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POSTEMERGENCE CONTROL OF CRABGRASS
DIGITARIA SPP. IN TURFGRASS WITH FENOXAPROP-
ETHYL AND TRIDIPHANE

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POSTEMERGENCE CONTROL OF CRABGRASS [DIGITARIA SPP.] IN TURFGRASS WITH FENOXAPROP-ETHYL AND TRIDIPHANE

By

Bruce Alan Jacobs

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ABSTRACT

POSTEMERGENCE CONTROL OF CRABGRASS [*DIGITARIA* SPP.] IN TURFGRASS WITH FENOXAPROP-ETHYL AND TRIDIPHANE

By

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Studies were conducted to evaluate the effectiveness of fenoxaprop-ethyl and tridiphane for control of crabgrass within turf and non-turf situations. Efficacy and timing of fenoxaprop-ethyl and tridiphane with preemergence herbicides, Kentucky bluegrass and creeping bentgrass cultivar sensitivity to fenoxaprop-ethyl, and antagonism of fenoxaprop-ethyl and tridiphane with broadleaf herbicides were studied.

Results indicated fenoxaprop-ethyl to be effective for control of four tiller crabgrass. Tridiphane provided erratic crabgrass control during both seasons. Fenoxaprop-ethyl applied as a split treatment (0.14 + 0.14 kg ha^{-1}) or tank-mixed with preemergence herbicides (0.20 + 8.4 kg ha^{-1}) produced season-long crabgrass control. Creeping bentgrass cultivars were severely injured by fenoxaprop-ethyl (0.14 and 0.20 kg ha^{-1}). Temporary injury was observed on most Kentucky bluegrass cultivars with fenoxaprop-ethyl (0.14 and 0.28 kg ha^{-1}). Both turfgrass species recovered by four weeks after application. 2,4-D amine, 2,4-D ester, and

clopyralid antagonized fenoxaprop-ethyl, while tridiphane was not affected.

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INTRODUCTION

Highly maintained turfgrass has become well known as a valuable commodity in increasing property value. Since the early 1900's, crabgrass (*Digitaria* spp.) has been a difficult weed to control in established turfgrass.

Mainly a native of Europe, the genus *Digitaria* consists of more than 325 annual and perennial species. They can be found in both tropical and temperate regions of the world. Inside the United States, there are approximately 24 native species of crabgrass. Most are weedy and thrive in moist, disturbed situations. In the southern United States, crabgrass has been used for forage and occasionally cut for hay. Large crabgrass (*Digitaria sanguinalis* (L.) Scop.) and smooth crabgrass (*Digitaria ischaemum* (Schreb.) Schreb.) are often found in both cultivated soil and fine turfgrass stands.

Crabgrass is a C_4 plant which can fix CO_2 more efficiently than C_3 plants, producing greater biomass under warm temperatures and high light. During the hot, dry summer months when most turfgrass plants are dormant, crabgrass can overtake a lawn within weeks.

Many preemergence and postemergence herbicides have been evaluated throughout the previous 25 years, producing variable crabgrass control results. Two new postemergence herbicides, fenoxaprop-ethyl [(±)-ethyl 2-[4-[(6-chloro-2-benzoxazoyl)oxy]phenoxy] propanoate] and tridiphane [2-(3,5-dichlorophenyl)-2-(2,2,2-trichloroethyl) oxirane] have demonstrated excellent results for crabgrass control. The objectives of this study were to evaluate the efficacy of combinations of preemergence and postemergence herbicides as influenced by rate, application timing, and stage of growth of crabgrass plants for effective control; evaluate phytotoxic effects from fenoxaprop ethyl to various turfgrass species; and examine postemergence and broadleaf herbicide combinations for potential antagonism in weed control.

CHAPTER 1

REVIEW OF LITERATURE

To gain an appreciation of the difficulty involved in controlling the crabgrass plant, a brief background of its characteristics is included. Preemergence and postemergence herbicide application research is also discussed to determine if past or present control strategies merit improvement.

Factors Influencing Crabgrass Germination

Crabgrass seed can lie dormant in the soil for up to 30 years (19). DeFrance (24) observed that dormant, hard crabgrass seed appeared extremely difficult to kill, and it is doubtful that crabgrass seed could be harmed with solutions that do not injure turfgrasses. Once crabgrass seeds have been established in a turf stand, the area has a potential problem for many years. King and Kramer (69) have found that seeds of large crabgrass and smooth crabgrass germinated from a depth of 3.5 centimeters. Peters (82) witnessed emergence from a soil depth of 6.4 centimeters with smooth crabgrass and at least 7.6 centimeters with large crabgrass.

When soil temperatures reach 18 C, crabgrass begins to germinate, given adequate moisture and light (9). Once established, crabgrass plants can grow at cutting heights of 4.8 mm, and in unmowed situations, plants can reach one meter (3). Peters (82) found that spaced smooth crabgrass plants could produce over 1,000 tillers, while large crabgrass could form over 780 tillers per plant. One undisturbed smooth crabgrass plant generated 210,000 seeds, while a large crabgrass plant produced 145,000 seeds. This demonstrates that crabgrass is a vigorous and abundant reproducer under proper environmental conditions.

Since germination is dependent on adequate environmental conditions, crabgrass can germinate at various times when exposed to differing climates. In California, new crabgrass seedlings were found during every winter month, with heavy seed germination occurring in January and February (107). Large crabgrass has been reported to germinate in late March in the Piedmont Region of Georgia (60). In Maryland, Dernoeden and Mathias (33) reported smooth crabgrass germination from March throughout May. In the Northeastern United States, crabgrass germinates primarily from April to July. Timely preemergence and postemergence herbicide applications are necessary to reduce the infestation of this troublesome weed.

PREEMERGENCE HERBICIDES

The effectiveness of a preemergence herbicide is based upon its ability to provide good initial control, and then to remain effective throughout the season without noticeable turfgrass phytotoxicity (9). For the past 40 years, preemergence herbicides have been extensively tested to determine the ideal herbicide for crabgrass control. The common preemergence herbicides examined include calcium methanearsonate (CMA), tricalcium arsenate (tricalcium arsenate), disodium monomethylarsenate (DMA), octyl-dodecyl ammonium methanearsonate (AMA), phenyl mercuric acetate (PMA), dimethyl tetrachloroterephthalate (DCPA), 1,2,4,5,6,7,8,8a-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene (chlordane), *O*,*O*-diisopropyl phosphorodithioate *S*-ester with *N*-(2-mercaptoethyl)benzene sulfonamide (bensulide), 1-(2-methylcyclohexyl)-3-phenylurea (siduron), *α*,*α*,*α*-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine (trifluralin), polychlorodicyclopentadiene isomers (bandane), *O*-(2,4-dichlorophenyl)*O*-methyl isopropyl-phosphoramidothioate (DMPA), *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzamine (pendimethalin), 2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one (oxadiazon), and *N*-butyl-*N*-ethyl-*α*,*α*,*α*-trifloro-2,6-dinitro-*p*-toluidine (benefin).

A preemergence herbicide is applied at a rate to give season long control. Engel (37) found that bandane applied in early spring at a rate of 67.2 kg ha^{-1} produced good control in a Kentucky bluegrass turf. Tricalcium arsenate was also effective in a variety of turfgrass stands (3, 5, 83). Ahrens et al. (2) demonstrated that calcium arsenate provided acceptable residual control the year following application.

Welton and Carroll (105) observed that lead arsenate at 871.2 and 1089 kg ha^{-1} provided effective crabgrass control. Calcium arsenate at rates of 731.8 kg ha^{-1} or higher was more effective than lead arsenate but injured the turfgrass significantly. Turfgrass injury caused by both lead and calcium arsenate did not appear until a year or more after application. Soil analysis revealed that elemental arsenic had penetrated to a depth of over 25.4 cm, and water soluble arsenic was found at 10.2 cm (105).

Increasing problems with the arsenate chemicals led to the development of safer herbicides requiring less material per hectare. Limpel et al. (72) reported that DCPA at 11.2 kg ha^{-1} was more effective than chlordane at 67.2 kg ha^{-1} or calcium arsenate at 497.3 kg ha^{-1}. DCPA demonstrated excellent results at low rates which would reduce soil residual. DCPA has provided excellent preemergence crabgrass control in Kentucky bluegrass and fine fescue areas (17, 44, 45, 47, 72, 84, 97, 101) but occasionally has caused severe phytotoxicity and thinning of red fescue stands at rates of 11.8 kg ha^{-1} (52, 81, 95, 97, 98, 103). DCPA has been shown to cause thinning of creeping bentgrass at rates of 11.2 kg ha^{-1} (51), while Cisar et al. (22) reported that rates up to 23.5 kg ha^{-1} did not injure a Penncross creeping bentgrass green in Rhode Island. These conflicting results could be due to cultural and/or environmental differences.

Bensulide, a phosphorothioate herbicide, has been reported to provide excellent preemergence crabgrass control at rates of 8.5 to 13.4 kg ha^{-1} throughout the United States (8, 15, 17, 27, 36, 62, 90). Bensulide has been found to inhibit the formation of roots of germinating seeds (38). In Rhode Island, bensulide applied at 3 and 7 weeks before crabgrass germination produced good control with slight turf injury (50). Bhowmik (9) found that bensulide at 11.2 kg ha^{-1} gave excellent crabgrass control in a Kentucky bluegrass-red fescue mixture over the entire season. Peters et al. (83) reported that bensulide restricted rooting of bluegrass sod at 4 weeks but not at 8, 16, or 18 weeks, demonstrating that at least 2 months are required before sod should be laid on the treated area. Bingham noted that when bensulide was applied to the soil prior to sod establishment, both 'Merion' Kentucky bluegrass and 'Kentucky 31' tall fescue roots could not penetrate the herbicide barrier (12).

Another promising herbicide was DMPA, which provided excellent control from a preemergence application to

Kentucky bluegrass (40, 68, 83) and also to a mixture of Colonial bentgrass, Kentucky bluegrass, and red fescue (3).

Siduron, a substituted urea, has been reported to be selective on germinating grasses (38). Kerr (67) found siduron to be an effective preemergence herbicide which can be applied safely before or after seeding or sodding Kentucky bluegrass. Siduron has been reported to be safe on Penncross creeping bentgrass (34), but not on young or recently sodded bermudagrass areas (12, 35). Tweedy reported that siduron (13.4 kg ha^{-1}) produced excellent seasonal crabgrass spp. control without phytotoxicity to cultivars of perennial ryegrass, tall fescue, creeping red fescue, Kentucky bluegrass, and red top (92). Unfortunately, variable crabgrass control with siduron has been reported by other researchers (26, 27).

Single applications of benefin at 2.2 kg ha^{-1} have been reported to provide unacceptable crabgrass control (17, 25, 33, 51). Dernoeden noted that one 2.2 kg ha^{-1} application of benefin failed to provide adequate control the first season, but during the third year a single treatment provided effective crabgrass control (27). Other research has shown that a higher single rate (3.4 kg ha^{-1}) or split applications (2.2 + 2.2 kg ha^{-1}) can produce effective crabgrass control (44, 62). Presently in the United States, bensulide, benefin, DCPA, oxadiazon, pendimethalin, siduron, and trifluralin are the most frequently used preemergence products.

Cultural practices were found to influence herbicidal activity. Raising the cutting height from 2.5 to 5.1 cm improved the effectiveness of DMPA and DCPA along with reducing crabgrass populations (1). Irrigation after preemergence herbicide application can be critical for season long crabgrass control. Dernoeden (26) reported that delaying irrigation on turf treated with bensulide reduced its effectiveness when compared to benefin or DCPA. Irrigation immediately following a DCPA application has been shown to greatly improve efficacy (26).

Cultivation practices following a preemergence herbicide application have not been recommended in the past for fear of disturbing the herbicide zone. Jagschitz (57) found that a renovation protocol of glyphosate, scalping and disk seeding reduced crabgrass control in areas treated with bensulide, benefin, pendimethalin, DCPA, or low rates of prodiamine at 9 and 15 weeks after treatment. Johnson (64) found that core cultivation to a common bermudagrass turf before or after oxadiazon, bensulide, benefin, or bensulide + oxadiazon applications did not affect preemergence crabgrass control. In Michigan, Branham and Rieke (18) reported that core cultivation or vertical mowing immediately following herbicide treatment did not affect crabgrass control with benefin (2.2 kg ha^{-1}), DCPA (11.8 kg ha^{-1}), or bensulide (11.2 kg ha^{-1}).

Timing of the preemergence herbicide application is important. Numerous researchers conducted trials to determine if a fall treatment might maintain control throughout the following year. Perkins et al. (81) applied DCPA (11.2 kg ha^{-1}), bensulide (14 kg ha^{-1}), and siduron (11.2 kg ha^{-1}) in the fall and evaluated crabgrass control during the next season. Both bensulide and DCPA provided excellent results, but DCPA thinned the fine fescue. A fall application of siduron was not effective. Ahrens et al. (1) found that calcium arsenate, chlordane, DCPA, and DMPA performed better when applied in the spring than in the fall. Vitolo, Ilnicki, and Else (94) found that spring treatments of benefin, bensulide, oxadiazon, and prodiamine gave greater crabgrass control than fall treatments of these herbicides. Jagschitz (51) noted bandane, bensulide, and DMPA applied in the fall or spring to be effective in controlling crabgrass with minimum turf injury. In Pennsylvania, napropamide applied at 2.2 kg ha^{-1} provided greater crabgrass control and less turf injury when applied late April than in late March (100). Engel et al. (39) found that a DCPA treatment in April was more efficacious than a May application, while a May treatment of benefin gave greater crabgrass control than an April application. In Rhode Island, March and May split applications of oxadiazon (1.7 + 1.7 kg ha^{-1}) performed better than May and June treatments, while siduron (5.6 kg ha^{-1}) applied in May provided greater crabgrass control than an application in March (93). Johnson (61) concluded that split applications of DCPA (5.6 + 5.6 kg ha^{-1}) did not produce greater large crabgrass control than a single application of 11.2 kg ha^{-1}.

Annual reapplications of preemergence herbicides have improved crabgrass control (104). Half rates of bensulide, bandane, DCPA, siduron, and nitralin applied in the second year after previous spring applications provided good to excellent crabgrass control in Rhode Island (52). Watschke et al. (104) found similar results using reduced rates the following year with prosulfalin, bensulide, benefin, and DCPA in Pennsylvania. Research has also shown that reduced rates of oxadiazon (2.2 kg ha^{-1}), following 4.5 + 4.5 kg ha^{-1} applications the previous summer, were effective in controlling crabgrass (25, 26).

Chemical formulation can have a dramatic impact on herbicide performance, turfgrass injury, and soil residual. In New Jersey, researchers reported dry formulations of DCPA and benefin outperformed liquid applications. Bingham and Schmidt (15) noted that fine granular benefin formulations outperformed both sprays and coarse granules. In Pennsylvania, the emulsified formulation of pendimethalin did not produce good crabgrass control while the granular formulation produced excellent results (96). Turgeon (90) noted that the wettable powder formulation of DCPA provided the best crabgrass control over granular and flowable formulations. Several researchers found the wettable powder formulation of DCPA to be more injurious to creeping red fescue than the granular formulation (96, 102). Bingham and

Schmidt (14) found that a granular bensulide formulation applied at 16.8 kg ha^{-1} once annually for four consecutive years was detected 11 months after the final application to a depth of 13 cm. An emulsifiable concentrate of bensulide applied at the same rate was not found in detectable quantities 11 months after application.

Research has demonstrated the practicality of substituting fertilizer for herbicide treatments in controlling weeds and annual grasses. Turner et al. (91) noted phosphorus fertilizer application to significantly reduce crabgrass encroachment in Merion Kentucky bluegrass. Johnson and Bowyer (65) found that DCPA, oxadiazon, bensulide, or prosulfalin in combination with nitrogen fertilizer applied to the same turf areas for four consecutive years controlled a higher percentage of large crabgrass when compared to either applied alone. Murray et al. (77) have shown that an interaction exists between crabgrass spp. control by both DSMA and siduron and high fertilizer rates (300 kg N ha^{-1}), in which the fertilizer increases the effectiveness of both preemergence herbicides.

