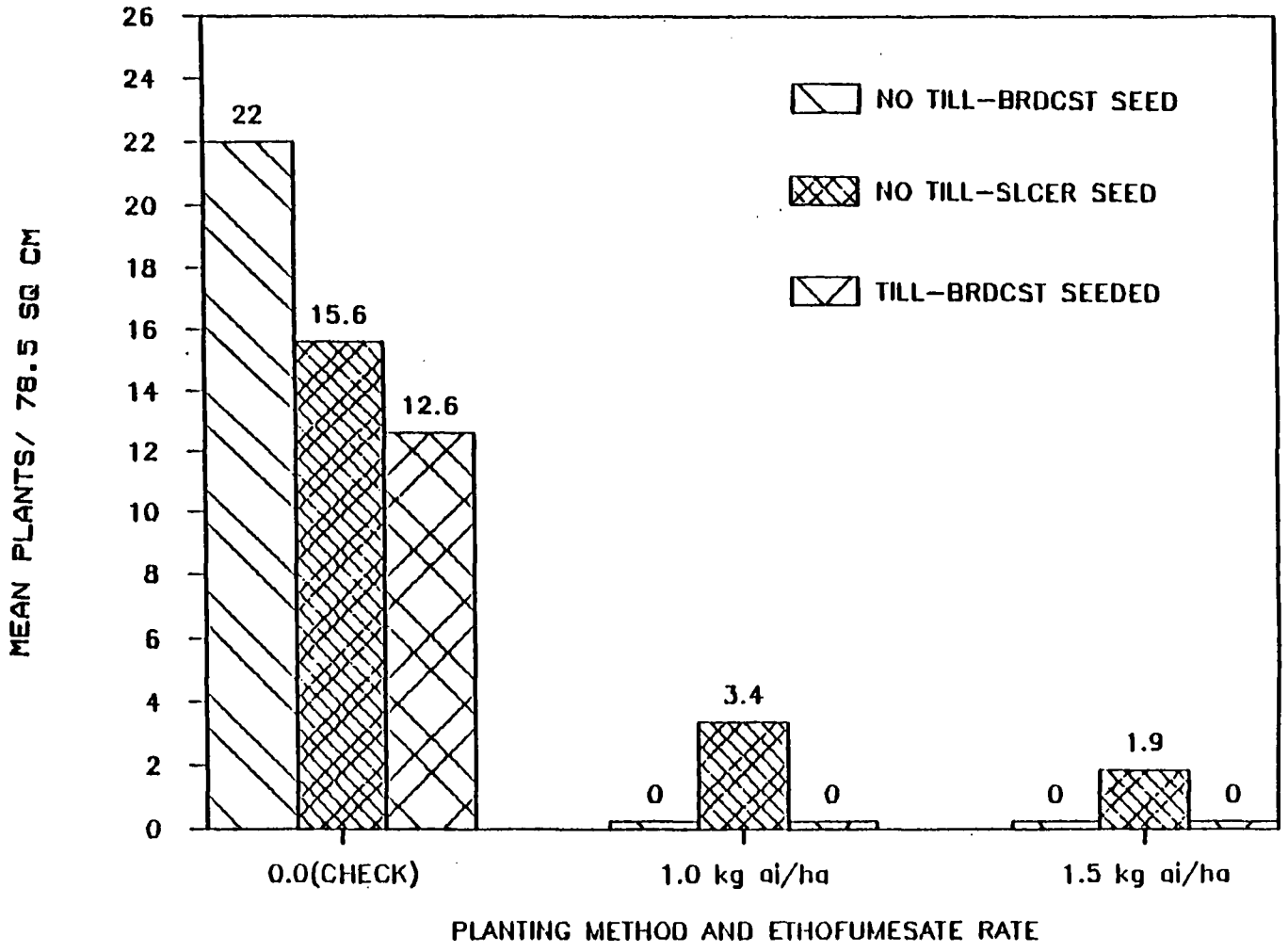

TABLE 1. GRASS CULTIVAR SPECIES IDENTIFICATION

Greenhouse screening trial # 1 and 2,
27 April and 2 May, 1983.

Common name	Scientific name	Cultivar
Perennial ryegrass	Lolium perenne L.	Yorktown II
		Pennant
		Palmer
		Barry
		Prelude
		Premier
		Diplomat
		Dasher
		Blazer
		Derby
		Yorktown
		Elka
		Omega
		Birdie II
		Regal
		Loretta
		Fiesta
		Citation
		Manhattan II
		Barclay
Tall fescue	Festuca arundinacea Schreb.	Rebel
		Mustang
		Jaguar
		Houndog
Annual bluegrass	Poa annua L.	

