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Title: THE CONTROL OF COLONIAL BENTGRASS (AGROSTIS TENUIS SIBTH.) WITH N-(PHOSPHONOMETHYL) GLYCINE

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Arnold P. Appleby

Field and greenhouse experiments were conducted to determine the effectiveness of glyphosate (N-(phosphonomethyl)glycine) and EPTC (ethyl N, N-dipropylthiocarbamate) as short-residual herbicides in controlling established bentgrass (Agrostis tenuis Sibth.).

The mono(dimethylamine) salt of glyphosate was applied to bentgrass foliage on six dates at rates of 1, 2, and 4 lb ae/A[1] in 42 gallons of water. Bentgrass control 9 months after the last application date ranged among the six application dates from 15-71% with 1 lb/A, 48-87% with 2 lb/A, and 78-90% with 4 lb/A. Windy conditions and moisture on the foliage during application may have reduced the effectiveness of glyphosate on several application dates. The 4 lb/A rate appeared to be less affected by adverse weather conditions than the two lower rates.

Tillage with a field rototiller 2 weeks after glyphosate

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[1] ae = acid equivalent

application produced excellent bentgrass control with all three herbicide rates. Tillage alone did not control bentgrass.

EPTC was not effective in controlling established bentgrass when applied at rates of 3 and 5 lb ai/A[2] in 42 gallons of water and incorporated with a field rototiller.

Bioassays using soil core samples indicated that EPTC remained in the soil for at least 21 days at levels toxic to annual ryegrass (Lolium multiflorum Lam.) while glyphosate was not toxic to Druchamp wheat (Triticum aestivum L.) or oats (Avena sativa L.) grown in core samples collected immediately after herbicide application. In further greenhouse experiments, glyphosate incorporated into soil before planting at rates of 30 and 60 lb ae/A reduced the shoot growth of wheat and oats by 14 to 42% but failed to completely kill them. Glyphosate also reduced the shoot growth of wheat when applied preemergence at 30 lb ae/A and either surface or sub-irrigated. Almost no effect was observed on wheat with rates of 1.5 and 3.0 lb ae/A.

Simulated rainfall reduced the toxicity of glyphosate to oats when applied up to five hours after herbicide treatment, but washing eight hours after treatment did not reduce toxicity.

Excising glyphosate-treated oat leaves at intervals after treatment indicated that glyphosate may have been translocated from the treated leaves within three hours after treatment and was still being translocated from the treated leaves 20 to 45 hours after treatment.

[2] ai = active ingredient

The Control of Colonial Bentgrass (*Agrostis tenuis* Sibth.) with N-(phosphonomethyl) Glycine

by

Bill Densmore Brewster

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THE CONTROL OF COLONIAL BENTGRASS (*AGROSTIS TENUIS* SIBTH.) WITH N-(PHOSPHONOMETHYL) GLYCINE

INTRODUCTION

Renovation of bentgrass (*Agrostis* spp.) pastures in western Oregon to pastures of superior forage species presently involves summer tillage to dry the bentgrass roots. However, many landowners are reluctant to use such control methods because bentgrass is persistent and has a high potential for regrowth. An effective short-residual herbicide may provide a more acceptable method of bentgrass control if predictability of results is good and costs are reasonable. Tillage could be limited to that needed for seedbed preparation to partially offset the herbicide cost.

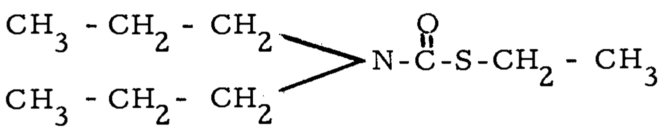
In this study, EPTC (ethyl *N*, *N*-dipropylthiocarbamate) and MON-0468, the mono(dimethylamine) salt of glyphosate (N-(phosphonomethyl)glycine) were compared in field trials to determine their effectiveness in controlling Colonial bentgrass (*Agrostis tenuis* Sibth.). Major objectives of the field experiments were to determine the optimum time for glyphosate applications and to determine how soon tillage could follow the applications. Greenhouse experiments were conducted to evaluate applications of simulated rainfall on the effectiveness of foliar-applied glyphosate, to determine the soil activity and rate of translocation of glyphosate, and to determine the residual life of EPTC in the soil.