Soil and environmental factors can influence a preemergence herbicide's activity. Johnson and Burns (66) found that large crabgrass control by DCPA or napropamide increased with decreasing soil pH levels from 5.6 to 5.0. Johnson (61) noted a correlation between soil temperature prior to DCPA treatment and the amount of large crabgrass control in Georgia, which indicated that poor control was related to crabgrass germination prior to herbicide application. Daniel (23) reported that application of preemergence herbicides prior to soil temperatures of 12 C under turfgrass conditions in Indiana can prevent emergence of many annual grasses.

POSTEMERGENCE HERBICIDES

When problems arise from an improper application or from a lack of soil residual of preemergence herbicides, postemergence herbicides can provide effective control. In previous years, arsenical and mercurial chemicals proved effective for postemergence crabgrass control (70). Beard and Daniel (7) concluded that DMA was the most effective and safest postemergence chemical available for home use in the mid 1950's. Research conducted in 1957 showed AMA to provide faster crabgrass control than DMA, but both products required two applications (7). Kesler et al. (68) showed that DMA, AMA, and CMA provided satisfactory postemergence results, but single applications did not maintain season-long control. Watschke (95) stated that a single application of monosodium methanearsonate (MSMA) did not give season-long postemergence control. This disagreed with Johnson (60) who stated that a single June application of MSMA (2.2 kg ha^{-1}) produced excellent large crabgrass control in a bermudagrass turf. These discrepancies could be due to varying levels of crabgrass pressure within locations, different growth stages, or environmental factors. Later research has demonstrated that split treatments of disodium methanearsonate (DSMA) and MSMA are more effective than single applications and give little or no discoloration to the turf (6, 93). Johnson (59) found that 12 days between MSMA applications (1.1 kg ha^{-1}) provided the best large crabgrass control. He further noted that a 12 to 19 day delay between applications of MSMA was the most effective when using higher rates of 1.7 or 2.2 kg ha^{-1} (59). Jagschitz reported that a 2-week interval between DSMA treatments for postemergence crabgrass control was the most effective while 3-week intervals resulted in poor control (55). Jagschitz (53) also found that three applications of DSMA (4.5 kg ha^{-1}) or MSMA (3 + 2.2 + 2.2 kg ha^{-1}) produced excellent results, but there was considerable injury to fescue and bentgrass. Perkins et al. reported that an MSMA-dicamba combination produced excellent results, but there was considerable thinning to the turf (81). PMA (4.5 kg ha^{-1}) and trifluralin (4.5 kg ha^{-1}) gave acceptable postemergence control (83), but both can also cause turfgrass discoloration (56, 81). Granular trifluralin exhibited excellent control when applied as an early post treatment. Phillips reported that a liquid combination of trifluralin and DSMA (0.56 + 3.9 kg ha^{-1}) worked well as a postemergence crabgrass control method (84). Jagschitz (54) noted that increasing the spray volume from 189.3 to 658.6 liters using DSMA reduced Kentucky bluegrass injury.

Researchers in Maryland (34) observed that 'Tufcote' bermudagrass recovered 2 weeks following excessive applications of MSMA (4.5 kg ha^{-1}), DSMA (8.3 kg ha^{-1}), and PMA (0.12 kg ha^{-1}). In Arkansas, MSMA (2.2 kg ha^{-1}) and sethoxydim (2-(1-(ethoxyimion)butyl)-5-(2-(ethylthio) propyl)-3-hydroxy-2-cyclohexen-1-one) at 0.44 kg ha^{-1} produced fair crabgrass control and also caused yellowing of tall fescue, creeping bentgrass, and common bermudagrass turf (76). Dernoeden and Fry (30) observed that MSMA at 1.1 kg ha^{-1} applied three times weekly or 2.2 kg ha^{-1} applied two times biweekly produced excellent postemergence control of three to six tiller stage crabgrass plants, but it was phytotoxic to perennial ryegrass.

Due to the constant concerns with phytotoxicity, poor seasonal control, and timing of sequential herbicide applications, new postemergence herbicides are constantly being sought. Desirable characteristics would include excellent control with one application, predictable results in a variety of climatic situations, an acceptable level of phytotoxicity to turfgrass, and low application rates.

Fenoxaprop ethyl [(±)-ethyl 2-[4-[(6-chloro-2-benzoxazoyl)oxy]phenoxy] propanoate] is a promising new postemergence herbicide for controlling large and smooth crabgrass, johnsongrass (*Sorghum halepense* L. Pers.), panicum spp. (*Panicum* spp.), goosegrass (*Eleusine indica* L. Gaertn.), barnyardgrass (*Echinochloa crus-galli* L. Beauv.) and foxtail spp. (*Setaria* spp.) within most cool season turfgrass stands (48, 87). Fenoxaprop ethyl, tested under the experimental designation HOE A2501, has demonstrated great potential as a postemergence crabgrass herbicide (9, 11, 13, 20, 28, 29, 32, 71, 94). Cisar and Jagschitz (21) reported on field and greenhouse evaluations of fenoxaprop ethyl. In the field, fenoxaprop ethyl applied in June was not injurious to Kentucky bluegrass or bentgrass at rates of up to 0.2 kg ha^{-1}. Applications of fenoxaprop ethyl in May at rates from 0.2 to 0.56 kg ha^{-1} damaged perennial ryegrass and Kentucky bluegrass but was safe on red fescue. In greenhouse studies, fenoxaprop ethyl produced injury up to 15 weeks on Kentucky bluegrass at rates as low as 0.08 kg ha^{-1}. Red fescue was noted to be the most tolerant and Kentucky bluegrass the most sensitive to fenoxaprop ethyl. Cisar and Jagschitz further believed that Kentucky bluegrass could be more sensitive to fenoxaprop ethyl in early May than in mid June (21). Further research is necessary to determine which Kentucky bluegrass cultivars are more or less susceptible to fenoxaprop ethyl.

Dernoeden and Fry (31) observed that older leaves of 'Midiron' bermudagrass treated with fenoxaprop ethyl and bensulide (0.17 + 8.4 kg ha^{-1}) developed a purple color. Fenoxaprop ethyl (0.17 kg ha^{-1}) alone or tank mixed with DCPA (11.8 kg ha^{-1}) produced a yellowish color and a density reduction was evident in all treatments. When applied to 'Tufcote' bermudagrass, fenoxaprop ethyl (0.17 kg ha^{-1}) caused a yellow-brown color less than 1 week after application, but no thinning of the bermudagrass occurred (31). McCarty et al. observed that single applications of fenoxaprop ethyl (0.07 kg ha^{-1}) severely injured centipedegrass for approximately 42 days (75). Fry et al. (45) indicated that fenoxaprop ethyl produced excellent control of two to four leaf smooth crabgrass with no discoloration to zoysiagrass turf. Other experiments indicated that a single treatment of fenoxaprop ethyl at either 0.17 or 0.28 kg ha^{-1} effectively controlled one to five tiller stage crabgrass, but was ineffective at the four to six tiller stages (30). In Massachusetts, fenoxaprop ethyl provided excellent control of two to four leaf crabgrass, but reinfestation occurred later in the season (10). These results demonstrate the need for further rate and timing experiments. Watschke (95) observed that fenoxaprop ethyl at 0.17, 0.28 and 0.39 kg ha^{-1} did not successfully control water stressed crabgrass, but when soil moisture was adequate, fenoxaprop ethyl provided excellent control. In Rhode Island, Kentucky bluegrass sod rooting was not inhibited when fenoxaprop ethyl was applied 3 to 6 weeks before transplanting (58).

Applying fenoxaprop ethyl in split applications or along with preemergence herbicides has provided excellent results (30, 78). Dernoeden and Fry (30) found that fenoxaprop ethyl tank mixed with either DCPA or oxadiazon provided excellent season-long control. These promising results warrant further preemergence/postemergence combination studies.

When two or more herbicides are combined in a tank mix, synergistic or antagonistic interactions can occur. Anderson (4) stated that a mixture is said to be antagonistic when the expected response induced by the herbicide combination is less than the expected sum total of the responses induced by each herbicide applied alone. Synergism occurs when the expected response induced by the herbicide combination is greater than the expected sum total of the responses induced by each herbicide applied alone.

In row crop situations, reseachers have reported antagonism with various herbicide tank mixtures or sequential applications. Godley and Kitchen (46) reported that acifluorfen (5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid) at 0.4 kg/ha applied in combination with, or one to three days prior to fluazifop (($\pm$)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid) at 0.4 kg ha^{-1} greatly reduced crabgrass control when compared to fluazifop alone. They also noted that the antagonism was not apparent when acifluorfen was applied at 1, 3, or 5 days after the fluazifop treatment, while the degree of antagonism with the tank mixture of fluazifop and acifluorfen was dependent upon climatic conditions. Whitwell et al. (106) reported acifluorfen to be highly antagonistic to the postemergence johnsongrass herbicides sethoxydim and difenopenten (4-[4-[4-(trifluormethyl) phenoxy]-2-pentenoic acid). Similarly, Rhodes and Coble (86) found bentazon to dramatically suppress the absorption of sethoxydim within goosegrass when applied in a mixture.

Researchers have reported antagonistic properties between diclofop-methyl (methyl 2-[4(2',4'-dichlorophenoxy)phenoxy]propanoate) and 2,4-D, where the injury symptoms from diclofop-methyl were nullified on wild oat (*Avena fatua* L.) (42, 49). Todd and Stobbe (89) also reported 2,4-D to be antagonistic to diclofop-methyl in controlling wild oat in a greenhouse situation. They determined that the antagonism caused by 2,4-D reduced the movement of the free acid diclofop to meristematic areas. Shimabukuro et al. (88) reported that reciprocal antagonism in corn and soybeans existed between diclofop-methyl and 2,4-D and was dependent upon the concentration of the other herbicide. In Alberta, Canada, 2,4-D has been shown to be antagonistic to diclofop and also flamprop (N-benzoyl-N-(3-chloro-4-fluorophenyl)-DL-alanine) for wild oat control (79, 80). Another phenoxy herbicide, MCPA, when tank mixed with diclofop, has been shown to inhibit herbicidal transport within wild oat (85). Qureshi and VandenBorn (85) attributed this problem to a formulation incompatability when both are combined.

Antagonism has also been reported with annual grass and broadleaf weed herbicides used in turfgrass situations. Johnson (63) reported a reduction in preemergence crabgrass control when combining bensulide (11 kg ha^{-1}) with 2,4-D, mecoprop, and dicamba (1.1 + 0.6 + 0.11 kg ha^{-1}) as compared to bensulide alone. Freeborg and Daniel (43) reported a reduction in postemergence crabgrass control with fenoxaprop-ethyl (0.28 kg ha^{-1}) tank mixed with 2,4-D plus mecoprop plus dicamba (0.43 + 0.22 + 0.04 kg ha^{-1}) when compared to fenoxaprop-ethyl alone. Watschke and Hamilton (99) also noted similar results and showed that by increasing the fenoxaprop-ethyl rate in the combination, crabgrass control also increased.

Tridiphane [2-(3,5-dichlorophenyl)-2-(2,2,2-trichloroethyl)oxirane] is another interesting new postemergence annual grass herbicide. Tridiphane has been successfully used for annual grass control in row crop situations. Research suggests that tridiphane either decreases or inhibits the metabolism of atrazine in giant foxtail (*Setaria faberii*) (16, 74). Ezra et al. has noted that tridiphane is synergistic with EPTC and alachlor, providing increased control of proso millet (*Panicum miliaceum*) in corn (41). Further research has shown that temperature has a dramatic effect on penetration, desorption, volatility, and metabolism of tridiphane when applied to giant foxtail (73).

Tridiphane has been tested along with MSMA and fenoxaprop ethyl to compare efficacy in turfgrass situations. Neal et. al (78) observed that early post applications of tridiphane, fenoxaprop ethyl, and MSMA provided excellent crabgrass control, although some reinfestation occurred. Tridiphane (1.1 kg ha^{-1}) was less effective when applied to one to three tiller crabgrass than fenoxaprop ethyl (0.2 kg ha^{-1}) or MSMA (2.2 kg ha^{-1}), although Vitolo et. al (94) found that tridiphane applied post to small plants provided excellent control at all rates tested. Jagschitz (56) reported that tridiphane (1.7 kg ha^{-1}) is safe on Kentucky bluegrass and perennial ryegrass, but injurious to red fescue. Higher rates or sequential applications of tridiphane were needed to control larger crabgrass. Due to the limited amount of research literature evaluating tridiphane, further investigations are needed in areas of preemergence-postemergence combinations, efficacy on mature crabgrass plants, and also broadleaf herbicide tank mixes.

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CHAPTER 2

EFFICACY AND TIMING OF FENOXAPROP-ETHYL AND TRIDIPHANE ALONE AND IN COMBINATION WITH PREEMERGENCE HERBICIDES FOR CRABGRASS CONTROL

ABSTRACT

Field studies were conducted during 1986 and 1987 to determine the effectiveness of fenoxaprop-ethyl (0.14, 0.20, 0.28, and 0.40 kg ha^{-1}) and tridiphane (1.1, 1.7, and 2.2 kg ha^{-1}) in controlling various crabgrass growth stages. Treatments of fenoxaprop-ethyl and tridiphane tank-mixed with preemergence herbicides were included to compare length of crabgrass control throughout the season. Fenoxaprop-ethyl (0.20 kg ha^{-1}) provided 91% control of eight tiller plants in 1986, and 83% control of four tiller crabgrass in 1987. Tridiphane (1.7 kg ha^{-1}) provided 95% and 73% control of six tiller plants in 1986 and 1987, respectively. Fenoxaprop-ethyl tank-mixed with bensulide (0.20 + 8.4 kg ha^{-1}) produced effective season-long crabgrass control during both years. Split applications of fenoxaprop-ethyl (0.14 + 0.14 and 0.20 + 0.20 kg ha^{-1}) provided excellent control throughout the summer months.

INTRODUCTION

Initial crabgrass (Digitaria spp.) emergence within a particular geographic location can vary considerably from season to season (7, 16). The extended germination period makes it difficult to maintain effective crabgrass control (4). If a preemergence herbicide is applied 2 to 4 weeks before crabgrass emergence, much of the herbicide residue may be lost. To gain the longest soil residual possible, a preemergence-postemergence tank mix can be employed. Researchers have reported excellent results with this combination (6, 9, 11, 12, 13). This concept utilizes crabgrass germination as a guide to correctly time the preemergence treatment. The postemergence herbicide could effectively control the initial flush of crabgrass, while the preemergence herbicide can prevent further infestation during peak germination periods.

Another alternative is to apply split treatments of a postemergence herbicide. Researchers have reported excellent crabgrass control with this method (1, 6, 10, 12). This treatment could eliminate the need for a preemergence grass herbicide and allow overseeding to be performed without the fear of chemical residues in the soil.

Fenoxaprop-ethyl and tridiphane are new postemergence graminicides for selectively controlling annual grasses in turfgrass stands. Recommended labeled rates for fenoxaprop-ethyl range from 0.13 kg ha^{-1} to 0.40 kg ha^{-1} for crabgrass growth stages from two leaves up to four tillers, respectively (8). Limited research is available on the largest crabgrass stages these herbicides can control. If a large tillered plant can be controlled by the postemergence herbicide, the preemergence-postemergence combination could be postponed for several weeks. This could extend the preemergence soil residual further into the summer and fall. The purpose of this research was to evaluate the preemergence-postemergence strategy for season-long crabgrass control, and also determine the largest crabgrass stage of growth which can be controlled using fenoxaprop-ethyl and tridiphane.

MATERIALS AND METHODS

Two field studies were conducted from June through September during 1986 and 1987 at the Hancock Turfgrass Research Center, East Lansing, MI. The soil type was an Owosso-Marlette sandy loam complex (Fine-loamy, mixed, mesic, Typic Hapludalfs). All herbicide applications were applied with a compressed CO_2 small plot sprayer, using a four nozzle boom equipped with 8002 flat fan nozzles. The spray volume was 520 L ha^{-1} with a pressure of 0.21 MPa. Plot dimensions were 1.2 by 1.8 m. The experimental design consisted of a randomized complete block with three replications. The site was not fertilized, mowed at 3.8 cm when needed, and supplemental irrigation was applied only during drought periods to encourage crabgrass germination.