TABLE 2. TEXTURAL ANALYSIS OF SOILS USED IN GREENHOUSE SCREENING TRIALS (TRIAL # 1 AND 2)

Soil Sample	% Sand	%Silt	% Clay	% Total Found
Sand #	96.7%	2.5%	0.8%	100%
Sand-Loam #	53.0%	32.6%	14.4%	100%

Soil analyzed by Oregon state University soil characterization lab, Corvallis, OR. Analysis done 20 April, 1983. Sand defined as: 0.05 - > 2.0 mm particle size
Silt defined as: 0.05 - 0.002 mm particle size
clay defined as: < 0.002 mm particle size

"Sand" soil classified as Sand based on this hydrometer analysis.

"Sand Loam" soil classified as Sand Loam based on this hydrometer analysis.

TABLE 3. EFFECTS OF ETHOFUMESATE ON EMERGENCE OF 25 CULTIVARS OF GRASS GROWN IN SAND FROM GREENHOUSE CULTURE STUDIES, 4 WKS AFTER TREATMENT, LEWIS BROWN FARM, CORVALLIS, OR, 1983.

Cultivar	Control Mean	Treatment Mean	Dif-erence
Dasher	20	19.5	0.5
Barry	22	20	2.0
Pennant	23	21	2.0
Palmer	23.8	21.5	2.3
Diplomat	23.8	20.5	3.3
Premier	23	19.8	3.3
Yorktown II	24	20.8	3.3
Elka	24.3	20.8	3.5
Prelude	23.8	20	3.8
Derby	19.5	15	4.5
Yorktown	18	12.5	5.5
Blazer	21.8	16.3	5.5
Birdie II	23.3	17.8	5.5
Loretta	20	13.5	6.5
Fiesta	23	16	7.0
Regal	21	14	7.0
Poa annua	7.5	0.3	7.3
Omega	23.3	15.5	7.8
Citation	20	12	8
Barclay	23.5	14	9.5
Manhattan II	24.5	15	9.5
Mustang	19.8	7	12.8
Rebel	23	9.3	13.8
Houndog	22.5	6.8	15.8
Jaguar	22.3	5.5	16.8
Mean	21.6	15.0	6.8
Std. Dev.	3.4	5.7	4.5
Sum	540.3	374	170.3
LSD (0.05) =			10.9

(Table values show actual plant count means. Treatment significance protected by ANOVA F=25.24, significant at 0.001 level, N=50.)

TABLE 4. EFFECTS OF ETHOFUMESATE ON EMERGENCE OF 25 CULTIVARS OF GRASS GROWN IN SAND LOAM SOIL FROM GREENHOUSE CULTURE STUDIES,4 WEEKS AFTER TREATMENT, LEWIS BROWN FARM, CORVALLIS, OR, 1983. TRIAL #2

Cultivar	Control Mean	Treatment Mean	Difference
Yorktown II	21	19.8	1.3
Pennant	23.5	18.8	4.8
Blazer	20.3	14.8	5.5
Palmer	24.3	18.5	5.8
Prelude	23.8	17.5	6.3
Barry	22.3	15.5	6.8
Diplomat	22.8	15.8	7
Premier	23.8	16.8	7
Omega	23.3	15.8	7.5
Yorktown	21	13.5	7.5
Derby	20.3	12.3	8
Manhattan II	22.8	13.5	9.3
Regal	21.3	11.8	9.5
Dasher	22.8	12.8	10
Citation	19.3	9.3	10
Rebel	19.3	8.8	10.5
Loretta	19.3	8.8	10.5
Fiesta	24	13.5	10.5
Birdie II	22.8	12	10.8
Elka	24.5	13	11.5
Barclay	23.5	10.3	13.3
Mustang	18.3	1.8	16.5
Poa annua	17	0	17
Jaguar	22.5	4	18.5
Houndog	23.8	3.8	20
Mean	21.9	12.1	9.8
Std Dev	2.1	5.3	4.5
Sum	546.8	301.8	245
LSD (0.05) =			9.35

(Table values show actual plant count means. Treatment significance protected by ANOVA F=74.6 significant at 0.001 level, N=50)

TABLE 5. GRASS CULTIVAR SPECIES IDENTIFICATION

Field screening trial 3, 13 April, 1986.

Common name	Scientific name	Cultivar
Perennial ryegrass	*Lolium perenne* L.	Palmer
		Blazer
		Loretta
		Dasher
		Regal
Annual bluegrass	*Poa annua* L.	

TABLE 6. GRASS CULTIVAR SPECIES IDENTIFICATION

Field screening trial 4, 6 April, 1986.