Ryegrass (Lolium multiflorum Lam.), oats (Avena sativa L.), and Druchamp winter wheat (Triticum aestivum L.) were used as indicator species in the greenhouse studies.

LITERATURE REVIEW

Properties of EPTC

EPTC is a member of the thiocarbamate herbicide family. Eptam, the commercial product used in this study, is an emulsifiable concentrate containing 7 lb/gal ethyl N, N-dipropylthiocarbamate. The pure chemical is a light yellow liquid with an amine odor, and has the following structure:



EPTC has a relatively high vapor pressure (1.62×10^{-2} mm Hg at 23°C) and has the unusual property of becoming less water soluble with increasing temperatures (636 ppm at 3°C and 375 ppm at 25°C). Johnsongrass (*Sorghum halepense* (L.) Pers.) and quackgrass (*Agropyron repens* (L.) Beauv.) are effectively controlled with pre-emergence treatments of EPTC (Herbicide Handbook of the Weed Science Society of America).

Several environmental factors have been found to influence the herbicidal effectiveness of EPTC in the soil. Ashton and Sheets (1959) noted more injury to oats (*Avena sativa* L.) when EPTC adsorption in the soil decreased, and that volatility loss of EPTC from moist surfaces was rapid. These observations were supported by Sheets (1959) who stated that EPTC is lost readily from moist soil by volatilization and can be leached below the effective depth.

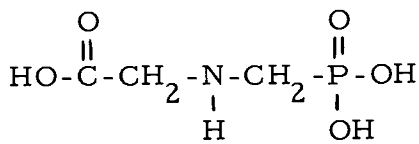
Several investigators (Antognini, 1958; Ashton and Sheets, 1959; Fang, Theisen and Freed, 1961) concluded that EPTC persists longer in dry soils because of stronger and more rapid adsorption. Vernetti and Freed (1963a, b) also indicated that more EPTC is lost from moist soil than from dry soil.

Thiocarbamate herbicides are also adsorbed more in soils high in clay and organic matter (Koren, Foy and Ashton, 1969). Leaching losses of these compounds were directly related to their water solubilities and inversely related to the organic matter content of the soil. Rapid infiltration into the soil and rapid drying of spray droplets on the soil surface reduced vapor losses of all compounds studied, but volatilization was greatest and adsorption was least with EPTC.

Because of rapid volatilization of EPTC, mechanical incorporation is usually necessary for effective weed control. Robinson and Fenster (1968) demonstrated that EPTC incorporated with a tandem disc or rotary incorporator gave better weed control than when incorporated with other implements. Other research (Burnside, 1964) found that EPTC incorporated with a rotary cultivator produced superior herbicidal activity in contrast to EPTC incorporated with a double disc or rotary hoe.

Properties of Glyphosate

MON-0468 is the mono(dimethylamine) salt and MON-1139 is the monoisopropylamine salt of N-(phosphonomethyl)glycine (glyphosate). MON-0468 and MON-1139 are formulated as 5 and 3 lb/gal water-soluble concentrates, respectively. The parent compound is a white solid in the pure state with a water solubility of approximately 10, 000 ppm at 25°C. The chemical structure is:



Derivatives of this compound are generally nonvolatile and have water solubilities similar to the parent compound. The acute oral LD_{50} for mixed sex rats was found to be 4320 mg/Kg for the parent compound and 9800 mg/Kg for the mono(dimethylamine) salt. Trout and bluegill fish have not been adversely affected by rates of glyphosate higher than 1000 ppm (Monsanto Company).