Prior to 1986, the test site consisted of a dense population of crabgrass along with many annual and perennial weeds and grasses. In early May of both seasons, the area was treated with a broadcast application of glyphosate at 1.12 kg ha^{-1} to eliminate all grassy and broadleaf weeds. The site was then verticut with a Ryan (OMC Lincoln, Lincoln, NE) Ren-O-Thin® to a depth of 1.3 cm and overseeded with smooth crabgrass (Digitaria ischaemum) in 1986, and large crabgrass (D. sanguinalis) in 1987 to supplement the natural seed reservoir. Plots were visually evaluated at two week intervals for percent crabgrass groundcover and all data was converted to percent control. Treatment means were separated using the least significant difference (LSD) technique.

The herbicide treatments consisted of tridiphane at rates ranging from 1.1 kg ha^{-1} to 2.2 kg ha^{-1} alone and in combination with bensulide (8.4 kg ha^{-1}), pendimethalin (2.2 kg ha^{-1}), and fluroxypyr (4-amino-3,5-dichloro-6-fluoro-2-pyridyloxyacetic acid methyl heptylester) at 0.28 and 0.56 kg ha^{-1}. Fenoxaprop ethyl was tested at rates of 0.14, 0.20, 0.28, and 0.40 kg ha^{-1} applied alone, sequentially, and in combination with bensulide (8.4 kg ha^{-1}), pendimethalin (2.2 kg ha^{-1}), and DCPA (8.4 kg ha^{-1}). All herbicide combinations were applied as a tank mix. Single applications of both tridiphane and fenoxaprop ethyl were applied at two week intervals to evaluate crabgrass control at various growth stages.

In 1986, treatments 1 through 17 (Table 1) were applied on 3 June and in 1987 treatments 1 through 19 (Table 1) were applied on 2 June to a crabgrass growth stage of two leaf to one tiller. Treatments 20 through 24 (Table 1) were applied to three leaf, three tiller crabgrass on 17 June 1986, while numbers 20 through 25 (Table 1) were applied to two to three leaf, one to three tiller plants on 15 June, 1987. Applications 26 through 33 (Table 1) were applied on July 1 in both 1986 and 1987 to a three leaf, two to four tiller crabgrass stage. Treatments 34 through 39 (Table 1) were applied to three to five leaf, four to six tiller crabgrass on 15 July 1986, and 14 July 1987. Treatments 40 through 47

(Table 1) were tested on four to six leaf, five to twelve tiller plants on 30 July 1986, and 29 July 1987.

RESULTS AND DISCUSSION

Tridiphane at 1.7 kg ha^{-1} applied to crabgrass at the two leaf to one tiller stage produced excellent control (92%) 4 weeks after treatment in 1986 (Table 1). Increasing the tridiphane rate to 2.2 kg ha^{-1} did not provide additional control. Control decreased by the sixth and eighth week for both rates due to newly germinating seeds within the area. The test site lacked a turfgrass canopy, resulting in rapid reinfestation. This explains the decreased control occuring at 4 weeks after treatment for most applications. In 1986, June and July produced rather mild temperatures (Table A1), with adequate precipitation (Table A3). These conditions were favorable in obtaining effective control. In June and July of 1987, the higher temperatures and lower precipitation could have caused the poor results attained with tridiphane at the 1.7 kg ha^{-1} rate. Dernoeden (5) also noted that the effectiveness of tridiphane was reduced by hot and dry conditions. The highest level of control (71%) was obtained 4 weeks after treatment and fell sharply when new seeds germinated during July. Increasing tridiphane to 2.2 kg ha^{-1} provided good control (89%) 4 weeks after application. Similar to 1986, control diminished by the sixth week.

A lower rate of tridiphane (1.1 kg ha^{-1}) was tank mixed separately with pendimethalin (2.2 kg ha^{-1}) and bensulide (8.4 kg ha^{-1}) to examine seasonal crabgrass control. In

1986, the addition of pendimethalin and bensulide dramatically improved the length of control through 8 weeks after treatment. Research has shown that higher rates of tridiphane (2.2 kg ha^{-1}) in combination with pendimethalin or DCPA provided excellent season-long crabgrass control (5). In 1987, neither preemergence herbicide provided additional control beyond 4 weeks when compared to tridiphane alone.

Unpublished research (Bruce Branham, Michigan State University, E. Lansing, MI.) has shown fluroxypyr to exhibit sufficient postemergence crabgrass activity, warranting inclusion in this study. Fluroxypyr applied alone to the two leaf to one tiller plants in June provided 88% control up to 4 weeks in 1986, but received lower ratings in 1987. The 1 July fluroxypyr treatment provided less control when applied to maturing crabgrass. Very little postemergence activity was seen on five to twelve tiller plants in both years following the late July treatment.

Tridiphane (1.7 kg ha^{-1}) applied on 3 leaf to 3 tiller crabgrass provided fair control (75%) through a six week period in 1986, and extremely poor control in 1987. Increasing tridiphane to 2.2 kg ha^{-1} provided significantly greater control during the first four weeks in 1986, and doubled the percent control to 64% in 1987 when compared to the lower tridiphane rate. The 1 July 1986 application of tridiphane (1.7 kg ha^{-1}) provided fair control (76%) of two to four tiller crabgrass for a four week period, while tridiphane in 1987 resulted in poor control (56%). Increasing tridiphane to 2.2 kg ha^{-1} resulted in slightly better control in 1986, and a dramatic improvement in 1987. Tridiphane at 1.7 kg ha^{-1} also provided good to excellent control of 4 to 6 tiller crabgrass in 1986, lasting for approximately six weeks. During 1987, this treatment provided 73% control at 4 weeks after application. The higher tridiphane rate produced excellent control through 6 weeks after treatment in the first season, and good control by 4 weeks in 1987. Late July applications of tridiphane could not effectively control mature crabgrass. Treatments in 1986 provided improved control, but the results were not considered acceptable.

In 1986, fenoxaprop-ethyl at all rates produced excellent control of plants up to eight tillers at 2 weeks after treatment. During the season, the main flush of crabgrass germination occurred from 1 June to 1 July. Consequently, plots treated with fenoxaprop-ethyl on 3 June and 17 June became reinfested with new plants, resulting in lowered percent control. Fenoxaprop-ethyl applications from 1 July to 30 July provided better season-long control due to less crabgrass germination. Results in 1987 indicate that fenoxaprop-ethyl alone effectively controlled crabgrass ranging from one to four tillers. All fenoxaprop-ethyl treatments on 14 July and 29 July 1987 resulted in poor control, possibly due to the crabgrass plants becoming water stressed during mid-summer. Watschke (14) also observed reduced control with fenoxaprop-ethyl when moisture was limiting.

Sequential applications of fenoxaprop-ethyl at rates of 0.14 + 0.14 and 0.20 + 0.20 kg ha^{-1} gave effective season-long control during both years. Researchers in Massachusetts (2) and Pennsylvania (13) also indicated excellent results with fenoxaprop-ethyl sequential treatments. Combinations of bensulide + fenoxaprop-ethyl provided the best seasonal control in both years as compared to DCPA and pendimethalin. All three preemergence-postemergence combinations performed well in 1986, but a late season reduction in control was evident with the DCPA and pendimethalin + fenoxaprop-ethyl tank mixes in 1987. When treating immature crabgrass plants, it is not necessary to increase the fenoxaprop-ethyl rate from 0.14 to 0.20 kg ha^{-1} in these preemergence-postemergence combinations.

When comparing the two postemergence herbicides, fenoxaprop-ethyl treatments provided more consistent crabgrass control than tridiphane throughout both seasons. Tridiphane was observed to be a slower acting herbicide, usually requiring two weeks or more for effective control. Bhowmik and Spokas (3) indicated that tridiphane at 2.2 kg ha^{-1} required at least eight weeks to provide excellent control of two to three leaf crabgrass. Crabgrass control from fenoxaprop-ethyl applications was evident within 1 week.

Fenoxaprop-ethyl + preemergence herbicide combinations applied to larger tillered plants warrants further investigation. If a fenoxaprop-ethyl rate greater than 0.20 kg ha^{-1} in combination with a preemergence herbicide were applied later in the season, longer control might be maintained.

TABLE 1: EFFICACY OF FENOXAPROP AND TRIDIPHANE ALONE AND IN COMBINATION WITH PREEMERGENCE HERBICIDES FOR CRABGRASS CONTROL.

TREATMENTS*	RATE (KG/HA)	1986 RATINGS* 2WAT	4WAT	6WAT	8WAT	1987 RATINGS 2WAT	4WAT	6WAT	8WAT
1. TRIDIPHANE (TRID)	1.7	82	92	63	60	20	71	5	0
2. TRID	2.2	82	90	55	56	50	89	49	21
3. TRID + PENDIMETH.	1.1 + 2.2	76	86	88	82	62	83	50	13
4. TRID + BENSULIDE	1.1 + 8.4	98	97	85	98	59	75	40	20
5. TRID + FLUROXYPYR	1.1 + 0.28	86	89	49	64	47	58	27	27
6. TRID + FLUROXYPYR	1.7 + 0.56	88	91	58	47	69	91	61	47
7. FLUROXYPYR	0.56	88	88	66	56	52	46	0	0
8. FENOXAPROP (FENOX)	0.14	92	38	25	43	91	79	65	50
9. FENOX	0.20	88	62	42	57	99	95	93	70
10. FENOX	0.28	--	--	--	--	95	75	79	46
11. FENOX	0.40	--	--	--	--	98	93	68	51
12. FENOX + FENOX	0.14 + 0.14	87	75	94	98	91	79	98	96
13. FENOX + FENOX	0.20 + 0.20	100	81	100	97	97	83	99	98
14. FENOX + BENSULIDE	0.14 + 8.4	98	93	93	97	92	86	87	75
15. FENOX + BENSULIDE	0.20 + 8.4	100	100	97	98	99	95	91	87
16. FENOX + DCPA	0.14 + 8.4	100	89	85	86	89	90	61	49
17. FENOX + DCPA	0.20 + 8.4	97	90	70	90	97	91	74	62
18. FENOX + PENDIMETH.	0.14 + 1.7	100	97	88	92	90	92	67	53
19. FENOX + PENDIMETH.	0.20 + 1.7	100	95	77	71	94	97	86	72
	LSD (0.05) =	16	20	30	35	22	24	48	46
20. TRID	1.7	75	75	75	48	11	33	19	3
21. TRID	2.2	93	96	91	72	10	64	36	11
22. FENOX	0.14	90	76	84	60	88	81	57	24
23. FENOX	0.20	92	84	84	69	96	87	76	52
24. FENOX	0.28	94	81	92	90	97	90	74	40
25. FENOX	0.40	--	--	--	--	86	67	57	41
	LSD (0.05) =	10	11	NS	NS	26	46	47	NS
26. TRID	1.7	73	76	59	53	39	56	41	25
27. TRID	2.2	78	88	85	70	26	94	80	50
28. TRID + FLUROXYPYR	1.7 + 0.56	90	89	74	73	45	83	68	57
29. FLUROXYPYR	0.56	67	31	20	18	20	46	25	19
30. FENOX	0.14	--	--	--	--	77	76	69	57
31. FENOX	0.20	98	93	98	92	59	83	56	23
32. FENOX	0.28	99	97	95	87	83	96	77	69
33. FENOX	0.40	99	96	97	99	85	95	83	70
	LSD (0.05) =	12	17	23	30	34	26	43	46
34. TRID	1.7	88	90	87	66	24	73	22	
35. TRID	2.2	93	95	91	82	32	87	36	
36. FENOX	0.14	--	--	--	--	1	1	0	
37. FENOX	0.20	91	70	80	68	0	0	8	
38. FENOX	0.28	93	95	91	86	14	13	2	
39. FENOX	0.40	96	97	98	83	30	12	9	
	LSD (0.05) =	NS	NS	NS	NS	NS	29	27	

TABLE 1 CONT:

TREATMENTS*	RATE (kg/ha)	1986 RATINGS* 2WAT	4WAT	6WAT	8WAT	1987 RATINGS 2WAT	4WAT	6WAT	8WAT
40. TRID	1.7	41	75	44	87	18	49		47
41. TRID	2.2	82	61	58	62	23	31		12
42. TRID + FLUROXYPYR	1.7 + 0.56	44	38	46	66	10	29		36
43. FLUROXYPYR	0.56	38	34	5	42	23	15		13
44. FENOX	0.14	--	--	--	--	4	0		0
45. FENOX	0.20	89	91	95	86	8	0		6
46. FENOX	0.28	96	95	98	96	14	4		22
47. FENOX	0.40	93	99	94	96	7	0		1
48. UNTREATED	----	0#	10#	10#	0#	5	1		0
	LSD (0.05) =	35	41	37	30	NS	36		30

@ Ratings are percent groundcover converted to as percent control, with WAT= Weeks After Treatment.

1986 Untreated ratings taken at same time as treatments 1-19.

* Application dates and stage of growth present:
  - trt 1-19 — 3 June 1986, 2 June 1987, with 2 leaf to 1 tiller crabgrass.
  - trt 20-25 — 17 June 1986, 15 June 1987, with up to 3 leaf, 3 tillers.
  - trt 26-33 — 1 July 1986, 1 July 1987, with 3 leaf, 2-4 tiller crabgrass.
  - trt 34-39 — 15 July 1986, 14 July 1987, with 3-5 leaf, 4-6 tillers.
  - trt 40-47 — 30 July 1986, 29 July 1987, with 4-6 leaf, 5-12 tillers.

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CHAPTER 3

KENTUCKY BLUEGRASS AND CREEPING BENTGRASS CULTIVAR SENSITIVITY TO FENOXAPROP-ETHYL

ABSTRACT

Forty-two cultivars of mature Kentucky bluegrass (*Poa pratensis* L.) were treated with fenoxaprop-ethyl at rates of 0.00, 0.14, and 0.28 kg ha^{-1} in June 1986 and July 1987. Visual injury evaluations were taken at 1, 2, 3, and 4 weeks after application for each cultivar. Temporary injury from a fenoxaprop-ethyl application at 0.14 kg ha^{-1} was considered to be acceptable for all cultivars tested in 1986 and 1987. In 1986, only the cultivar America was rated unacceptable two weeks after treatment with the 0.28 kg ha^{-1} rate. 'Enmundi' was the only Kentucky bluegrass cultivar which did not exhibit injury from either fenoxaprop-ethyl rate tested in 1986 and 1987. In July 1987, fourteen mature creeping bentgrass (*Agrostis palustris* Huds.) cultivars and one velvet bentgrass (*Agrostis canina* L.) cultivar were treated with fenoxaprop-ethyl at rates of 0.00, 0.09, 0.14, and 0.20 kg ha^{-1}. In a second study, fenoxaprop-ethyl at rates of 0.00, 0.04, 0.07, and 0.09 kg ha^{-1} were applied in late August to the same cultivars. Visual injury evaluations were taken at 1, 2, 3, and 4 weeks

after application for the July study, and 2, 4, and 5 week evaluations were recorded for the August study. The most severe injury was apparent at 2 weeks after treatment for most cultivars in both experiments. The 0.20 kg ha^{-1} rate produced significant injury to all bentgrass cultivars when compared to untreated plots at 1, 2 and 3 weeks after treatment. Most cultivars recovered from the 0.14 kg ha^{-1} rate by the three week evaluation. In July, a rate of 0.09 kg ha^{-1} produced acceptable injury for all cultivars except 'Toronto'. This same rate applied in August produced unacceptable injury to most cultivars. The 0.07 kg ha^{-1} rate produced injury ranging from mild to severe, but all cultivars recovered by four weeks after treatment. Fenoxaprop-ethyl at 0.04 kg ha^{-1} produced slight injury at 2 weeks after treatment, with all cultivars recovering by the 4th week. Overall, 'Penncross', 'Penneagle', 'Carmen', and 'B853WWK' were most tolerant, while 'Toronto' was extremely sensitive to fenoxaprop-ethyl. Chemical name used: (±)-ethyl 2-[4-[(6-chloro-2-benzoxazoyl)oxy]phenoxy] propanoate.