Common name	Scientific name	Cultivar
Perennial ryegrass	*Lolium perenne* L.	Palmer
Tall fescue	*Festuca arundinacea* Schreb.	Mustang
Kentucky bluegrass	*Poa pratensis* L.	America
Roughstalk bluegrass	*Poa trivialis* L.	Sabre
Hard fescue	*Festuca ovina var. duriuscula* L. Koch	Scaldis
Red fescue	*Festuca rubra var. rubra* L.	Ensylva
Chewings fescue	*Festuca rubra var. commutata* Gaud.	Checker
Colonial bentgrass	*Agrostis tenuis* Sibth.	Exeter
Annual bluegrass	*Poa annua* L.	

TABLE 7. EFFECTS OF ETHOFUMESATE ON EMERGENCE OF ANNUAL BLUEGRASS 7 MONTHS AFTER TREATMEMT, LEWIS BROWN FARM, CORVALLIS, OR., 1985.

Grass	Treat-ment	Rate kg ai/ha	Stage	Annual bluegrass	Mean
Loretta	Ethofumesate	1.0	Pre	0.0	
Loretta	Ethofumesate	1.0	1 lf	0.0	0.0
Blazer	Ethofumesate	1.0	Pre	0.0	
Blazer	Ethofumesate	1.0	1 lf	0.0	0.0
Dasher	Ethofumesate	1.0	Pre	0.0	
Dasher	Ethofumesate	1.0	1 lf	0.0	0.0
Palmer	Ethofumesate	1.0	Pre	0.0	
Palmer	Ethofumesate	1.0	1 lf	0.0	0.0
Regal	Ethofumesate	1.0	Pre	0.0	
Regal	Ethofumesate	1.0	1 lf	0.0	0.0
Loretta	Untreated	0.0	Pre	25.0	
Loretta	Untreated	0.0	1 lf	22.5	23.8
Blazer	Untreated	0.0	Pre	26.3	
Blazer	Untreated	0.0	1 lf	27.5	26.9
Dasher	Untreated	0.0	Pre	26.8	
Dasher	Untreated	0.0	1 lf	28.8	27.8
Palmer	Untreated	0.0	Pre	30.5	
Palmer	Untreated	0.0	1 lf	28.8	29.6
Regal	Untreated	0.0	Pre	33.8	
Regal	Untreated	0.0	1 lf	28.8	31.3
	LSD (0.05)				3.4

To determine statistical differences between means, subtract one entry mean from another entry mean. Statistical differences occur when this value is larger than corresponding LSD value.

TABLE 8. EFFECT OF ETHOFUMESATE ON ESTABLISHMENT OF NINE COOL SEASON TURFGRASSES. FIELD TRIAL #4 LEWIS BROWN FARM, CORVALLIS, OR., 1986.

GRASS	CONTROL MEAN	TREATMENT MEAN	DIFF-ERENCE	TOTAL MEAN
PALMER	84.3	84.3	0.0	84.3
MUSTANG	84.3	84.3	0.0	84.3
AMERICA	62	53.8	8.2	57.9
SCALDIS	63.3	48.3	15	55.8
ENSYLVA	64.9	47.2	17.7	56.1
CHECKER	61.8	41.5	20.3	51.7
SABRE	82.3	59.9	22.4	71.1
POA ANNUA	66	41.5	24.5	53.8
EXETER	82	48.4	33.6	65.2
MEAN	72.3	56.6	20.2	
STD DEV	10.5	16.7	8.0	
TOTAL	650.9	509.2	141.7	
Protected LSD(0.05)			12.87	

To determine statistical differences between means, subtract one entry mean from another entry mean. Statistical differences occur when this value is larger than corresponding LSD value.

(Table values show arcsine transformation values derived from percent cover plant counts comparing treatment and control means (Refer to Table 13). Grass response and ethofumesate treatment differences significant at 0.001 level)

TABLE 9. EFFECT OF ETHOFUMESATE ON EMERGENCE OF ANNUAL BLUEGRASS, FIELD TRIAL #4, LEWIS BROWN FARM, CORVALLIS, OR., 1986.

	Annual bluegrass mean #		TOTAL
CULTIVAR	0.0 (CHECK)	1.0 KG AI	MEAN
PALMER	31.5	1.8	16.7
MUSTANG	33.7	4.3	19
AMERICA	37.5	12.3	24.9
SCALDIS	30.3	3.2	16.8
ENSYLVA	35.2	2.0	18.6
CHECKER	36.6	1.6	19.1
SABRE	24.7	1.3	13
POA ANNUA	38.3	2.3	20.3
EXETER	29.6	4.2	16.9
MEAN	33	3.7	
STD DEV	4.4	3.4	
TOTAL	297	33.3	
PROTECTED LSD (0.05)			8.18

To determine statistical differences between means, subtract one entry mean from another entry mean. Statistical differences occur when this value is larger than corresponding LSD value.