Experiments in Latin America with the mono(dimethylamine) salt produced more than 90% control of Johnsongrass, Bermudagrass (*Cynodon dactylon* (L.) Pers.), paragrass (*Panicum purpurascens* Raddi.), and purple nutsedge (*Cyperus rotundus* L.) 5 to 7 weeks after application at rates less than 2 lb/A. Studies with quackgrass in Missouri indicated that split applications (one in the fall and the other the following spring) were superior to applying the total amount in either the fall or the spring. In general, control of perennial plants increased in these studies for 7 to 10 weeks after treatment and then declined as escapes and vegetative propagules proliferated. No herbicidal activity was found in the soil when applied at normal field rates (1/4 to 4 lb/A) (Baird et al., 1971).

Several factors have been found to affect the performance of these herbicides (Baird and Begeman, 1972). Better quackgrass control was obtained when tillage followed herbicide treatment by more than 2 weeks, and later growth stages were more susceptible than earlier ones. Furthermore, both shading and high temperatures following application appeared to reduce herbicidal activity, as did rain within 9 hours after treatment. This latter observation was supported by similar findings with simulated rainfall applied with a manual sprayer.

Researchers studying other herbicides (Bovey and Diaz-Colon, 1969; Upchurch, Coble and Keaton, 1969) found that water-soluble herbicide formulations are generally more susceptible to removal by artificial rainfall than oil-soluble formulations, and that removal, as measured by plant injury, decreases as time between the herbicide application and subsequent washing increases.

Bentgrass Pasture Renovation

Paraquat (salts of 1, 1-dimethyl-4, 4-bipyridinium) and dalapon

(2, 2-dichloropropionic acid) have been used experimentally to selectively improve the composition of pastures infested with bentgrass. Allen (1965) reported that dalapon at 15 lb/A (active ingredient) controlled the top growth of Agrostis stolonifera L., but after 15 months frequency counts were only 20% lower than the untreated checks because of regeneration by unkilled roots.

Other experiments in Great Britain and New Zealand (Davies, Hunter and King, 1960; Gardner, 1960; Bramely, 1961; Jones (J.), 1962; Jones (L.), 1962) produced similar results on several species of bentgrass with dalapon rates as high as 20 lb/A. In contrast, Allen (1968) found more than 90% bentgrass control one year after a dalapon application of 7.5 lb/A. However, some of this effect may have been partially due to competition from dalapon-resistant species.

Paraquat has not been effective for year-around control of bentgrass (Jones (L.), 1962; Allen, 1965) although good results have been obtained over a 3-month period (Bramley, 1960).

Both dalapon and paraquat cause contact injury, which, particularly at high rates, impedes translocation of these compounds from the treated area. Repeated applications of moderate rates often give better results on perennial species than a single high dosage, but repeated applications increase treatment costs. In conclusion, neither of these short residual herbicides has shown a practical potential for eradicating bentgrass to allow the establishment of more productive forage species.

FIELD EXPERIMENTS

Experimental Area and General Procedures

Three experiments were established on a bentgrass (*Agrostis tenius* Sibth.)/subclover (*Trifolium subterraneum* L.) pasture during the spring of 1971. The experimental area was located in the Coast Range foothills of western Benton County, Oregon, about 5 miles north of Blodgett. The area has a general southern exposure with a 0 to 10% slope. The soil is well drained and is classified in the Apt series, which was derived from sedimentary rock and evolved under a coniferous forest.[1]

Exclosures were constructed the day prior to the first treatment on each site to prevent livestock grazing. Individual plots of 8 x 30 feet were arranged in randomized block designs with four replications in each experiment. Herbicides were applied with a bicycle sprayer which delivered 42 gal/A at 30 psi.

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[1] Personal communication with Eugene Sturtevant, Benton County Soil Conservation Service.

GLYPHOSATE TIMING TRIAL ON ESTABLISHED BENTGRASS

Materials and Methods

The objective of this experiment was to evaluate the effects of various rates of glyphosate when applied at several stages of bentgrass growth. The mono(dimethylamine) salt of glyphosate was applied at rates of 1, 2, and 4 lb ae/A with 10 ml of MON-0027 surfactant added to each liter of spray solution. Treatments were made on six dates in the spring and early summer of 1971 at approximately 2-week intervals. Intervals between treatments were not exactly 2 weeks because of a need to make applications under favorable weather conditions whenever possible. The general weather conditions and growth stages of bentgrass and subclover on each treatment date are listed in Table 1. Sheep and cattle grazing, which had occurred through April 18, had removed approximately 2 inches of bentgrass growth. Subclover had been grazed only lightly since it was just emerging from the soil.