INTRODUCTION

Crabgrass (*Digitaria* spp.) infestations within turfgrass can be controlled with either preemergence or postemergence herbicides. Effectiveness of these herbicides varies considerably from region to region and year to year (2). Frequently used arsenical postemergence herbicides such as monosodium methanearsonate (MSMA) have been shown to be only marginally effective in controlling crabgrass (2, 10, 18), and can also severely damage desired turfgrass stands (17). Fenoxaprop-ethyl is a new selective postemergence graminicide which has been shown to be effective for control of annual grasses such as crabgrass (1, 4, 9, 10, 11, 14, 16, 17). Split applications of fenoxaprop-ethyl can provide season-long crabgrass control (2, 15) while other researchers have found that one properly timed application can provide season-long control (7, 10).

Application timing and age of the turfgrass can affect the phytotoxicity obtained from a fenoxaprop-ethyl application. Bingham (3) observed fenoxaprop-ethyl applied mid-May to be more injurious than a mid-June treatment to a 'Glade', 'Plush', 'Ram' Kentucky bluegrass blend less than one year old. Fenoxaprop-ethyl has also been shown to significantly reduce the density of a seven month old 'South Dakota Common' Kentucky bluegrass turf (6).

On mature turfgrass, Cisar and Jagschitz (5) noted objectionable injury to an established Kentucky bluegrass stand from May fenoxaprop-ethyl (0.2 kg ha^{-1}) treatments, however June applications to Kentucky bluegrass or bentgrass at the same rate did not cause injury. Dernoeden and Fry (10) observed injury to a three year old 'America' Kentucky bluegrass stand from fenoxaprop-ethyl to last for three to four weeks from a mid-May (0.28 kg ha^{-1}) or late June (0.39 kg ha^{-1}) application, while a blend of 'Merion', 'Sydsport', and 'Vantage' was only injured from the late June application. No phytotoxicity was noted on a four year old unirrigated stand of 'Sydsport', 'Vantage', 'Pennstar' Kentucky bluegrass treated with fenoxaprop-ethyl at 0.17 and 0.28 kg ha^{-1} during periods of drought and heat stress in July (10). Bhowmik (2) reported 6 weeks of mild injury to 'Baron' Kentucky bluegrass caused by a late May treatment of fenoxaprop-ethyl (0.28 kg ha^{-1}). When a second 0.28 kg ha^{-1} application was applied to the same area in mid July, no increase in injury was observed. Higgins et. al. (13) noted that the differential tolerance of a 'Tifgreen II' bermudagrass putting green to fenoxaprop-ethyl was related to application timing. The researchers reported that June applications ranging from 0.07 to 0.15 kg ha^{-1} produced injury for up to 7 weeks, while bermudagrass treated in August at the same rates recovered within 4 weeks (13).

A safener consisting of nitrogen and chelated iron (24.4 kg N ha^{-1} + 0.6 kg ha^{-1}) has been reported by several researchers (8, 12) to be effective in reducing bentgrass phytotoxicity from fenoxaprop-ethyl. Dernoeden (12) noted the addition of pendimethalin to the above fenoxaprop-ethyl + safener combination to be severely harmful to 'Penncross' creeping bentgrass. Cisar and Jagschitz (4,5) observed that crop oil in combination with fenoxaprop-ethyl slightly increased Kentucky bluegrass injury.

Due to the variable results and limited information pertaining to cultivar sensitivity to fenoxaprop-ethyl, the objectives of this research were to evaluate Kentucky bluegrass and creeping bentgrass cultivar phytotoxicity to single fenoxaprop-ethyl applications.

MATERIALS AND METHODS

Kentucky bluegrass studies. Two field studies were conducted during June 1986, and July 1987 at the Hancock Turfgrass Research Center, East Lansing, MI. The Kentucky bluegrass cultivar trial was established in the summer of 1981. The soil type was an Owosso-Marlette sandy loam complex (Fine-loamy, mixed, mesic, Typic Hapludalfs). Soil tests indicated a pH of 7.2 and 7.1 in 1986 and 1987 respectively. Kentucky bluegrass plot dimensions were 1 by 2 meters. On 30 May 1986, MCPP (2-[(4-chloro-o-tolyl)oxy]propionic acid) was applied at a rate of 1.4 kg ha^{-1} to control broadleaf weeds. On 13 July 1987, triclopyr ([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid) + 2,4-D ((2,4-dichlorophenoxy)acetic acid) was applied at a rate of 0.42 + 0.84 kg ha^{-1}. Fertilizer was applied at rates of 220 and 137 kg N ha^{-1} yr^{-1} in 1986 and 1987 respectively. The area was maintained at a 4.4 cm height, and supplemental irrigation was applied as needed to maintain a quality turf.

The experimental design for both species was a split block design with three replications. Each main plot was subdivided into three smaller plots to receive herbicide treatments. Bluegrass plots were treated on 11 June 1986 and 1 July 1987 with fenoxaprop-ethyl at rates of 0.0, 0.14, and 0.28 kg ha^{-1}. Bentgrass plots were treated with fenoxaprop-ethyl at rates of 0.00, 0.09, 0.14, and 0.20 kg ha^{-1} on 1 July 1987, and 0.00, 0.04, 0.07, and 0.09 kg ha^{-1}

on 21 August 1987. Treatments were applied with a CO_2 pressurized sprayer utilizing a four nozzle boom equipped with one 8002 flat fan tip and three plugs. The spray volume was 475 L ha^{-1} at a pressure of 0.21 MPa. Turfgrass injury was rated visually on a scale of 9 to 1, with 9 representing no injury and 1 representing complete turfgrass kill. Ratings below 6.0 were considered unacceptable. Observations were recorded on 18 June, 25 June, 2 July, and 9 July 1986 and also on 8 July, 15 July, 22 July and 29 July 1987. Analysis of variance was performed for each experiment and treatment means were separated using the least significant difference (LSD) method.

Creeping bentgrass studies. Two field studies were conducted on 1 July and 21 August, 1987 at the Hancock Turfgrass Research Center, East Lansing, MI. The test site consisted of a bentgrass cultivar trial containing 'Penncross', 'Penneagle', 'Toronto', 'Seaside', 'Emerald', 'Prominent', 'Carmen', 'B853WWK', 'V851WWK', 'V852WWK', 'V858WWK', 'C-18', 'C-28', 'C-38' creeping bentgrass and 'Kingstown' velvet bentgrass. The cultivar trial was established during the summer of 1981 on a modified loamy sand containing 83% sand, 11% silt, and 6% clay. Bentgrass plot dimensions were 2 by 3 meters. Soil tests indicated a pH of 7.3, and fertilizer was applied at 171 kg N ha^{-1} Yr^{-1}. Supplemental irrigation, fungicides, and insecticides were applied as needed to maintain healthy turf. To control broadleaf weeds, 2,4-D ester (0.56 kg ha^{-1}) and MCPP (1.1 kg

ha^{-1}) were applied on 26 May 1987, and a package mix of 2,4-D + MCPP + dicamba (0.4 + 0.2 + 0.04 kg ha^{-1}) was applied on 13 July and 31 August, 1987. The area was managed as a golf green and mowed at 4.8 mm. The cultivar trial received very little traffic throughout 1987.

Visual phytotoxicity ratings were taken at weekly intervals, using a 9 to 1 scale as previously described. Analysis of variance was performed for both studies and treatment means were separated using the least significant difference (LSD) method.

RESULTS AND DISCUSSION

Kentucky bluegrass studies. Untreated plots of 'Fylking', 'Welcome', 'Merion', 'Kenblue', and 'Barblue' received a rating of 8.7 two weeks after treatment in 1986 (Table 2). Untreated 'Enoble' and 'Vantage' plots received 8.3 for this same date, and 8.7 three weeks after treatment for 'Vantage'. In 1987, untreated plots of 'Nugget', 'Harmony', and 'Welcome' received an 8.7 rating three weeks after treatment, while 'Adelphi' received 8.7 for one, two and three weeks after treatment. All other untreated plots received a rating of 9.0 for the dates evaluated.

In 1986, fenoxaprop-ethyl at 0.14 kg ha^{-1} did not significantly injure 'Enmundi', 'Sydsport', 'Cheri', 'Fylking', 'Birka', 'Vanessa', 'A-34', 'Geromino', 'Nugget', 'Harmony', 'Welcome', 'Victa', 'Wabash', 'Eclipse', 'Baron', 'Plush', 'Mosa', and 'Bristol' when compared to controls for all evaluation dates.

'Plush', 'Bristol', 'Trenton', 'Bonnieblue', 'Shasta', 'Mystic', 'Columbia', 'Monopoly', 'Majestic', 'Glade', 'Kenblue', 'Ram-1', 'Barblue', 'Touchdown', and 'America' plots treated with 0.28 kg ha^{-1} of fenoxaprop-ethyl received ratings below 7.0 at two weeks after treatment. At three weeks after treatment, all cultivars except 'Columbia', 'Monopoly', 'Glade', 'Kenblue', 'Barblue', 'Touchdown', and 'America' received ratings higher than 8.0. By four weeks after treatment, all cultivars received a rating of 9.0

except 'Mystic' and 'Monopoly' treated with 0.28 kg ha^{-1} and 'Ram-1' at both rates of fenoxaprop-ethyl. 'Ram-1' was the only cultivar that did not show an increase in injury as rates were increased from 0.14 to 0.28 kg ha^{-1}.

In July of 1987, phytotoxicity did not develop as quickly as in June 1986 but remained approximately one week longer in most cultivars. In 1987, analysis of variance at one week after treatment demonstrated no differences between Kentucky bluegrass cultivars receiving the same rate. Only 'Fylking', 'Geronimo', 'Parade', 'Majestic', 'Kenblue', 'Barblue', 'Touchdown', and 'America' had significantly lower ratings than the control plots when treated with 0.14 kg ha^{-1} of fenoxaprop-ethyl during the four week evaluation period. Injury of 'Vanessa', 'Nugget', 'Eclipse', 'Plush', 'Bristol', 'Merion', 'Enoble', 'Rugby', 'Vantage', 'Shasta', 'Majestic', 'Glade', 'Ram-1', 'Touchdown', and 'America' was increased dramatically at one week after treatment when the fenoxaprop-ethyl rate was raised to 0.28 kg ha^{-1}. At two weeks after treatment, all cultivars treated with 0.28 kg ha^{-1} received a rating of 7.0 or greater except 'Touchdown' (6.7) and 'America' (6.0). When comparing the two and three week after treatment ratings at 0.28 kg ha^{-1}, most cultivars either maintained or recovered from the injury caused by fenoxaprop-ethyl. 'Cello', 'Fylking', 'Victa', 'Wabash', 'Glade', and 'Touchdown' became slightly more injured at three weeks after treatment. At four weeks after treatment, there were no differences between the fenoxaprop-ethyl rates within individual cultivars.

In both years, the most phytotoxicity from 0.14 kg ha^{-1} was evident at two weeks after treatment, with all injury judged to be acceptable. In 1986 cultivars treated with 0.28 kg ha^{-1} fenoxaprop-ethyl in June showed the most severe injury at two weeks after treatment. The July 1987 treatments of the same rate produced injury which extended into the third week after treatment. This could be due to slower turfgrass growth under the higher daily temperatures witnessed in mid to late July of 1987 (Table A1). In the 1986 experiment at 2 weeks after treatment, the newest, exposed leaf of injured Kentucky bluegrass plants became tan colored while still clinging to the next developing leaf. Dernoeden and Fry (10) observed similar results with Kentucky bluegrass. Once these dead leaf blades were mowed, overall appearance of the turfgrass improved dramatically. In 1987, this type of injury symptom was not observed.

<u>Creeping bentgrass studies</u>. On 1 July, prior to fenoxaprop-ethyl treatments, all plots received a rating of 8.7 or higher (Table 3). The 0.20 kg ha^{-1} rate produced significant injury to all bentgrass cultivars when compared to the untreated plots for the 1, 2, and 3 week after treatment evaluations. At 1 week after treatment, injury on 'Penncross', 'Prominent', 'Carmen', 'B853WWK', 'C-18', and 'C-38' was considered acceptable, while 'Penneagle', 'Toronto', 'Seaside', 'Emerald', 'Kingstown', 'V851WWK',

'V852WWK', 'V858WWK', and 'C-28' received ratings below 6.0. 'Toronto' was significantly more sensitive to the 0.20 kg ha^{-1} rate than other cultivars at 1 week after treatment. This could be due to stripe smut (*Ustilago striiformis* (West.) Niessl) found only within the 'Toronto' plots. At 2 weeks after treatment, all cultivars were judged unacceptable except 'Kingstown' and B853WWK'. In Maryland, researchers (11) reported similar unacceptable injury to tee height 'Penncross' creeping bentgrass with fenoxaprop-ethyl (0.17 and 0.28 kg ha^{-1}). The highest level of injury was apparent during the second week after application for all cultivars except for 'Penneagle' and 'Kingstown'. 'Toronto' plots were severely damaged by this high rate at two weeks after treatment. At three weeks after treatment, most cultivars began recovering except for the vegetatively propagated cultivars 'C-18', 'C-28', and 'C-38' which received ratings of 2.7, 3.0, and 4.3, respectively. Injury of 'Penncross', 'Penneagle', 'Prominent', 'Kingstown', 'Carmen', 'B853WWK', 'V851WWK', and 'V852WWK' was considered acceptable. At four weeks after treatment, 'Penncross', 'Penneagle', 'Seaside', 'Prominent', 'Carmen', 'B853WWK', and 'V852WWK' were not significantly different from the untreated bentgrass plots. 'Toronto', 'Emerald', 'Kingstown', 'V858WWK', 'C-18', 'C-28', and 'C-38' received statistically lower ratings than untreated plots. 'Toronto', 'C-18', and 'C-28' were the only cultivars to exhibit unacceptable injury into the fourth week after treatment with the 0.20 kg ha^{-1} rate. Turfgrass density of 'Toronto' was severely thinned.

At 1 week after treatment, the 0.14 kg ha^{-1} rate of fenoxaprop-ethyl produced injury rated at or below 7.0 for all cultivars, with phytotoxicity considered acceptable for all cultivars except 'Toronto'. At 2 weeks after application, 'Kingstown' showed slight recovery, while injury remained unchanged for 'Penncross', 'Penneagle', 'Seaside', 'Carmen', 'V851WWK', 'V852WWK' and 'C-28'. Objectionable injury was apparent on 'Toronto', 'V858WWK', 'C-18', and 'C-38'. At 3 weeks after treatment, phytotoxicity of most cultivars improved to acceptable levels except for 'Toronto', 'C-18', and 'C-38'. Even though injury was acceptable, all cultivars exhibited significantly lower ratings than the untreated plots at three weeks after treatment. At 4 weeks, 'Toronto', 'Emerald', 'C-28', and 'C-38' remained slightly injured, but 'C-18' was the only cultivar to receive unacceptable ratings at four weeks after the 0.14 kg ha^{-1} treatment. All other bentgrasses recovered within four weeks when compared to the untreated plots.

Injury from the 1 July 0.09 kg ha^{-1} fenoxaprop-ethyl treatment was considered acceptable for all cultivars except 'Toronto' and 'C-18' from 1 to 4 weeks after application. Most cultivars received ratings from 7.0 to 7.7 for 1, 2, and 3 weeks after treatment. The greatest level of phytotoxicity generally occured during the first week after treatment and remained throughout the second week. Turfgrass recovery was apparent for most cultivars by the third week following treatment. By 4 weeks after fenoxaprop-ethyl application, 'Penncross', 'Penneagle', 'Seaside', 'Prominent', 'Kingstown', 'Carmen', 'B853WWK', 'V851WWK', 'V852WWK', 'V858WWK', and 'C-38' recovered, while 'Toronto', 'Emerald', 'C-18', and 'C-28' received significantly lower but acceptable ratings when compared to untreated plots.