(Table values show mean annual bluegrass plant counts. Annual bluegrass plant count differences by cultivar significant at 0.001 level. N=216)

TABLE 10. EFFECTS OF ETHOFUMESATE ON EMERGENCE OF ANNUAL BLUEGRASS 7 MONTHS AFTER TREATMENT, LEWIS BROWN FARM, CORVALLIS, OR., 1984 AND 1985.

Trial	Treatment	Rate kg ai/ha	Stage	Annual bluegrass	Mean
T111	Ethofumesate	1.5	Pre	0.0	
1984	Ethofumesate	1.5	1 lf	0.0	
	Ethofumesate	1.5	2 lf	0.0	0.0
	Ethofumesate	1.0	Pre	0.0	
	Ethofumesate	1.0	1 lf	0.0	
	Ethofumesate	1.0	2 lf	0.8	0.3
	Ethofumesate	0.5 X 3	Pre	0.0	
	Ethofumesate	0.5 X 3	1 lf	0.8	
	Ethofumesate	0.5 X 3	2 lf	1.0	0.6
	Ethofumesate	0.5 X 2	Pre	1.8	
	Ethofumesate	0.5 X 2	1 lf	0.5	
	Ethofumesate	0.5 X 2	2 lf	1.3	1.2
	Ethofumesate	0.5	Pre	7.0	
	Ethofumesate	0.5	1 lf	1.3	
	Ethofumesate	0.5	2 lf	5.5	4.6
	Untreated	0.0	Pre	21.5	
	Untreated	0.0	1 lf	26.3	
	Untreated	0.0	2 lf	23.8	23.8
	LSD (0.05)				6.3
T111	Ethofumesate	1.5	Pre	0.0	
1985	Ethofumesate	1.5	1 lf	0.0	
	Ethofumesate	1.5	2 lf	0.0	0.0
	Ethofumesate	1.0	Pre	0.0	
	Ethofumesate	1.0	1 lf	0.0	
	Ethofumesate	1.0	2 lf	0.0	0.0
	Ethofumesate	0.5 X 3	Pre	0.0	
	Ethofumesate	0.5 X 3	1 lf	0.3	
	Ethofumesate	0.5 X 3	2 lf	0.0	0.1
	Ethofumesate	0.5 X 2	Pre	0.0	
	Ethofumesate	0.5 X 2	1 lf	0.3	
	Ethofumesate	0.5 X 2	2 lf	0.0	0.1
	Ethofumesate	0.5	Pre	1.0	
	Ethofumesate	0.5	1 lf	0.0	
	Ethofumesate	0.5	2 lf	3.0	1.3
	Untreated	0.0	Pre	17.5	
	Untreated	0.0	1 lf	13.8	
	Untreated	0.0	2 lf	12.0	14.4
	LSD (0.05)				3.5

To determine statistical differences between means, subtract one entry mean from another. Statistical differences occur when this value is larger than corresponding LSD value.

TABLE 11. EFFECTS OF ETHOFUMESATE ON EMERGENCE OF ANNUAL BLUEGRASS 7 MONTHS AFTER TREATMENT, LEWIS BROWN FARM, CORVALLIS, OR., 1985.

Trial	Treatment	Rate kg al/ha	Stage	Annual bluegrass	Mean
No till 1985	Ethofumesate	1.5	Pre	0.0	
	Ethofumesate	1.5	1 lf	0.0	
	Ethofumesate	1.5	2 lf	0.0	0.0
	Ethofumesate	1.0	Pre	0.0	
	Ethofumesate	1.0	1 lf	0.0	
	Ethofumesate	1.0	2 lf	0.0	0.0
	Untreated	0.0	Pre	25.8	
	Untreated	0.0	1 lf	17.5	
	Untreated	0.0	2 lf	22.8	22.0
	LSD (0.05)				7.8
Till 1985	Ethofumesate	1.5	Pre	0.0	
	Ethofumesate	1.5	1 lf	0.0	
	Ethofumesate	1.5	2 lf	0.0	0.0
	Ethofumesate	1.0	Pre	0.0	
	Ethofumesate	1.0	1 lf	0.0	
	Ethofumesate	1.0	2 lf	0.0	0.0
	Untreated	0.0	Pre	13.8	
	Untreated	0.0	1 lf	11.0	
	Untreated	0.0	2 lf	13.0	12.6
	LSD (0.05)				2.4

To determine statistical differences between treatments, subtract one treatment mean from another treatment mean. Statistical differences occur when this value is larger than corresponding LSD value.

TABLE 12. EFFECTS OF ETHOFUMESTATE ON EMERGENCE OF ANNUAL BLUEGRASS 7 MONTHS AFTER TREATMENT, EUGENE COUNTRY CLUB, EUGENE, OR., 1986.