The efficacy of glyphosate under the conditions of this experiment was determined by taking forage yields and making visual evaluations. Yields were obtained by harvesting the above-ground growth in five 1-sq. ft. hoops in each plot on July 26, 1971, 30 days after the last treatment. The harvested plant material was placed in plastic bags and stored at $0^{\circ}F$ for 2 months, after which the samples

Table 1. Weather conditions and bentgrass and subclover growth stages on six glyphosate application dates in 1971.

Date	Weather	Stage of growth	
		Bentgrass	Subclover
April 19	Clear, foliage dry 60°F, wind calm	2-3" tall	1/2-1" tall
May 1	Clear, humid, foliage dry, 70°F, wind gusting 0-8 mph	2-4" tall	1/2-1" tall
May 19	Overcast, foliage dry, 54°F, wind 5-10 mph, showers following day	3-5" tall	early bloom
May 29	Overcast, slight mist, 52°F, wind 0-4 mph	4-6" tall	bloom
June 12	Overcast, heavy dew, 52°F, wind 3-6 mph	late bloom	full bloom
June 26	Clear, foliage dry, 67°F, wind calm	fully headed out, pre-anthesis	post bloom

were air dried for 2 weeks at 70°F. Only the green plant material in each sample was separated by species and weighed.

Independent visual evaluations of the treatments were made by two researchers on November 29, 1971, and March 29, 1972. Ratings on a scale of 0 to 100 were used, with 0 being no injury and 100 being complete eradication.

Results

Bentgrass control ranged from poor to good with this glyphosate salt depending on the rate used and date of application. Bentgrass yields were low on all treatment dates compared to the untreated control plots (Table 2 and Appendix Table 1). These data indicate that glyphosate greatly affected the above-ground growth of bentgrass with all treatments used. Nevertheless, yields from the two lower rates of the April 19 treatments were significantly higher than all other treatments except the 1 lb/A rate on June 12 and the untreated controls. Increasing the rate of glyphosate generally reduced the yields on all dates, although these differences were not significant.

Evaluations on November 29, 5 months after the last application, also revealed a trend for better bentgrass control with the higher rates. Differences were significant between the 1 lb/A rate and the 4 lb/A rate on all application dates except May 1 and June 26 (Table 2 and Appendix Table 2). Application on June 26 also produced significantly better control than any other date except May 1 (Figure 1). Only the May 19 application showed a significant difference between the 2 and 4 lb/A rates.

Since the 4 lb/A treatments among all application dates were not significantly different, most of the differences among application dates were attributed to differences among the lower rates. The least effective treatments were the 1 lb/A treatments on the last two dates in May and the first date in June.

Evaluations of bentgrass control on March 29, 1972, were somewhat lower than the November evaluations (Table 2 and Appendix Table 3). Proliferation of escapes and regeneration from root

Table 2. The effect of glyphosate foliage applications to established bentgrass on six application dates in 1971.[1]

Application date	Rate (lb/A)	Treatment means (% control)		
		Dry weight	November evaluation	March evaluation
April 19	1	95.1	72	37
	2	93.2	80	58
	4	98.2	90	79
May 1	1	99.4	81	71
	2	99.6	90	88
	4	99.6	93	80
May 19	1	98.1	40	15
	2	99.6	65	48
	4	99.9	98	90
May 29	1	99.6	64	43
	2	T	89	82
	4	100	96	86
June 12	1	97.1	66	32
	2	99.9	85	72
	4	99.9	98	87
June 26	1	99.8	97	49
	2	99.8	98	70
	4	T	99	86
control	0	0	0	0

T = Trace (99.9 < T < 100)

[1]Plants were harvested on July 26, 1971, and visual evaluations were made on November 29, 1971, and March 29, 1972.