In the August experiment, plots received ratings ranging from 7.7 to 9.0 prior to herbicide treatment. The 0.09 kg ha^{-1} fenoxaprop-ethyl rate produced greater levels of injury to all cultivars when compared to the same rate applied in July. These lower ratings in the second experiment were most likely caused by the bentgrass plots receiving two treatments within the same season. 'Penncross', 'B853WWK', and 'C-38' were the only cultivars that were judged to have an acceptable tolerance to this rate at 2 weeks after treatment. All other cultivars received ratings of 5.7 to 4.3. 'Toronto' and 'C-18' were the most sensitive cultivars to the 0.09 kg ha^{-1} rate in both July and August studies at the two week evaluation. At four weeks after treatment, analysis of variance demonstrated no differences between 'Penncross', 'Penneagle', 'Toronto', 'Seaside', 'Prominent', 'Kingstown', 'Carmen', 'B853WWK', 'V851WWK', and V852WWK' and their respective control plots. By five weeks after treatment, Phytotoxicity ratings of 'Emerald', 'V858WWK', 'C-18', and 'C-28' were significantly lower than the control plots, but were at or above 7.3.

The 0.07 kg ha^{-1} rate of fenoxaprop-ethyl produced unacceptable injury to 'Toronto', 'Emerald', 'Carmen', 'V851WWK', 'V858WWK', and 'C-18' creeping bentgrass at 2 weeks after treatment. All bentgrass cultivars were significantly injured when compared to untreated plot ratings except for 'B853WWK'. At 4 weeks after application 'Emerald', 'V858WWK', 'C-18', 'C-28', 'C-38' were still exhibiting lower injury ratings than control plots. At the 5 week evaluation, 'Penncross', 'Penneagle', 'Toronto', 'Seaside', 'Kingstown', 'Carmen', 'B853WWK', 'V851WWK', and 'V852WWK' had recovered. Dernoeden (8) observed similar results on 'Penncross' creeping bentgrass, with unacceptable injury lasting four weeks at rates above 0.06 kg ha^{-1}.

The 0.04 kg ha^{-1} rate produced acceptable injury to all cultivars, with evaluations ranging from 8.7 to 6.0 at 2 weeks after treatment. This agreed with Dernoeden's observations with mid June treatments of the same fenoxaprop-ethyl rate on 'Penncross' (8). 'B853WWK' was completely unaffected, while 'Toronto' was the most sensitive to this rate. All treated plots were not different from the untreated plots at 4 weeks after treatment.

Overall, 'Penncross', 'Penneagle', 'Carmen', and 'B853WWK' were judged the most tolerant, while 'Toronto' creeping bentgrass was extremely sensitive to fenoxaprop-ethyl which may have been due to infection with stripe smut. Most cultivars recovered to acceptable injury levels at 4 weeks after treatment in both experiments regardless of fenoxaprop-ethyl rate. Future studies are needed to evaluate split applications of low fenoxaprop-ethyl rates on creeping bentgrass golf greens that receive daily traffic.

TABLE 2: INJURY RATINGS FOR KENTUCKY BLUEGRASS CULTIVAR STUDY TREATED WITH FENOXAPROP-ETHYL DURING 1986 AND 1987. HANCOCK TURFGRASS RESEARCH CENTER, E. LANSING MI.

		1986 RATINGS[v]				1987 RATINGS			
CULTIVAR[w]	RATE (kg/ha)	1WAT[x]	2WAT	3WAT	4WAT	1WAT	2WAT	3WAT	4WAT
1. Enmundi	0.14	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
2. Cello	0.14	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.7	8.7	9.0	9.0	8.7	8.7	8.3	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
3. Sydsport	0.14	8.7	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.3	8.3	9.0	9.0	9.0	8.7	9.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
4. Cheri	0.14	9.0	9.0	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	8.3	7.7	9.0	9.0	8.7	8.7	9.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
5. Fylking	0.14	9.0	9.0	9.0	9.0	8.3	8.7	8.7	9.0
	0.28	9.0	8.3	9.0	9.0	8.7	8.7	8.3	9.0
	0.00	9.0	8.7	9.0	9.0	9.0	9.0	9.0	9.0
6. Birka	0.14	9.0	8.7	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	7.7	7.0	9.0	9.0	9.0	8.7	8.7	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
7. Vanessa	0.14	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.7	7.7	9.0	9.0	8.3	8.0	8.3	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
8. A-34	0.14	8.7	8.7	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.3	7.7	8.7	9.0	9.0	8.3	8.3	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
9. Geronimo	0.14	8.7	9.0	9.0	9.0	8.3	9.0	8.7	9.0
	0.28	8.0	8.3	8.7	9.0	8.3	8.3	9.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
10. Nugget	0.14	8.7	9.0	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	8.3	7.7	9.0	9.0	8.3	8.0	8.7	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	8.7	9.0
11. Harmony	0.14	9.0	8.7	9.0	9.0	8.7	8.7	9.0	9.0
	0.28	8.3	7.7	8.3	9.0	8.7	8.3	8.7	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	8.7	9.0
12. Welcome	0.14	8.7	9.0	9.0	9.0	9.0	9.0	8.7	9.0
	0.28	7.7	7.3	8.7	9.0	8.7	8.0	9.0	9.0
	0.00	9.0	8.7	9.0	9.0	9.0	9.0	8.7	9.0

TABLE 2 CONT:

CULTIVAR[w]	RATE (kg/ha)	1986 RATINGS[v] 1WAT[x]	2WAT	3WAT	4WAT	1987 RATINGS 1WAT	2WAT	3WAT	4WAT
13. Victa	0.14	8.7	8.7	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.0	7.7	9.0	9.0	8.7	8.7	8.0	8.3
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
14. Bono	0.14	8.7	8.3	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	8.0	7.3	8.7	9.0	8.7	8.7	8.7	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
15. Wabash	0.14	8.7	8.7	9.0	9.0	8.7	8.7	9.0	9.0
	0.28	8.0	7.7	8.3	9.0	9.0	8.3	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
16. Eclipse	0.14	8.7	9.0	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	8.0	7.3	8.7	9.0	8.3	7.7	8.7	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
17. Baron	0.14	8.7	9.0	9.0	9.0	8.7	9.0	9.0	9.0
	0.28	7.7	7.3	9.0	9.0	8.3	8.3	8.3	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
18. Plush	0.14	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.7	6.7	8.3	9.0	8.3	8.0	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
19. Mosa	0.14	8.7	8.7	9.0	9.0	9.0	9.0	8.7	9.0
	0.28	8.0	7.3	8.3	9.0	8.7	8.0	8.3	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
20. Bayside	0.14	8.3	8.7	9.0	9.0	9.0	9.0	8.7	9.0
	0.28	7.3	7.3	8.3	9.0	8.7	8.7	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
21. Merit	0.14	8.3	8.7	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	7.7	7.3	9.0	9.0	9.0	8.0	8.0	8.3
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
22. Holiday	0.14	8.7	8.0	9.0	9.0	9.0	8.7	8.7	9.0
	0.28	7.7	7.0	8.7	9.0	8.7	8.3	8.3	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
23. Bristol	0.14	8.7	8.7	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	8.0	6.7	8.7	9.0	8.3	8.0	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
24. Merion	0.14	8.7	8.3	9.0	9.0	9.0	8.7	8.7	9.0
	0.28	8.3	7.3	9.0	9.0	8.0	8.0	8.3	8.7
	0.00	9.0	8.7	9.0	9.0	9.0	9.0	9.0	9.0

TABLE 2 CONT.

CULTIVAR[w]	RATE (kg/ha)	1986 RATINGS[v] 1WAT[x]	2WAT	3WAT	4WAT	1987 RATINGS 1WAT	2WAT	3WAT	4WAT
25. Trenton	0.14	8.7	8.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	8.0	6.7	8.3	9.0	8.7	8.0	8.0	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
26. Enoble	0.14	8.0	8.3	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	8.0	7.3	8.7	9.0	8.3	8.0	8.3	9.0
	0.00	9.0	8.3	9.0	9.0	9.0	9.0	9.0	9.0
27. Adelphi	0.14	8.3	8.7	9.0	9.0	8.7	8.7	8.7	9.0
	0.28	8.0	7.3	8.3	9.0	8.3	8.3	8.3	9.0
	0.00	9.0	9.0	9.0	9.0	8.7	8.7	8.7	9.0
28. Parade	0.14	8.0	8.3	9.0	9.0	9.0	8.3	9.0	9.0
	0.28	7.3	7.0	8.3	9.0	9.0	7.7	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
29. Rugby	0.14	8.0	8.0	9.0	9.0	9.0	9.0	9.0	9.0
	0.28	7.7	7.0	8.3	9.0	8.3	7.7	8.0	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
30. Vantage	0.14	8.3	7.7	8.7	9.0	9.0	9.0	9.0	9.0
	0.28	7.7	7.0	8.3	9.0	8.3	8.0	8.0	8.7
	0.00	9.0	8.3	8.7	9.0	9.0	9.0	9.0	9.0
31. Bonnieblue	0.14	8.0	8.0	9.0	9.0	9.0	8.7	9.0	9.0
	0.28	6.3	6.3	8.3	9.0	8.7	8.0	8.3	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
32. Shasta	0.14	8.3	8.0	8.7	9.0	9.0	8.7	9.0	9.0
	0.28	7.3	6.3	8.0	9.0	8.0	7.7	7.7	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
33. Mystic	0.14	8.0	8.3	8.7	9.0	9.0	9.0	9.0	9.0
	0.28	6.7	6.0	8.0	8.3	8.7	8.0	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
34. Columbia	0.14	8.7	8.0	8.7	9.0	8.7	8.7	8.7	9.0
	0.28	7.0	6.3	7.7	9.0	8.7	7.3	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
35. Monopoly	0.14	8.3	8.0	8.7	9.0	8.7	8.7	9.0	9.0
	0.28	7.3	6.7	7.3	8.3	8.7	8.0	8.0	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
36. Majestic	0.14	8.0	7.7	8.7	9.0	8.7	8.3	8.7	9.0
	0.28	7.3	6.3	8.7	9.0	8.0	8.0	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

TABLE 2 CONT:

CULTIVAR[w]	RATE (kg/ha)	1986 RATINGS[v] 1WAT[x]	2WAT	3WAT	4WAT	1987 RATINGS 1WAT	2WAT	3WAT	4WAT
37. Glade	0.14	8.7	8.0	9.0	9.0	8.7	9.0	8.7	9.0
	0.28	8.0	6.0	7.7	9.0	8.0	8.0	7.3	8.3
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
38. Kenblue	0.14	8.3	7.7	9.0	9.0	8.7	8.3	9.0	9.0
	0.28	7.0	6.3	7.7	9.0	8.3	8.0	8.0	8.7
	0.00	9.0	8.7	9.0	9.0	9.0	9.0	9.0	9.0
39. Ram-1	0.14	8.0	7.3	8.0	8.3	9.0	8.7	8.7	9.0
	0.28	8.0	6.7	8.0	8.3	8.3	7.3	7.7	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
40. Barblue	0.14	8.3	7.3	8.7	9.0	8.7	8.0	8.0	8.7
	0.28	7.7	6.3	7.7	9.0	8.3	7.0	7.0	8.3
	0.00	9.0	8.7	9.0	9.0	9.0	9.0	9.0	9.0
41. Touchdown	0.14	8.3	7.7	8.7	9.0	8.7	7.7	8.3	9.0
	0.28	7.7	6.3	7.0	9.0	8.0	6.7	6.3	8.3
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
42. America	0.14	7.0	7.3	8.7	9.0	8.3	7.7	8.3	8.7
	0.28	6.3	5.3	7.7	9.0	7.7	6.0	7.7	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	[y]LSD(0.05)=	0.7	0.8	0.6	0.2	N.S.	0.6	0.6	0.3
	[z]LSD(0.05)=	0.6	0.7	0.6	N.S.	0.6	0.6	0.6	N.S

[v]Herbicide treatments applied on 11 June 1986 and 1 July 1987.
[w]Rated visually on a scale of 9 to 1; 9=No Injury, 1=Dead. Above 6.0=Acceptable
[x]WAT = Weeks After fenoxaprop-ethyl Treatment.
[y]LSD comparing two Kentucky bluegrass cultivars at one fenoxaprop-ethyl rate.
[z]LSD comparing two fenoxaprop-ethyl rates within one Kentucky bluegrass cultivar.

TABLE 3: INJURY EVALUATIONS OF FENOXAPROP-ETHYL APPLIED TO A CREEPING BENTGRASS CULTIVAR TRIAL. HANCOCK TURFGRASS RESEARCH CENTER, E. LANSING, MI. (TREATMENT DATES= 7-1-87, 8-21-87)

CULTIVAR	RATE[x] (KG/HA)	PHYTOTOX[w] (7-1-87) 0WAT[u]	1WAT	2WAT	3WAT	4WAT	RATE (KG/HA)	PHYTOTOX (8-21-87) 0WAT	2WAT	4WAT	5WAT
1. PENNCROSS	0.09	9.0	7.3	7.3	7.7	9.0	0.04	9.0	7.7	8.7	9.0
	0.14	9.0	6.3	6.3	7.0	9.0	0.07	9.0	7.0	8.7	8.7
	0.20	9.0	6.0	5.7	6.7	9.0	0.09	9.0	6.3	8.3	8.7
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	9.0	9.0	9.0	9.0
2. PENNEAGLE	0.09	9.0	7.0	7.0	8.0	9.0	0.04	9.0	7.7	9.0	9.0
	0.14	9.0	6.0	6.0	8.0	9.0	0.07	9.0	6.7	8.3	8.7
	0.20	9.0	5.7	5.7	6.7	8.7	0.09	9.0	5.7	8.0	8.3
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	9.0	8.7	9.0	9.0
3. TORONTO	0.09	9.0	5.7	5.7	5.7	7.3	0.04	7.7	6.0	8.0	9.0
	0.14	9.0	5.3	4.7	5.3	7.0	0.07	7.7	4.3	7.3	8.0
	0.20	9.0	4.3	3.0	4.7	5.7	0.09	7.7	4.0	6.7	8.0
	0.00	9.0	8.7	8.3	7.7	8.3	0.00	7.7	8.0	7.7	8.7
4. SEASIDE	0.09	9.0	7.0	7.3	7.3	8.0	0.04	7.7	7.3	7.3	8.3
	0.14	9.0	6.0	6.0	6.7	8.0	0.07	7.7	6.0	7.0	8.0
	0.20	9.0	5.7	5.0	5.7	8.0	0.09	7.7	5.7	6.7	8.0
	0.00	9.0	9.0	9.0	8.0	8.0	0.00	7.7	8.3	7.7	8.7
5. EMERALD	0.09	9.0	7.0	7.0	7.3	8.0	0.04	8.7	7.7	8.7	9.0
	0.14	9.0	6.7	6.3	6.7	8.0	0.07	8.7	5.7	6.7	8.0
	0.20	9.0	5.7	4.3	5.0	7.3	0.09	8.7	5.3	6.3	7.3
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	8.7	8.7	9.0	9.0
6. PROMINENT	0.09	9.0	7.3	7.0	7.7	8.7	0.04	8.3	8.0	8.7	9.0
	0.14	8.7	6.7	6.3	6.7	8.7	0.07	8.3	6.0	7.7	8.0
	0.20	9.0	6.0	5.3	6.0	8.3	0.09	8.0	5.3	7.7	8.7
	0.00	9.0	9.0	9.0	8.7	9.0	0.00	8.3	8.7	8.7	9.0
7. KINGSTOWN [v]	0.09	9.0	7.0	7.3	7.7	8.3	0.04	8.3	7.7	8.7	9.0
	0.14	8.7	6.3	6.7	7.0	8.7	0.07	8.3	6.7	8.3	9.0
	0.20	9.0	5.3	6.0	6.0	8.0	0.09	8.3	5.7	8.0	8.3
	0.00	8.7	8.7	8.7	8.3	9.0	0.00	8.3	8.3	8.7	9.0
8. CARMEN	0.09	9.0	7.3	7.3	7.7	9.0	0.04	8.3	7.0	8.3	9.0
	0.14	9.0	6.3	6.3	7.0	9.0	0.07	8.3	5.7	8.0	8.7
	0.20	9.0	6.0	5.7	7.0	9.0	0.09	8.3	5.3	8.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	8.3	8.3	9.0	8.7
9. B853WWK	0.09	9.0	7.7	7.7	8.3	9.0	0.04	9.0	8.7	9.0	9.0
	0.14	9.0	7.0	6.7	7.7	9.0	0.07	9.0	7.7	8.7	9.0
	0.20	9.0	6.3	6.0	7.3	9.0	0.09	9.0	7.0	9.0	9.0
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	9.0	8.7	9.0	9.0
10. V851WWK	0.09	8.7	7.0	7.0	7.0	8.0	0.04	8.3	7.3	8.3	8.7
	0.14	9.0	6.3	6.3	6.7	8.0	0.07	8.3	5.7	8.3	8.0
	0.20	9.0	5.7	5.3	6.7	8.0	0.09	8.3	4.3	8.0	8.3
	0.00	9.0	8.7	8.7	8.7	8.7	0.00	8.3	8.3	8.7	8.3