Treatment	Rate kg ai/ha	Stage	Annual bluegrass	Mean
Ethofumesate	1.5	Pre	0.3	
Ethofumesate	1.5	1 lf	3.5	1.9
Ethofumesate	1.0	Pre	2.3	
Ethofumesate	1.0	1 lf	4.5	3.4
Ethofumesate	0.0	Pre	16.3	
Ethofumesate	0.0	1 lf	15	15.6
LSD (0.05)				10.23

To determine statistical difference between means, subtract one entry mean from another entry mean. Statistical differences differences occur when this value is larger than corresponding LSD value.

Conclusions

Ethofumesate applied at 1.0 kg ai/ ha or 1.5 kg ai/ha was effective in controlling annual bluegrass during establishment of perennial ryegrass and tall fescue. Results were similar whether ethofumesate treatments were applied as single doses or in two or three repeat applications of 0.5 kg ai/ha at 10-day intervals. Annual bluegrass control was complete, regardless of growth stage of perennial ryegrass (pre-emergent, one-leaf, or two-leaf stage). Annual bluegrass was controlled at the three to four leaf stage in all trials. Annual bluegrass reduction ranged from 100% in till trials 3, 5, 6, and 7, and 100% in no till-broadcast seeded trial 8, to 83% in no till-slicer seeder Trial 9. Seed bed preparation method appears to influence annual bluegrass susceptibility to ethofumesate. Other studies suggest organic matter and soil moisture in seed beds may reduce the phytoxicity of ethofumesate (Haggar and Bastian, 1976; McAuliffe and Appleby, 1981; McAuliffe, 1983). Of the three establishment methods studied here, the till and the no-till-broadcast methods resulted in excellent annual bluegrass reduction (97.3% control in five till experiments, 100% growth suppression of one no-till broadcast seeded

experiment).

The greenhouse cultivar emergence differences grown in soils with two different textural compositions suggest that soil texture may influence ethofumesate tolerance. Soil texture was found to make a difference of five to six times in ethofumesate degredation rates in previous studies (McAuliffe, 1983).

These studies suggest that perennial ryegrass and tall fescue, and to a lesser extent, Kentucky bluegrass, appear able to survive initial ethofumesate phytoxicity suffered the first month following planting while hard fescue, red fescue, chewings fescue, roughstalk bluegrass, annual bluegrass, and colonial bentgrass do not. Five perennial ryegrass cultivars were not different in tolerence to ethofumesate 8 months after field planting. Significant differences in ethofumesate tolerance had been observed between these cultivars in greenhouse studies. More study is necessary to determine if other tall fescue and perennial ryegrass cultivars show as much ethofumesate field tolerance as those found in this study. More study is necessary to determine Kentucky bluegrass tolerance to ethofumesate in field trials using different establishment methods and ethofumesate rates. Results of these studies suggest that perennial ryegrass and tall fescue are

tolerant to ethofumesate applied preemergent and early postemergent and that ethofumesate could be used successfully in turf renovation where removal of annual bluegrass.

Five conclusions can be drawn from this study:

First, there appear to be differences in species and cultivar tolerance to ethofumesate under greenhouse conditions. Perennial ryegrass is most tolerant. Tall fescue is less tolerant, and annual bluegrass is highly susceptible.

Second, perennial ryegrass cultivars injured in greenhouse studies were tolerant under field conditions.

Third, ethofumesate was effective in annual bluegrass control at cumulative rates of 1.0 and 1.5 kg ai/ha in the field studies.

Fourth, ethofumesate controlled annual bluegrass without injuring perennial ryegrass when applied preemergence, at one-leaf, and two-leaf stages of perennial ryegrass.

And fifth, seed bed preparation method did not affect annual bluegrass control although there was a trend toward better control with till and no-till broadcast methods than with no-till slicer seeder-planted procedures.

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APPENDICES

APPENDIX A: HERBICIDES TESTED FOR ANNUAL BLUEGRASS CONTROL

Herbicide (WSSA NAME)	Type Application	Ref. Cited
asulam	postemergence	Kirkham & Richardson 1983
atrazine	pre/post	Jagschitz 1970 Lee 1981
benefin	preemergence	Gibeault 1967,1974 Downing et al 1970 Jagschitz 1970, 1979 Elmore et al 1972 Beard et al 1978 Goss et al 1980 Johnson 1982 Beard 1988
bensulide	preemergence	Duich and Perkins 1967 Gibeault 1971, 1974 Downing et al 1970 Jagschitz 1970, 1979 McMaugh 1970 Woolhouse & Shildrick 1971 Elmore et al 1972 Cook 1977 a & b Beard et al 1978 Warwick 1979 Warwick et al 1980 Johnson 1982 Brauen 1986 Beard 1988
bromacil	pre/post	Neidlinger 1965 Beard et al 1978
butralin	premerge	Jagschitz 1979
calcium arsenate	pre/post	Kerr 1968 Gibeault 1974 Turgeon 1974 Beard et al 1978