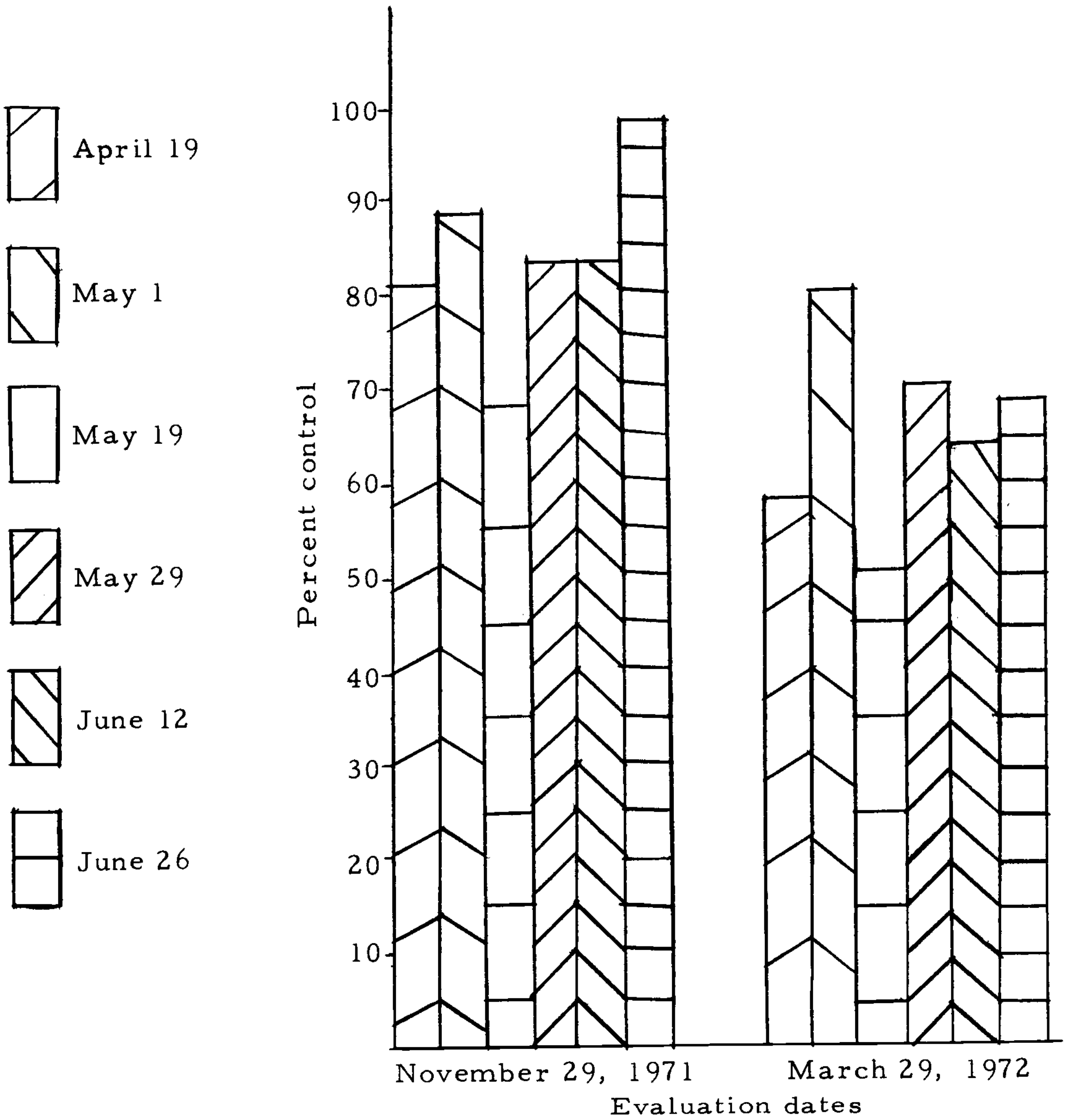

Figure 1. Percent bentgrass control from foliar applications of glyphosate on six dates in 1971 and evaluated on two subsequent dates.

systems accounted for most of the regrowth.