TABLE 3 CONTINUED:	RATE[x] (KG/HA)	PHYTOTOX[w] (7-1-87) 0WAT[u]	1WAT	2WAT	3WAT	4WAT	RATE (KG/HA)	PHYTOTOX (8-21-87) 0WAT	2WAT	4WAT	5WAT
11. V852WWK	0.09	9.0	7.7	7.3	7.3	9.0	0.04	8.3	8.0	8.7	8.7
	0.14	9.0	6.7	6.7	7.7	8.7	0.07	8.3	6.7	8.3	8.7
	0.20	9.0	5.7	5.3	6.3	8.3	0.09	8.7	5.7	8.3	8.3
	0.00	9.0	9.0	9.0	8.7	9.0	0.00	8.3	8.3	8.7	8.7
12. V858WWK	0.09	9.0	7.0	6.7	7.7	9.0	0.04	8.7	7.7	8.3	9.0
	0.14	9.0	6.0	5.3	6.3	8.3	0.07	8.7	5.7	6.3	7.3
	0.20	9.0	5.7	4.7	5.7	8.0	0.09	8.7	5.7	7.0	7.3
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	8.7	9.0	8.7	9.0
13. C-18	0.09	8.7	7.3	5.3	5.0	7.3	0.04	7.7	7.0	8.3	8.7
	0.14	9.0	6.0	5.3	3.3	5.3	0.07	7.7	4.3	6.0	7.0
	0.20	9.0	6.7	4.0	2.7	5.0	0.09	7.7	4.3	6.7	7.7
	0.00	9.0	9.0	9.0	8.7	9.0	0.00	7.7	8.7	8.7	8.7
14. C-28	0.09	8.7	6.7	7.0	6.7	7.7	0.04	8.0	7.7	8.3	8.7
	0.14	9.0	7.0	6.0	6.0	7.3	0.07	8.0	6.3	7.0	8.0
	0.20	8.7	5.7	4.7	3.0	5.3	0.09	8.0	5.3	6.0	7.3
	0.00	8.7	8.3	8.7	8.3	8.7	0.00	8.0	8.7	9.0	9.0
15. C-38	0.09	9.0	8.0	6.7	7.0	8.3	0.04	9.0	8.3	8.3	8.7
	0.14	9.0	6.3	5.0	5.3	7.7	0.07	9.0	7.0	6.3	7.3
	0.20	9.0	7.0	5.0	4.3	7.3	0.09	8.3	7.0	6.7	8.3
	0.00	9.0	9.0	9.0	9.0	9.0	0.00	9.0	9.0	9.0	9.0
	[y]LSD (0.05)=	NS	0.9	0.8	1.1	0.8		0.8	1.1	1.0	0.9
	[z]LSD (0.05)=	NS	0.9	0.9	1.0	0.7		NS	1.1	1.0	0.8

[x] Fenoxaprop-ethyl rate.
[w] Phytotoxicity rating scale= 9 TO 1, 9=Healthy green turfgrass, 1=Dead turf.
[u] WAT= Weeks After Treatment.
[v] Velvet bentgrass cultivar.
[y] LSD comparing two creeping bentgrass cultivars at one fenoxaprop-ethyl rate.
[z] LSD comparing two fenoxaprop-ethyl rates within one creeping bentgrass cultivar.

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CHAPTER 4

EFFICACY AND ANTAGONISM OF FENOXAPROP-ETHYL AND TRIDIPHANE ALONE AND IN COMBINATION WITH BROADLEAF HERBICIDES

ABSTRACT

Field studies were conducted in 1986 and 1987 to evaluate combinations of fenoxaprop-ethyl (0.20 and 0.40 kg ha^{-1}) and tridiphane (1.1 and 2.2 kg ha^{-1}) with broadleaf herbicides to determine if antagonism or synergism was evident. Crabgrass growth stages tested ranged from one to ten tillers. Broadleaf herbicides tested were 2,4-D amine, 2,4-D ester, bromoxynil, dicamba, mecoprop, fluroxypyr, DPX-L5300, chlorflurenol, triclopyr, clopyralid, and a package mixture of 2,4-D amine, mecoprop, and dicamba. Tridiphane (2.2 kg ha^{-1}) provided 88% control of five tiller crabgrass in 1986, and 80% control of one tiller plants in 1987. All broadleaf herbicides tested were not antagonistic with tridiphane. Fenoxaprop-ethyl produced greater than 90% control of one to five tiller plants during both years tested. Combinations of fenoxaprop-ethyl with 2,4-D amine, 2,4-D ester, clopyralid, bromoxynil, and the package mixture 2,4-D amine, mecoprop, and dicamba produced antagonism. Fenoxaprop-ethyl combined with fluroxypyr (0.40 + 0.56 kg ha^{-1}) provided 100% control of five to ten tiller crabgrass,

indicating synergism.

INTRODUCTION

When two or more herbicides are combined in a tank mix, synergistic or antagonistic interactions can occur. Anderson (1) stated that a mixture is said to be antagonistic when the expected response induced by the herbicide combination is less than the expected sum total of the responses induced by each herbicide applied alone. Synergism occurs when the expected response induced by the herbicide combination is greater than the expected sum total of the responses induced by each herbicide applied alone (1).

In row crop situations, researchers have reported antagonism with various herbicide tank mixtures or sequential applications. Godley and Kitchen (4) reported that acifluorfen (5-[2-chloro-4-trifluoromethyl)phenoxy]-2-nitrobenzoic acid) at 0.4 kg ha^{-1} applied in combination with, or one to three days prior to a fluazifop (($\pm$)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid) treatment at 0.4 kg ha^{-1} greatly reduced crabgrass control when compared to fluazifop alone. They also noted that the antagonism was not apparent when acifluorfen was applied at 1, 3, or 5 days after the fluazifop treatment, while the degree of antagonism with the tank mixture of fluazifop and acifluorfen was dependent upon climatic conditions. Whitwell et. al (15) reported acifluorfen to be highly antagonistic to the postemergence johnsongrass herbicides sethoxydim and difenopenten (4-[4-[4-(trifluoromethyl)phenoxy]phenoxy]-2-pentenoic acid). Similiarly, Rhodes and Coble (11) found bentazon (3-isopropyl-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one2,2-dioxide) to dramatically suppress the absorption of sethoxydim within goosegrass when applied in a mixture.

Researchers have reported antagonistic properties between diclofop-methyl (methyl 2-[4(2',4'-dichlorophenoxy)phenoxy]propanoate) and 2,4-D, where the injury symptoms from diclofop-methyl were nullified on wild oat (*Avena fatua* L.) (2,5). Todd and Stobbe (13) also reported 2,4-D to be antagonistic to diclofop-methyl in controlling wild oat in a greenhouse situation. They determined that the antagonism caused by 2,4-D reduced the movement of the free acid diclofop to meristematic areas (13). Shimabukuro et. al (12) reported that reciprocal antagonism in corn (*Zea mays* L.)and soybeans (*Glycine max* L.) existed between diclofop-methyl and 2,4-D and was dependent upon the concentration of the other herbicide. In Alberta, Canada, 2,4-D has been shown to be antagonistic to diclofop and also flamprop (N-benzoyl-n-(3-chloro-4-fluorophenyl)-DL-alanine) for wild oat control (8,9). Another phenoxy herbicide, MCPA, when tank mixed with diclofop, has been shown to inhibit herbicidal transport within wild oat (10). Qureshi and VandenBorn attributed this problem to a formulation incompatability when both are combined (10).

Antagonism has also been reported with annual grass and broadleaf weed herbicides used in turfgrass situations. Johnson (6) reported a reduction in preemergence crabgrass control when combining bensulide (11 kg ha^{-1}) with 2,4-D, mecoprop, and dicamba (1.1 + 0.6 + 0.11 kg ha^{-1}) as compared to bensulide alone. Freeborg and Daniel (3) reported a reduction in postemergence crabgrass control with fenoxaprop-ethyl (0.28 kg ha^{-1}) tank mixed with 2,4-D plus mecoprop plus dicamba (0.43 + 0.22 + 0.04 kg ha^{-1}) when compared to fenoxaprop-ethyl alone. Watschke and Hamilton (14) also noted similar results and showed that by increasing the fenoxaprop-ethyl rate in the combination, crabgrass control also increased.

Due to the limited information pertaining to antagonism with postemergence graminicides and various broadleaf herbicides in turfgrass, the objectives of this research were to determine which broadleaf herbicides are antagonistic or synergistic to either fenoxaprop-ethyl or tridiphane, and also to examine various grass herbicide rates which could affect antagonism.

MATERIALS AND METHODS

Four field experiments were conducted during the summer months of 1986 and 1987 to determine if the action of fenoxaprop-ethyl was antagonized by broadleaf herbicides. Greenhouse studies on the antagonism of 2,4-D ester in combination with fenoxaprop-ethyl were conducted in 1988.

General procedures for field experiments. The experimental design consisted of a randomized complete block with three replications. Plot dimensions were 1.2 meters by 1.8 meters. All applications were applied with a CO_2 pressurized sprayer utilizing a four nozzle boom equipped with 8002 flat fan nozzles. The spray volume was 475 L ha^{-1} at a pressure of 0.21 MPa. Plots were visually evaluated for percent groundcover of crabgrass and all data was converted to percent control. Analysis of variance was performed for each experiment and treatment means were separated using the least significant difference technique.

Field study 1. On 22 July 1986, a study was performed on an unirrigated site in Okemos, MI consisting of a mature Kentucky bluegrass and perennial ryegrass (*Lolium perenne* L.) turf. The soil type was a Marlette loam (Fine-loamy, mixed, mesic, Glossoboric Hapludalfs). On 1 July 1986, the site was core-aerified with a Ryan[1] (OMC Lincoln, Lincoln, NE) Greensaire® to alleviate compaction and stimulate crabgrass germination, and fertilized at a rate of 27 kg N ha^{-1}. At the time of application, a natural infestation of smooth crabgrass was at a two to four leaf, five tiller growth stage, with an average 45% groundcover within all plots. The area was maintained at a 5.0 cm height.

Fenoxaprop-ethyl at 0.00, 0.20, and 0.40 kg ha^{-1} along with tridiphane at 0.00, 1.12 and 2.24 kg ha^{-1} were tested alone and in combination with 2,4-D amine (alkanolamine salts (of the ethanol isopropanol series) of (2,4-dichlorophenoxy)acetic acid) at 1.12 kg ha^{-1}, dicamba (3,6-dichloro-2-methoxybenzoic acid) at 0.56 kg ha^{-1}, fluroxypyr (4-Amino-3,5-dichloro-6-fluoro-2-pyridyloxyacetic acid methyl heptylester) at 0.56 kg ha^{-1}, bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) at 0.28 kg ha^{-1}, and mecoprop ((($\pm$)-2-(4-chloro-2-methylphenoxy)propanoic acid)potassium salt) at 1.12 kg ha^{-1}. Combinations of fenoxaprop-ethyl at 0.20 kg ha^{-1} with bromoxynil + 2,4-D amine (0.28 + 0.28 kg ha-1), 2,4-DP ((2-(2,4-dichlorophenoxy)propionic acid) butoxyethyl ester) at 1.12 kg ha^{-1}, 2,4-D amine (dimethylamine salt of(2,4-dichlorophenoxy) acetic acid) + mecoprop (dimethylamine salt) + dicamba (1.1 + 0.56 + 0.11 kg ha^{-1}), triclopyr ester (([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid)butoxyethyl ester) + 2,4-D ester (2,4-dichlorophenoxyacetic acid, butoxyethyl ester) (0.42 + 0.84 kg ha^{-1}), and DPX-M6316 (methyl 3-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl aminocarbonyl]aminosulfonyl]-2-thiophenecarboxylate (8 g ha^{-1}) were also included.

<u>Field study 2</u>. On 20 August 1986, the identical treatment list as previously described was performed at the

Hancock Turfgrass Research Center, in East Lansing, MI on an irrigated annual bluegrass (Poa annua var. reptans (Hauskns) Timm.) turf maintained at 1.3 cm. The area was established by seed in the summer of 1981. The soil type was a Owosso-Marlette sandy loam complex (Fine-loamy, mixed, mesic, Typic Hapludalfs). Soil tests indicated a pH of 7.5, and fertilizer was applied at a rate of 484 kg N ha^{-1} yr^{-1}. On 18 June 1986, the area was verticut in two directions utilizing a Ryan Ren-O-Thin® to a depth of 0.6 cm and overseeded with smooth crabgrass at a rate of 30 kg ha^{-1} to enhance the natural population. At time of application, smooth crabgrass ranged in size from two leaf to two tillers, with approximately 5 to 15% crabgrass groundcover throughout the area. In addition to percent groundcover ratings, visual annual bluegrass injury was recorded using a rating scale of 9 to 1, in which 9 represents no injury and 1 represents complete turfgrass kill. Ratings below 6.0 were considered unacceptable.

Field study 3: On 4 August 1987, an experiment was conducted at Clio Country Club, in Clio, MI on a mature stand of Kentucky bluegrass/perennial ryegrass turf. The soil type was a Ceresco fine sandy loam (Coarse-loamy, mixed mesic Aquic Fluventic Hapludolls). The area was maintained at 5.0 cm and irrigated daily. Fertilizer was applied at a rate of 118 kg N ha^{-1} yr^{-1}. At time of application, the smooth crabgrass growth stage approached four leaves and five to ten tillers. The average smooth crabgrass groundcover within plots was near 70 percent.

Treatments included tridiphane (0.00, 1.12, and 2.24 kg ha^{-1}) alone and in combination with 2,4-D ester (1.12 kg ha^{-1}), dicamba (0.56 kg ha^{-1}), fluroxypyr (0.56 kg ha^{-1}), bromoxynil (0.28 kg ha^{-1}), and mecoprop (1.12 kg ha^{-1}). Fenoxaprop-ethyl (0.00, 0.20, and 0.40 kg ha^{-1}) was tested alone and tank mixed with the identical broadleaf herbicides listed above plus triclopyr at 0.56 kg ha^{-1}, DPX-L5300 (Methyl 2-[[[[N-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoate) at 0.84 kg ha^{-1}, clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) at 0.28 kg ha^{-1}, and chlorflurenol (methyl 2-chloro-9-hydroxyfluorene-9-carboxylate) at 0.14 kg ha^{-1}. Fenoxaprop-ethyl (0.20 kg ha^{-1}) was also combined with bromoxynil + 2,4-D ester (1.12 + 0.28 kg ha^{-1}), triclopyr ester + 2,4-D ester (0.42 + 0.84 kg ha^{-1}), 2,4-D + dicamba + mecoprop (1.12 + 0.60 + 0.10 kg ha^{-1}), and 2,4-DP (1.12 kg ha^{-1}).

<u>Field study 4</u>: On 5 August 1987, the identical treatments as described in the third field study were applied to a six year old Kentucky bluegrass blend at the Hancock Turfgrass Research Center, in East Lansing, MI. The soil type consisted of an Owosso-Marlette sandy loam (Fine-loamy, mixed, mesic, Typic Hapludalfs). The site was irrigated and mowed regularly at 3.8 cm. Soil tests indicated a pH of 7.1, and fertilizer was applied at a rate of 122 kg N ha^{-1} yr^{-1}. On 7 July 1987, the turfgrass was

scalped to a height of 2.5 cm and verticut in four directions with a Ryan Ren-O-Thin® to a depth of 1.3 cm. The lifted thatch was removed and large crabgrass was overseeded at a rate of 40 kg ha^{-1}. The area was mowed several times per week for 2 weeks at 2.5 cm to allow light to penetrate for adequate crabgrass germination. Supplemental irrigation was applied daily for several weeks to hasten crabgrass germination. Once adequate crabgrass pressure was obtained, the cutting height was raised to 3.8 cm. At time of herbicide applications, plots averaged 10 to 12 percent crabgrass groundcover, with a three leaf to one tiller growth stage. In addition to percent groundcover ratings, visual injury ratings of the Kentucky bluegrass were recorded at 2-week intervals utilizing a 9 to 1 scale as described previously in field study 2.