chlorflurenol & MH	seedhead supression	Beard et al 1978
chlorpropham	pre/post	Beard et al 1978 Lee 1981
cinmethylin	premerge	Brauen 1986
cyanazine	premerge	Kirkham & Richardson 1983
DCPA	premerge	Duich & Perkins 1967 Gibeault 1971,1974 Downing et al 1970 Jagschitz 1970, 1979 Beard et al 1978 Warwick 1979 Warwick et al 1980 Goss et al 1980 Johnson 1982 Brauen 1986 Beard 1988
dichlobenil	premerge	Downing et al 1970
diphenamid	premerge	Duich and Perkins 1967
diuron	pre/post	Jagschitz 1979, 1982 Lee 1981
DMPA	premerge	Beard et al 1978
DSMA	postmerge	Beard et al 1978
endothall	postmerge	Engel & Aldrich 1960 McMaugh 1970 Woolhouse & Shildrick 1971 Elmore et al 1972 Turgeon et al 1972 Cook 1977 a & b Beard et al 1978 Jagschitz 1979,1982 Warwick 1979 Goss et al 1980 Warwick et al 1980 Beard 1988
EPTC	premerge	Downing et al 1970

ethofumesate	pre/post	Ekins & Day 1978 Haggar & Bastian 1976 Schweitzer 1975 Lee 1977,1981 Griffiths et al 1978 Haggar & Passman 1978 Dickens 1979 Haggar & Kirkham 1981 Kamp 1981 McAuliffe & Appleby 1981 Ekins 1983 Kirkham & Richardson 1983 McAuliffe 1983 Peel 1983 Beard 1988
Fluorophenoxy-acetic acid	seedhead suppression	Engel & Aldrich 1960
glyphosate	postmerge	Johnson 1976
lead arsenate	pre/post	Sprague & Burton 1937 Kerr 1963 Jagschitz 1970 Beard et al 1978
linuron	pre/post	Beard et al 1978 Jagschitz 1979,1982 Warwick 1979 Warwick et al 1980
MH, maleic hydrazide	seedhead suppress.	Engel & Aldrich 1960
mefluidide	seedhead suppress.	Cook 1981
methabenzthia-zuron	pre/post	Budd 1970 Woolhouse & Shildrick 1971 Haggar & Kirkham 1981 Kamp 1981
metamitron	postmerge	Kirkham & Richardson 1983
metribuzin	pre/post	Beard 1988

MSMA	postmerge	Elmore et al 1972
napropamide	premerge	Beard 1988
neburon	postmerge	Duich & Perkins 1967 Jagschitz 1970
oryzalin	premerge	Beard 1988
oxadiazon	premerge	Jagschitz 1979 Johnson 1982 Beard 1988
paraquat	postmerge	Beard et al 1978
pendimethalin	pre/post	Brauen 1986 Beard 1988
prodiamine	premerge	Brauen 1986
pronamide	pre/post	Elmore et al 1972 Gibeault 1974 Beard 1988
propham	pre/post	Lee 1981
prosulfalin	premerge	Jagschitz 1979
Rubigan	premerge	Guillikson & Johnson 1986
siduron	premerge	Duich & Perkins 1967 Jagschitz 1979
simazine	pre/post	Jagschitz 1970 Lee 1981
sodium arsenite	pre/post	Engel & Aldrich 1960 Kerr 1963
terbacil	pre/post	Lee 1981 Jagschitz 1982
terbutol	premerge	Elmore et al 1972 Gibeault 1974
tricalcium arsenate	pre/post	Kerr 1963 Jagschitz 1970
trifluralin	premerge	Gibeault 1971, 1974

APPENDIX B: CHEMICAL HERBICIDE NAMES

Common Name	Trade Name	Chemical Name
asulam	Asulox,Asilan	methyl sulfanilyl-carbamate
atrazine	Aatrex,Gesaprim Atra-Pril	2-chloro-4(ethylamino)-6-(isopropylamino)-s-triazine
benefin	Balan,Balafin, Banafine,Quilan	n-butyl-n-ethyl-@-@-@-trifluro-2,6-dinitro-p-toluidine
besulide	Betasan,Prefar, Betamec,Pre-San	O,O-diisopropyl phosphorodithioate-S-ester with N-(2-mercaptoethyl) benzenesulfon amide
bromacil	Hyvar X,Urox	5-bromo-3-sec-butryl-6-methyl-uracil
butralin	Amex, MEX 820, Amchem, Tamex	4-(1,1-dimethylethyl)-N-(1-methyl-propyl)-2,6-dinitrobenzenamine
calcium arsenate	Chip-Cal	
chlorflurenol	CF 125,Curbiset, Multiprop,Maintain	methyl 2-chloro-9-hydroxy-fluorene-9-carboxylate
chlorpropham	Furloe,Chloro IPC, Sprout Nip,Bud Nip	isopropyl m-chloro-carbanilate
cinmethylin		
cyanazine	Bladex	2-[[4-chloro-6-(ethyl-amino)-s-triazin-2yl] amino]-2-methyl-propionitrile
DCPA	Dacthal,Chlorthal-dimethyl	dimethyl tetrachloro-terephthalate