As with the November evaluations, differences among the 4 lb/A treatments were not significant, although the two earliest application dates had lower ratings for this dosage than the other dates. The four least effective treatments were the same as those on the November evaluation, although the 1 lb/A rate on June 26 was also low on the March evaluation. The trend for better bentgrass control with increasing rates appeared more pronounced on the latter evaluation, but the only significant difference between the 2 lb/A and 4 lb/A rates was still from the May 19 application.

The weather data in Table 1 illustrate conditions which may have affected the performance of glyphosate on several application dates. In particular, wind velocity was relatively high on May 19 with rain the following day, and considerable moisture was on the foliage during application on May 29 and June 12.

Variability in trailing blackberry (*Rubus ursinus* C. & S.) and subterranean clover yield data (Appendix Tables 4 and 5 respectively) indicate the irregular distribution of these species over the trial area. In spite of this variability, significant rate x date interactions were found for both species. The highest yields were obtained from the earliest treatment dates for both species, and although differences were not significant, there was a trend for lower yields with increasing rates of glyphosate.

Albinism and occasional necrosis of the terminal leaves of blackberry were noted on some of the early treatments, as was stunted growth of subclover leaves.

A canopy effect by the bentgrass may have affected the activity of glyphosate on the blackberry and subclover, particularly on the last two application dates. Furthermore, resistance on the earlier dates may have been due to incomplete emergence of these species when the herbicide was applied.

A number of other species occurred in minor amounts and were generally found in greater abundance in plots treated on the first three application dates in contrast to untreated plots and plots treated on the last three dates. These species included small hopclover (*Trifolium dubium* Sibth.), dovefoot geranium (*Geranium molle* L.), common dandelion (*Taraxacum officinale* Weber), soft chess (*Bromus mollis* L.), buckhorn plantain (*Plantago lanceolata* L.), strawberry (*Fragaria cuneifolia* Nutt.), western bracken (*Pteridium aquilinum* (L.) Kuhn var. *pubescens* Underw.), and spotted catsear (*Hypochaeris radicata* L.).

GLYPHOSATE TILLAGE TRIAL ON ESTABLISHED BENTGRASS

Materials and Methods

This experiment was designed to determine the effect of tillage on the control of glyphosate treated bentgrass. The mono(dimethylamine) salt of glyphosate was applied at rates of 1, 2, and 4 lb ae/A to established bentgrass on May 22, 1971. MON-0027 surfactant was added to the spray solution in a ratio of 10 ml surfactant per liter of spray solution. Tillage treatments included no tillage, tillage within 1 hour after herbicide application, and tillage on June 5, 2 weeks after herbicide application. Tillage to a depth of 5 to 6 inches was accomplished with a single pass of a tractor-driven field rototiller.

Conditions during spraying were as follows: bentgrass 4-5" high, foliage dry; skies clear; temperature 65^{o}F; wind gusting to 8 mph.

Evaluations of bentgrass control were based on independent visual ratings by two researchers. Ratings were from 0 to 100 with 0 being no control and 100 being complete kill of all bentgrass in a plot. Evaluations were made on November 29, 1971, and March 29, 1972.

Results

Evaluations on November 29, 1971, and March 29, 1972, showed that tillage within 1 hour after application of glyphosate resulted in a greater decrease in bentgrass at all rates than tillage alone (Figures 2 and 3, and Appendix Tables 6 and 7). However, this method reduced bentgrass control when compared to treated, untilled plots.

Excellent bentgrass control was obtained with all three rates of glyphosate when tillage followed the application of herbicide by 14 days. And these treatments appeared superior to all the other treatments when evaluated on March 29, 1972, although not all differences were significant. Furthermore, no advantage was found with increasing the rate of glyphosate when tillage followed herbicide application by 2 weeks.