RESULTS AND DISCUSSION

Field studies. Fenoxaprop-ethyl at both rates (0.20 and 0.40 kg ha^{-1}) provided greater than 90% control of one to five tiller crabgrass during 1986 and 1987. Fenoxaprop-ethyl applied alone at the above rates provided 64% and 60% control of five to ten tiller plants at four weeks after treatment in 1987. Tridiphane at 1.1 kg ha^{-1} produced 81% control of two tiller crabgrass in 1986 (Table 4). During the same season, the identical rate provided very little control (11%) of five tiller plants (Table 5). Increasing the rate of tridiphane to 2.2 kg ha^{-1} dramatically improved crabgrass control results of two tiller (98%) and five tiller plants (88%). Tridiphane applied at 1.1 kg ha^{-1} in 1987 resulted in poor control of three leaf to one tiller crabgrass. Increasing the rate to 2.2 kg ha^{-1} provided 80% control (Table 6). At Clio Country Club, both neither tridiphane rate (1.1 or 2.2 kg ha^{-1}) provided control of five to ten tiller plants (Table 7). In 1986, fluroxypyr (0.56 kg ha^{-1}) applied alone gave 89% control of two tiller crabgrass, and 58% control of five tiller plants at 4 weeks after treatment. All other broadleaf herbicides lacked postemergence crabgrass activity.

Combinations of 2,4-D amine, 2,4-D ester, dicamba, and mecoprop with tridiphane at 1.1 and 2.2 kg ha^{-1} were not considered antagonistic. In 1986, bromoxynil tank mixed with tridiphane (1.1 + 2.2 kg ha^{-1}) significantly reduced percent control of five tiller crabgrass when compared to tridiphane alone at 8 weeks after treatment. In 1987, the identical combination also reduced one tiller crabgrass control to 17% compared to 80% with tridiphane alone. At Clio Country club, tridiphane plus bromoxynil at both rates (1.1 + 1.1 and 2.2 + 1.1 kg ha^{-1}) significantly increased the percent control of five to ten tiller crabgrass when compared to tridiphane alone. Tridiphane in combination with fluroxypyr (1.1 + 0.56 kg ha^{-1}) significantly improved control of five tiller crabgrass when compared to tridiphane alone at 2, 4, and 8 weeks after treatment during 1986. The identical treatment also improved control of one tiller crabgrass in 1987.

Antagonism was not observed with tank mixes of fenoxaprop-ethyl (0.20 or 0.40 kg ha^{-1}) and chlorflurenol, dicamba, fluroxypyr, mecoprop, or triclopyr. Fenoxaprop-ethyl in combination with 2,4-D amine (0.20 + 1.1 kg ha^{-1}) produced 43% control of five tiller crabgrass (Table 5), compared to 100% control with fenoxaprop-ethyl alone. When the rate of fenoxaprop-ethyl was increased (0.40 kg ha^{-1}) in the combination, percent crabgrass control improved to 77%, but was still considered antagonistic. When fenoxaprop-ethyl and 2,4-D amine (0.20 + 1.1 kg ha^{-1}) were applied to two tiller crabgrass at the Hancock Turfgrass Research Center (HTRC), similar results were observed. The combination provided 67% control compared to 100% control from fenoxaprop-ethyl alone, indicating antagonism. When fenoxaprop-ethyl was increased to 0.40 kg ha^{-1} in the combination, the antagonism was overcome, resulting in 95% control. Even though 2,4-D amine is antagonistic to fenoxaprop-ethyl, the increased rate of fenoxaprop-ethyl was enough to control the smaller crabgrass growth stage. It is possible that 2,4-D inhibited the movement of the free acid fenoxaprop within the plant, similar to results of diclofop and 2,4-D antagonism by Todd and Stobbe (13).

In 1987, 2,4-D ester was tested in combination with fenoxaprop-ethyl. At Clio Country Club, this combination also produced antagonism, resulting in extremely poor control of five to ten tiller crabgrass at both fenoxaprop-ethyl rates (Table 7). Fenoxaprop-ethyl and 2,4-D ester (0.2 + 1.1 kg ha^{-1}) tested at the HTRC also provided poor control (40%) of one tiller crabgrass when compared to 93% control with fenoxaprop-ethyl alone. Similar to 1986 results with fenoxaprop-ethyl and 2,4-D amine, by increasing the rate of fenoxaprop-ethyl to 0.40 kg ha^{-1} with 2,4-D ester, excellent control was achieved due to the small crabgrass growth stage present.

Fenoxaprop-ethyl at 0.20 kg ha^{-1} combined with a package mixture of 2,4-D amine, mecoprop amine, and dicamba (1.1 + 0.56 + 0.11 kg ha^{-1}) also produced noticeable antagonism when applied to one tiller crabgrass. By increasing the fenoxaprop-ethyl rate to 0.40 kg ha^{-1}, 91% control was achieved. At Clio, the low rate of fenoxaprop-ethyl with 2,4-D + mecoprop + dicamba gave poor control of five to ten tiller plants. Increasing fenoxaprop-ethyl to 0.40 kg ha^{-1} in the combination improved control to 37%. Combinations of fenoxaprop-ethyl at 0.20 and 0.40 kg ha^{-1} with DPX-L5300 (0.84 kg ha^{-1}) produced significant antagonism of both one tiller and five to ten tiller crabgrass. The extremely high DPX-L5300 rate was applied by mistake, but revealed interesting results. DPX-L5300 applied alone produced significant injury to the Kentucky bluegrass (Table 6). When the higher rate of fenoxaprop-ethyl was combined with DPX-L5300, fenoxaprop-ethyl reduced the amount of turf injury caused by DPX-L5300, indicating reciprocal antagonism between these two compounds.

Fenoxaprop-ethyl combined with clopyralid (0.20 + 0.28 kg ha^{-1}) provided poor control (21%) of five to ten tiller crabgrass. Antagonism was eliminated when the rate of fenoxaprop-ethyl was increased to 0.40 kg ha^{-1}, improving crabgrass control to 71%.

In 1987, a combination of fenoxaprop-ethyl and bromoxynil (0.2 + 1.1 kg ha^{-1}) provided poor control (30%) of one tiller crabgrass, unlike 1986 results. Fenoxaprop-ethyl at both rates tank mixed with bromoxynil also reduced control of five to ten tiller plants. Bromoxynil severely damaged the crabgrass leaf blades within 24 hours. This leaf necrosis restricted absorption and translocation of fenoxaprop-ethyl into the crabgrass plant, reducing percent control. These results were not observed in 1986, warranting further research with various bromoxynil formulations and fenoxaprop-ethyl.

As a general recommendation, all formulations of 2,4-D should not be tank mixed with fenoxaprop-ethyl. Tank mixing triclopyr ester with fenoxaprop-ethyl (0.56 + 0.20 kg ha^{-1}) resulted in lower crabgrass control as compared to fenoxaprop-ethyl alone, regardless of plant stage. This combination was not considered antagonistic, yet there exists a trend toward antagonism. Therefore, a tank mixture of triclopyr ester and fenoxaprop-ethyl is not recommended. Future herbicide studies are needed to evaluate triclopyr amine and fenoxaprop-ethyl combinations.

When attempting to control one to two tiller crabgrass along with broadleaf weeds, tank mixtures of fenoxaprop-ethyl with dicamba, fluroxypyr, mecoprop, chlorflurenol, or clopyralid were considered acceptable. After crabgrass reaches a five to ten tiller growth stage, only fenoxaprop-ethyl with mecoprop, and chlorflurenol provided comparable control to fenoxaprop-ethyl applied alone. The addition of fluroxypyr (0.56 kg ha^{-1}) with fenoxaprop-ethyl (0.2 kg ha^{-1}) improved control to 80% as compared to 64% with fenoxaprop-ethyl alone. When fenoxaprop-ethyl was increased to 0.40 kg ha^{-1} in the combination, 100% crabgrass control was achieved, indicating synergism. This combination proved to be effective in eliminating crabgrass once considered too large to control. Future experiments with various rates of fenoxaprop-ethyl and fluroxypyr could provide valuable postemergence crabgrass control information for the turfgrass industry.

TABLE 4: GRASS AND BROADLEAF CONTROL WITH POSTEMERGENCE HERBICIDE COMBINATIONS APPLIED TO *POA ANNUA* L. (HANCOCK TURFGRASS RESEARCH CENTER, E. LANSING, MI. TREATMENT DATE = 8-20-86). (DIGITARIA GROWTH STAGE= 2 LEAF TO 2 TILLERS.)

TREATMENTS[v]	RATE (KG/HA)	% CONTROL CRABGRASS[w] 2WAT	4WAT	POA ANNUA PHYTOTOX[x] 2WAT	4WAT
1. FENOX + BROM + 2,4-D A	.20 + 1.1 + .28	87	93	9.0	9.0
2. FENOX + TRICLOPYR + 2,4-D E	.20 + .42 + .84	82	86	9.0	9.0
3. FENOX + 2,4-D A + MCPP + DIC	.20 + 1.1 + .56 + .11	65	50	9.0	9.0
4. FENOX + 2,4-DP	.20 + 1.1	93	100	8.7	9.0
5. FENOX + DPX-M6316	.20 + (8 g/ha)	83	97	9.0	9.0
6. FENOXAPROP-ETHYL	.20	91	100	9.0	9.0
7. FENOX + 2,4-D AMINE	.20 + 1.1	65	67	9.0	9.0
8. FENOX + DICAMBA	.20 + .56	100	100	8.7	8.7
9. FENOX + FLUROXYPYR	.20 + .56	96	100	8.0	9.0
10. FENOX + BROMOXYNIL	.20 + 1.1	96	100	9.0	9.0
11. FENOX + MCPP	.20 + 1.1	98	98	9.0	9.0
12. FENOXAPROP-ETHYL	.40	93	100	8.7	9.0
13. FENOX + 2,4-D AMINE	.40 + 1.1	91	95	8.7	9.0
14. FENOX + DICAMBA	.40 + .56	100	100	9.0	9.0
15. FENOX + FLUROXYPYR	.40 + .56	100	100	8.0	8.7
16. FENOX + BROMOXYNIL	.40 + 1.1	93	100	8.3	9.0
17. FENOX + MCPP	.40 + 1.1	98	100	8.3	9.0
18. TRIDIPHANE	1.1	21	81	7.0	7.7
19. TRID + 2,4-D AMINE	1.1 + 1.1	51	93	7.7	6.3
20. TRID + DICAMBA	1.1 + .56	38	72	7.3	7.0
21. TRID + FLUROXYPYR	1.1 + .56	46	93	6.0	5.7
22. TRID + BROMOXYNIL	1.1 + 1.1	68	91	7.7	6.7
23. TRID + MCPP	1.1 + 1.1	60	88	8.0	7.7
24. TRIDIPHANE	2.2	62	98	6.3	4.7
25. TRID + 2,4-D AMINE	2.2 + 1.1	59	93	6.7	4.7
26. TRID + DICAMBA	2.2 + .56	39	84	7.0	5.0
27. TRID + FLUROXYPYR	2.2 + .56	66	95	5.3	3.3
28. TRID + BROMOXYNIL	2.2 + 1.1	78	96	6.7	5.0
29. TRID + MCPP	2.2 + 1.1	20	84	7.7	6.7
30. 2,4-D AMINE	1.1	7	10	8.7	9.0
31. DICAMBA	.56	8	31	9.0	9.0
32. FLUROXYPYR	.56	84	89	9.0	9.0
33. BROMOXYNIL	1.1	10	20	9.0	9.0
34. MCPP	1.1	0	22	9.0	9.0
35. CONTROL	---	0	0	9.0	9.0
	LSD(0.05)=	22	18	0.7	0.8

[v] The abbreviated treatments are as follows: FENOX=fenoxaprop-ethyl, BROM=bromoxynil, 2,4-D E= 2,4-D ester, 2,4-D A=2,4-D amine, MCPP=mecoprop, DIC=dicamba, TRID=tridiphane.

[w] Percent crabgrass control scale: 0 to 100%, 100=dead crabgrass, 0=unaffected.

[x] Percent *Poa annua* L. phytotoxicity scale = 9 to 1, 9=Healthy turfgrass, 1=Dead turfgrass.

TABLE 5: GRASS AND BROADLEAF CONTROL WITH POSTEMERGENCE HERBICIDE COMBINATIONS APPLIED TO KENTUCKY BLUEGRASS. (FAIRWAY DRIVING RANGE, OKEMOS, MI). TREATMENT DATE = 7-22-86). (DIGITARIA GROWTH STAGE = 3 LEAF, 5 TILLER.)

		PERCENT CONTROL OF CRABGRASS[b]			
TREATMENTS[a]	RATE (KG/HA)	2WAT	4WAT	6WAT	8WAT
1. FENOX + BROM + 2,4-D A	.20 + 1.1 + .28	58	89	77	52
2. FENOX + TRICLOPYR + 2,4-D E	.20 + .42 + .84	60	83	58	47
3. FENOX + 2,4-D A + MCPP + DIC	.20 + 1.1 + .56 + .11	40	8	0	0
4. FENOX + 2,4-DP	.20 + 1.1	69	87	86	77
5. FENOX + DPX-M6316	.20 + (8 g/ha)	89	100	100	100
6. FENOXAPROP-ETHYL	.20	93	100	96	99
7. FENOX + 2,4-D AMINE	.20 + 1.1	46	43	0	6
8. FENOX + DICAMBA	.20 + .56	89	95	98	99
9. FENOX + FLUROXYPYR	.20 + .56	99	100	100	100
10. FENOX + BROMOXYNIL	.20 + 1.1	97	96	97	100
11. FENOX + MCPP	.20 + 1.1	87	100	95	91
12. FENOXAPROP-ETHYL	.40	100	100	100	100
13. FENOX + 2,4-D AMINE	.40 + 1.1	73	77	48	13
14. FENOX + DICAMBA	.40 + .56	96	100	100	100
15. FENOX + FLUROXYPYR	.40 + .56	100	100	100	100
16. FENOX + BROMOXYNIL	.40 + 1.1	98	100	99	99
17. FENOX + MCPP	.40 + 1.1	100	100	100	100
18. TRIDIPHANE	1.1	13	37	63	11
19. TRID + 2,4-D AMINE	1.1 + 1.1	12	33	48	33
20. TRID + DICAMBA	1.1 + .56	33	54	33	16
21. TRID + FLUROXYPYR	1.1 + .56	50	71	67	52
22. TRID + BROMOXYNIL	1.1 + 1.1	13	21	16	15
23. TRID + MCPP	1.1 + 1.1	37	53	28	28
24. TRIDIPHANE	2.2	28	72	83	88
25. TRID + 2,4-D AMINE	2.2 + 1.1	39	70	78	58
26. TRID + DICAMBA	2.2 + .56	21	71	80	54
27. TRID + FLUROXYPYR	2.2 + .56	54	79	82	95
28. TRID + BROMOXYNIL	2.2 + 1.1	57	80	75	51
29. TRID + MCPP	2.2 + 1.1	54	79	84	82
30. 2,4-D AMINE	1.1	30	19	0	0
31. DICAMBA	.56	38	15	0	0
32. FLUROXYPYR	.56	26	58	13	0
33. BROMOXYNIL	1.1	4	0	0	0
34. MCPP	1.1	0	0	0	0
35. CONTROL	---	15	0	3	0
	LSD(0.05)=	35	25	34	27

[a] The abbreviated treatments are as follows: FENOX=fenoxaprop-ethyl, BROM=bromoxynil, 2,4-D E= 2,4-D ester, 2,4-D A=2,4-D amine, MCPP=mecoprop, DIC=dicamba, TRID=tridiphane.

[b] Percent crabgrass control scale: 0 to 100%, 100=dead crabgrass, 0=unaffected.

TABLE 6: GRASS AND BROADLEAF CONTROL WITH POSTEMERGENCE HERBICIDE COMBINATIONS APPLIED TO A KENTUCKY BLUEGRASS BLEND. (HTRC, E. LANSING, MI 8-5-87). (DIGITARIA GROWTH STAGE = 3 LEAF TO 1 TILLER.)