dichlobenil	Casoron,Norosac, Dyclomec	2,6-dichlorobenzo-nitrile
diphenamid	Enide,Dymid	N,N-dimethyl-2,2-diphenylacetamide
diuron	Karmex,Drexel, Diuron,Direx	3-(3,4-dichlorophenyl)-1,1-dimethylurea
DMPA	Zytron	O-(2,4-dichlorophenyl) O-methyl isopropylphos-phoramidothioate
DSMA	Weed-E-Rad	WSSA common name: MAA Methanearsonic acid
endothall	Endothall,Endothal, Aquathol,Hydrothol, Des-L-Cate, Accelerate	7-oxabicyclo[2,2,1] heptane-2,3-di-carboxylic acid (3, 6-endoxohexahydro-phthalic acid)
EPTC	Eptam,Genap, Eradicane	S-ethyl dipropylthio-carbamate
ethofumesate	Nortron, Prograss	(±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate
fenoxa-propethyl	Acclaim	
fluorophenoxy-acetic acid		
glyphosate	Roundup,Kleenup, Rodeo,Accord	N-(phosphonomethyl) glycine
lead arsenate		
linuron	Lorox,Linuron, Linex,Pro Turf-Selective	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
MH, maleic hydrazide	MH-30,Sprout Stop, Retard,Slo-Gro, Sucker Stuff, Fair	1,2-dihydro-3,6-pyridazinedione(1,2,3,6-tetrahydro-3,6-dioxonpyridazine)

mefluidide	Embark,Vistar	N-[2,4-dimetyl-5-[[(trifluoromethyl) sulfonyl]amino] phenyl]-acetamide
methabenzthia-zuron	Tribunyl	
metamitron		
metoxuron		
metribuzin	Sencor,Lexone	4-amino-6-tert-butyl-3-(methyl-thio)-as-triazin-5(4H)-one
MSMA	Arsonate,Bueno, Daconate,Dal-E-Rad,Mesamate, Transvert,Weed-Hoe	
napropamide	Devrinol	2-(@-naphthoxy)-N,N-diethyl-propionamide
neburon		
nitralin & DCPA	Planavin	nitralin = 4-(methyl-sulfonyl)-2,6-dinitro-N,N-dipropylaniline
oryzalin	Ryzelan,Surflan	3,5-dinitro-N,N-dipropylsul-fanilamide
oxadiazon	Ronstar	2-tert-butyl-4-(2,4-dichloro-5-isopropoxy-phenyl)-ˆ-1,3,4-oxadiazolin-5-one
paraquat	Paraquat,Gramoxone	1,1'-dimethyl-4,4'-bipyridinium ion
pendimethalin	Prowl,Stomp, Herbadox	N-(1-ethylpropyl)-3, 4 dimethyl-2,6 dinitrobenzenamine

prodiamine	Blockade, Rydex	2,4-dinitro-N,N-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine
pronamide	Kerb	3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide
propham	Chem-Hoe	isopropyl carbanilate
prosulfalin	Sward	N-[[4-(dipropylamino)-3,5-dinitrophenyl] sulfonyl]-S,S-dimethysulfilimine
Rubigan	Rubigan (fenarimol)	
siduron	Tupersan	1-(2-methylcyclohexyl)-3-phenylurea
simazine	Princep,Primatol, Gesatop	
sodium arsenite	Arcadian Sodium Arsenite "8" Solution, Niagara Sodium Arsenite Weed Killer, Kill All Sodium Arsenite, Penite Sodium Arsenite	sodium arsenite
terbacil	Sinbar	
terbutol	Azak,Hercules 9573	2,6-di-tertbutyl-p-tolyl methylcarbamate
tricalcium arsenate		
trifluralin	Treflan,Trefanocide, Elancolan,Trifluralin	

APPENDIX C:TABLE 13. EFFECT OF ETHOFUMESATE ON EMERGENCE OF NINE COOL SEASON TURFGRASSES. PERCENT GRASS PLOT COVERAGE, TRIAL #4, LEWIS BROWN FARM, CORVALLIS, OR., 1986

Table plant growth means are expressed as a percent of the plot covered. N=216.

Grass	Control MEAN	Treatment MEAN	% Reduction
Palmer	90	90	0
Mustang	90	90	0
America	69.16	57.08	12.08
Scaldis	71.25	47.5	23.8
Ensylva	73.3	45	28.3
Checker	69.2	35	34.2
Sabre	87.9	64.2	23.8
Poa annua	75.4	35	40.4
Exeter	87.9	47.1	40.8

Protected LSD (0.05) for arcsine transformed data is 12.87.

APPENDIX C: (CONTINUED):
TABLE 14. STATISTICAL ANALYSIS OF ANNUAL BLUEGRASS MEAN PLANT COUNTS FOLLOWING ETHOFUMESATE APPLICATION, 7 MONTHS AFTER TREATMENT, LEWIS BROWN FARM, CORVALLIS, OR., 1984, (TRIAL #5)

Treatment levels	1.5	1.0	0.5 X 3	0.5 X 2	0.5	0.0
kg/ha						
1.5		0.3	0.6	1.2	4.6	23.8#
1.0			0.3	0.9	4.3	23.6#
0.5 X 3				0.6	4.0	23.3#
0.5 X 2					3.4	22.7#
0.5						19.3#
0.0						

LSD Critical Value (0.05) = 6.32

ANOVA

1983-1984

Variance source	df	Mean squares	F
Treatment Rate	5	1051.091	52.918***
Stage	2	2.203	0.111
Trmnt/Stage Interaction	10	11.957	0.602
Error	54	19.863	
Total	71		

*** Response significant at 0.001 level.

(Table values show annual bluegrass mean plant count differences by ethofumesate treatment rate, N=72. LSD protected by F test at 0.001 level of significance)

APPENDIX C: (CONTINUED):
TABLE 15. STATISTICAL ANALYSIS OF ANNUAL BLUEGRASS MEAN PLANT COUNTS FOLLOWING ETHOFUMESATE APPLICATION, 7 MONTHS AFTER TREATMENT, AT LEWIS BROWN FARM, CORVALLIS, OR., 1985. (TRIAL #6)

Treatment	1.5	1.0	0.5 X 3	0.5 X 2	0.5	0.0
kg/ha						
1.5		0	0.1	0.1	1.3	14.4#
1.0			0.1	0.1	1.3	14.4#
0.5 X 3				0	1.3	14.3#
0.5 X 2					1.3	14.3#
0.5						13.1#
0.0						

LSD Critical Value (0.05) = 3.5

ANOVA

1984-1985

Variance source	df	Mean squares	F	
Treatment rate	5	401.781	65.896	***
stage	2	3.431	0.563	
Trmnt/stage Interaction	10	7.531	1.235	
Error	54	6.097		
Total	71			

*** Response significant at 0.001 level.

(Table values show annual bluegrass mean plant count differences by treatment rate, N=72. LSD protected by F test at 0.001 level of significance.)

APPENDIX C: (CONTINUED):
TABLE 16. STATISTICAL ANALYSIS OF ETHOFUMESATE INHIBITION OF ANNUAL BLUEGRASS NO TILL AND TILL FIELD STUDIES AT LEWIS BROWN FARM, CORVALLIS, OR., 1985.

Table values show mean plant count differences by treatment rate, N=36. LSD protected by treatment F test at 0.001 level of significance.

Treatment Rate	Till 1.5	Till 1.0	Till 0.0	No Till 1.5	No Till 1.0	No Till 0.0
1.5		0	12.6 #		0	22.0 ##
1.0			12.6 #			22.0 ##
0.0						

LSD critical value (0.05)=2.4 ## LSD (0.05)=7.8

ANOVA

Variance source	Till TRIAL # 7 df	Till TRIAL # 7 Mean squares	Till TRIAL # 7 F	No Till TRIAL # 8 df	No Till TRIAL # 8 Mean squares	No Till TRIAL # 8 F
Treatment rate	2	633.361	241.7***	2	1936.0	66.5***
stage	2	2.694	1.028	2	23.25	0.8
Trmnt/stage Interaction	4	2.694	1.028	4	23.25	0.8
Error	27	2.62		27	29.13	
Total	35			35		

*** Response significant at 0.001 level. (N=36)

APPENDIX C: (CONTINUED):

TABLE 17. EFFECT OF ETHOFUMESATE ON ANNUAL BLUEGRASS EMERGENCE IN A NO TILL SLICER SEEDED PLOT.
TRIAL # 9, EUGENE COUNTRY CLUB, EUGENE, OR., 1986.

Table values show mean annual bluegrass plant count differences by treatment rate. N=24. LSD protected by F test at 0.005 level of significance.

Treatment	1.5	1.0	0.0
1.5 kg/ha		1.5	13.8 #
1.0			12.3 #
0.0			

LSD Critical value (5%) = 10.23

ANOVA

Variance source	df	Mean squares	F
Treatment rate	2	455.17	9.591 **
stage	1	12.04	0.254
Trmnt/Stage Interaction	2	11.17	0.235
Error	18	47.458	
Total	23		

** Response significant at 0.005 level.