TREATMENTS	RATE (KG/HA)	% CONTROL OF CRABGRASS[a] 2WAT	4WAT	6WAT	KB PHYTOTOX[b] 2WAT	4WAT
1. FENOXAPROP-ETHYL (FENOX)	.20	92	93	88	7.7	9.0
2. FENOX + 2,4-D ESTER (2,4-D E)	.20 + 1.1	40	40	33	8.7	9.0
3. FENOX + DICAMBA (DIC)	.20 + .56	90	90	90	8.7	9.0
4. FENOX + FLUROXYPYR	.20 + .56	100	100	94	8.0	9.0
5. FENOX + BROMOXYNIL	.20 + 1.1	45	30	9	8.7	9.0
6. FENOX + MECOPROP (MCPP)	.20 + 1.1	92	95	97	8.3	9.0
7. FENOX + DPX-L5300	.20 + .84	0	0	0	6.3	6.0
8. FENOX + CHLORFLURENOL	.20 + .14	87	93	84	8.3	9.0
9. FENOX + TRICLOPYR	.20 + .56	100	80	48	8.7	8.7
10. FENOX + CLOPYRALID	.20 + .28	86	98	96	8.0	9.0
11. FENOX + 2,4-D A + MCPP + DIC	.20 + 1.1 + .56 + .11	46	54	24	9.0	9.0
12. FENOX + 2,4-DP	.20 + 1.1	85	89	82	8.0	8.3
13. FENOX + BROM + 2,4-D E	.20 + 1.1 + .28	59	32	32	8.7	9.0
14. FENOX + TRICLOPYR + 2,4-D E	.20 + .42 + .84	92	87	65	8.0	9.0
15. FENOXAPROP-ETHYL	.40	97	97	97	6.3	8.0
16. FENOX + 2,4-D ESTER	.40 + 1.1	86	100	90	7.0	8.3
17. FENOX + DICAMBA	.40 + .56	95	97	95	8.0	9.0
18. FENOX + FLUROXYPYR	.40 + .56	100	100	88	6.3	7.3
19. FENOX + BROMOXYNIL	.40 + 1.1	92	93	79	7.0	8.7
20. FENOX + MCPP	.40 + 1.1	96	100	80	7.3	8.3
21. FENOX + DPX-L5300	.40 + .84	0	15	13	7.0	8.3
22. FENOX + CHLORFLURENOL	.40 + .14	100	100	100	7.3	8.0
23. FENOX + TRICLOPYR	.40 + .56	100	100	98	7.7	8.3
24. FENOX + CLOPYRALID	.40 + .28	93	96	91	6.3	8.7
25. FENOX + 2,4-D A + MCPP + DIC	.40 + 1.1 + .56 + .11	95	91	82	8.3	8.7
26. TRIDIPHANE (TRID)	1.1	0	17	0	9.0	9.0
27. TRID + 2,4-D ESTER	1.1 + 1.1	38	37	13	8.7	9.0
28. TRID + DICAMBA	1.1 + .56	0	24	11	9.0	9.0
29. TRID + FLUROXYPYR	1.1 + .56	45	56	75	8.7	9.0
30. TRID + BROMOXYNIL	1.1 + 1.1	8	8	0	9.0	9.0
31. TRID + MCPP	1.1 + 1.1	24	70	53	8.7	9.0
32. TRIDIPHANE	2.2	19	80	80	9.0	9.0
33. TRID + 2,4-D ESTER	2.2 + 1.1	43	92	67	8.7	9.0
34. TRID + DICAMBA	2.2 + .56	17	65	32	9.0	9.0
35. TRID + FLUROXYPYR	2.2 + .56	43	88	83	9.0	9.0
36. TRID + BROMOXYNIL	2.2 + 1.1	28	10	17	9.0	9.0
37. TRID + MCPP	2.2 + 1.1	15	83	84	8.7	9.0
38. 2,4-D ESTER	1.1	0	0	0	8.7	9.0
39. DICAMBA	.56	0	0	0	9.0	9.0
40. FLUROXYPYR	.56	10	3	14	8.7	9.0
41. BROMOXYNIL	1.1	8	0	8	9.0	9.0
42. MCPP	1.1	0	0	0	9.0	9.0
43. DPX-L5300	.84	0	0	0	6.7	6.0
44. CHLORFLURENOL	.14	0	0	0	9.0	9.0
45. TRICLOPYR	.56	0	0	0	9.0	9.0
46. CLOPYRALID	.28	0	0	0	8.7	9.0
47. 2,4-D E + MCPP + DICAMBA	1.1 + .56 + .11	0	0	0	9.0	9.0
48. CONTROL	---	0	0	0	8.7	9.0
	LSD(0.05)=	25	24	31	1.0	1.0

[a] Percent crabgrass control scale: 0 to 100%, 100=dead crabgrass, 0=unaffected.

[b] Phytotoxicity to Kentucky bluegrass caused by the herbicide treatments. Rating scale = 9 to 1, 9=dark green turf, 1=dead turf.

[c] 1984 formulation of fenoxaprop-ethyl. (All other fenoxaprop-ethyl treatments were 1986 formulations.)

TABLE 7: GRASS AND BROADLEAF CONTROL WITH POSTEMERGENCE HERBICIDE COMBINATIONS APPLIED TO A KENTUCKY BLUEGRASS/PERENNIAL RYEGRASS TURF. (CLIO COUNTRY CLUB, CLIO, MI. TREATMENT DATE = 8-4-87). (DIGITARIA GROWTH STAGE = 4 LEAF, 5 TO 10 TILLERS).

TREATMENTS[v]	RATE (KG/HA)	% CONTROL OF CRABGRASS[w] 2WAT	4WAT
1. FENOXAPROP-ETHYL (FENOX)	.20	21	64
2. FENOX + 2,4-D ESTER (2,4-D E)	.20 + 1.1	2	2
3. FENOX + DICAMBA	.20 + .56	22	40
4. FENOX + FLUROXYPYR	.20 + .56	59	80
5. FENOX + BROMOXYNIL (BROM)	.20 + 1.1	42	28
6. FENOX + MCPP	.20 + 1.1	14	56
7. FENOX + DPX-L5300	.20 + .84	11	6
8. FENOX + CHLORFLURENOL	.20 + .14	31	52
9. FENOX + TRICLOPYR AMINE	.20 + .56	11	34
10. FENOX + CLOPYRALID	.20 + .28	0	21
11. FENOX + 2,4-D A + MCPP + DIC	.20 + 1.1 + .56 + .11	3	1
12. FENOX + 2,4-DP	.20 + 1.1	18	31
13. FENOX + BROM + 2,4-D E	.20 + 1.1 + .28	21	18
14. FENOX + TRICLOPYR E + 2,4-D E	.20 + .42 + .84	24	32
15. FENOXAPROP-ETHYL	.40	38	60
16. FENOX + 2,4-D ESTER	.40 + 1.1	13	10
17. FENOX + DICAMBA	.40 + .56	41	51
18. FENOX + FLUROXYPYR	.40 + .56	67	100
19. FENOX + BROMOXYNIL	.40 + 1.1	18	13
20. FENOX + MCPP	.40 + 1.1	24	65
21. FENOX + DPX-L5300	.40 + .84	0	1
22. FENOX + CHLORFLURENOL	.40 + .14	44	68
23. FENOX + TRICLOPYR	.40 + .56	52	63
24. FENOX + CLOPYRALID	.40 + .28	49	72
25. FENOX + 2,4-D A + MCPP + DIC	.40 + 1.1 + .56 + .11	38	37
26. TRIDIPHANE (TRID)	1.1	2	10
27. TRID + 2,4-D ESTER	1.1 + 1.1	2	2
28. TRID + DICAMBA	1.1 + .56	2	20
29. TRID + FLUROXYPYR	1.1 + .56	8	13
30. TRID + BROMOXYNIL	1.1 + 1.1	46	55
31. TRID + MCPP	1.1 + 1.1	6	3
32. TRIDIPHANE	2.2	5	6
33. TRID + 2,4-D ESTER	2.2 + 1.1	1	26
34. TRID + DICAMBA	2.2 + .56	3	7
35. TRID + FLUROXYPYR	2.2 + .56	3	25
36. TRID + BROMOXYNIL	2.2 + 1.1	55	45
37. TRID + MCPP	2.2 + 1.1	2	10
38. 2,4-D ESTER	1.1	0	0
39. DICAMBA	.56	2	4
40. FLUROXYPYR	.56	0	0
41. BROMOXYNIL	1.1	5	5
42. MCPP	1.1	0	0
43. DPX-L5300	.84	0	0
44. CHLORFLURENOL	.14	0	0
45. TRICLOPYR	.56	0	0
46. CLOPYRALID	.28	0	0
47. 2,4-D E + MCPP + DICAMBA	1.1 + .56 + .11	2	0
48. CONTROL	---	5	3
	LSD(0.05)=	35	40

[v] The abbreviated treatments are as follows: MCPP=mecoprop, DIC=dicamba.

[w] Percent crabgrass control scale: 0 to 100%, 100=dead crabgrass, 0=unaffected.

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APPENDIX

TABLE A1: Daily temperatures for Lansing, MI, during summer months of 1986 and 1987. (TEMP=C)

	DAY OF MONTH																														
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
(JUNE 86)																															
MAX TEMP.	27	17	22	28	20	20	26	26	24	23	27	22	24	23	26	28	20	24	26	22	28	30	27	18	22	25	28	27	26	19	
MIN TEMP.	09	03	01	09	14	14	17	14	07	10	18	13	13	09	14	13	07	07	15	13	12	19	14	10	05	12	21	16	13	11	
(JULY 86)																															
MAX TEMP.	21	24	22	29	32	33	28	27	26	26	21	27	28	24	29	31	33	33	33	30	26	28	30	31	27	28	29	28	27	29	30
MIN TEMP.	11	14	08	13	22	22	20	18	17	13	14	17	18	14	13	19	23	23	23	20	15	15	16	19	19	18	15	17	16	12	16
(AUG. 86)																															
MAX TEMP.	27	28	25	27	27	24	24	27	28	22	22	24	24	26	28	29	31	28	28	28	29	28	24	24	24	23	17	18	20	23	25
MIN TEMP.	15	13	10	12	12	18	17	17	14	14	08	07	08	14	20	18	14	15	11	10	13	12	12	11	11	16	06	02	07	05	08
(SEPT. 86)																															
MAX TEMP.	27	27	28	27	23	19	17	20	23	24	24	19	20	19	22	17	20	18	20	20	19	29	23	25	29	26	27	27	26	21	
MIN TEMP.	09	11	12	14	10	05	02	03	06	14	17	09	09	05	06	01	03	12	15	15	14	16	13	13	17	17	17	17	19	13	
(JUNE 87)																															
MAX TEMP.	27	28	26	22	27	27	32	27	21	24	27	31	31	36	31	33	32	34	35	28	26	23	29	31	31	25	20	28	27	24	
MIN TEMP.	17	19	14	09	08	11	18	16	09	04	16	17	14	16	15	11	13	17	16	22	20	17	16	16	19	14	12	12	18	17	
(JULY 87)																															
MAX TEMP.	23	28	29	27	27	29	30	32	30	31	32	33	29	22	17	26	29	32	33	34	32	33	33	34	32	31	29	28	32	33	33
MIN TEMP.	15	13	17	12	16	19	21	21	19	21	22	23	17	10	07	10	15	19	22	21	19	18	22	24	21	19	14	12	16	18	18
(AUG. 87)																															
MAX TEMP.	28	33	33	31	26	29	32	21	28	27	28	28	31	27	33	32	27	26	26	26	29	25	22	20	21	16	17	19	24	27	21
MIN TEMP.	21	22	18	19	14	12	17	17	17	17	14	12	17	22	24	21	16	14	12	11	18	14	12	08	09	13	14	13	11	15	10
(SEPT. 87)																															
MAX TEMP.	21	20	23	24	29	28	29	24	25	27	26	26	21	22	24	23	24	18	22	18	17	19	21	20	17	24	27	27	21	17	
MIN TEMP.	08	09	06	08	13	16	17	16	14	13	17	14	09	07	09	16	18	14	11	11	07	07	08	08	02	08	10	12	11	06	

TABLE A2: Daily temperatures for Flint, MI, during August and September, 1987. (TEMP=C)

DAY OF MONTH	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
(AUG. 87)																
MAX TEMP.	27	34	32	32	26	28	32	23	28	27	27	28	31	30	33	34
MIN TEMP.	21	22	19	19	14	11	16	16	18	18	14	13	18	23	23	22
(SEPT. 87)																
MAX TEMP.	21	21	21	24	28	27	29	25	24	27	26	27	22	22	22	24
MIN TEMP.	08	11	07	07	10	16	18	17	16	13	17	16	09	08	11	14

DAY OF MONTH	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
(AUG. 87)															
MAX TEMP.	28	27	26	26	27	25	21	21	22	16	18	21	23	27	22
MIN TEMP.	17	13	13	10	17	12	10	04	08	13	14	12	10	13	09
(SEPT. 87)															
MAX TEMP.	25	18	23	22	16	19	22	19	18	23	28	27	21	17	
MIN TEMP.	18	15	11	11	07	07	09	08	03	06	11	13	12	06	

TABLE A3: Daily precipitation for Lansing and Flint, MI, during the summer months of 1986 and 1987. (PRECIP=mm)

	DAY OF MONTH																														
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
LANSING																															
(JUNE 86)	1.0	0.0	0.0	0.5	65.8	0.0	14.5	0.0	0.0	4.1	125.7	1.5	0.0	1.5	8.4	0.0	0.0	0.0	17.3	0.0	0.0	0.8	3.8	0.3	0.0	2.3	9.7	0.0	0.0	2.5	
(JULY 86)	0.8	0.0	0.0	0.0	0.0	0.0	0.0	10.7	1.5	0.0	3.8	4.8	0.0	0.0	14.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	1.3	0.0	0.0	0.0
(AUG. 86)	0.0	1.8	0.0	0.0	0.0	22.6	0.5	2.3	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	0.0	0.3	19.8	0.0	0.0	0.0	0.0	0.0
(SEPT. 86)	0.0	0.0	2.3	3.8	0.0	0.0	0.0	0.0	0.8	16.8	33.5	0.0	0.0	0.3	2.0	0.0	0.3	8.9	0.0	0.5	1.8	17.0	10.7	0.3	24.1	28.4	0.5	14.5	36.8	8.6	
(JUNE 87)	0.5	2.3	0.0	0.0	0.0	11.7	0.0	1.0	0.0	0.0	2.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.0	0.0	0.0	0.0	6.4	0.0	0.8	0.0	7.9	3.6	
(JULY 87)	0.0	0.0	0.0	0.0	7.6	0.0	2.8	0.0	33.0	8.9	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	1.8	6.9	0.0	0.0	0.0	0.0	18.3
(AUG. 87)	3.8	0.0	0.0	0.5	0.0	0.0	0.0	9.7	14.0	0.0	0.0	0.0	0.0	18.8	0.0	7.4	10.4	1.0	0.0	0.0	0.0	47.0	0.0	0.0	0.0	30.5	1.5	0.5	0.0	0.3	0.0
(SEPT 87)	2.3	0.3	0.0	0.0	0.0	0.0	0.0	7.4	0.0	15.5	18.0	12.7	0.0	0.0	9.1	3.8	1.3	0.0	0.5	4.3	9.9	6.4	0.0	0.0	0.0	0.0	0.3	2.0	23.1	7.1	
FLINT																															
(AUG. 87)	1.5	0.0	0.0	0.3	0.0	0.0	0.0	2.3	18.0	0.0	0.0	0.0	0.0	13.0	0.0	16.8	0.5	0.8	0.0	0.0	8.4	31.0	0.0	0.0	0.0	25.7	0.3	1.3	0.0	5.8	2.5
(SEPT 87)	2.3	1.0	0.0	0.0	0.0	0.0	3.3	58.9	0.0	0.0	24.8	5.3	0.0	0.0	10.2	3.6	1.3	0.0	0.0	8.9	5.8	0.0	0.0	0.0	0.0	0.0	2.0	0.0	13.7	2.8	