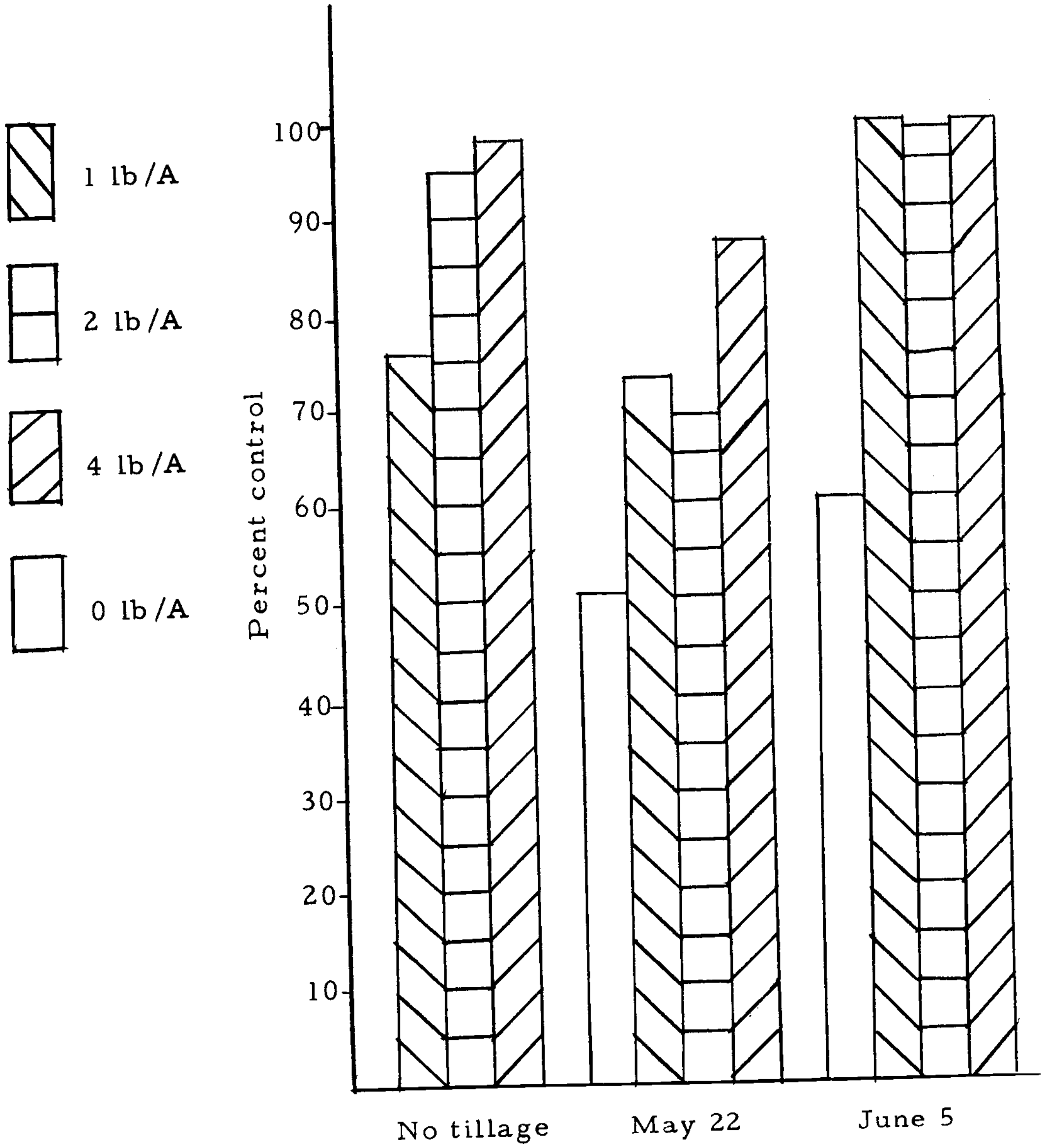

Figure 2. Percent bentgrass control from foliar applications of glyphosate on May 22, 1971, and subsequent tillage on May 22 and June 5. Visual evaluations were made on November 29, 1971.

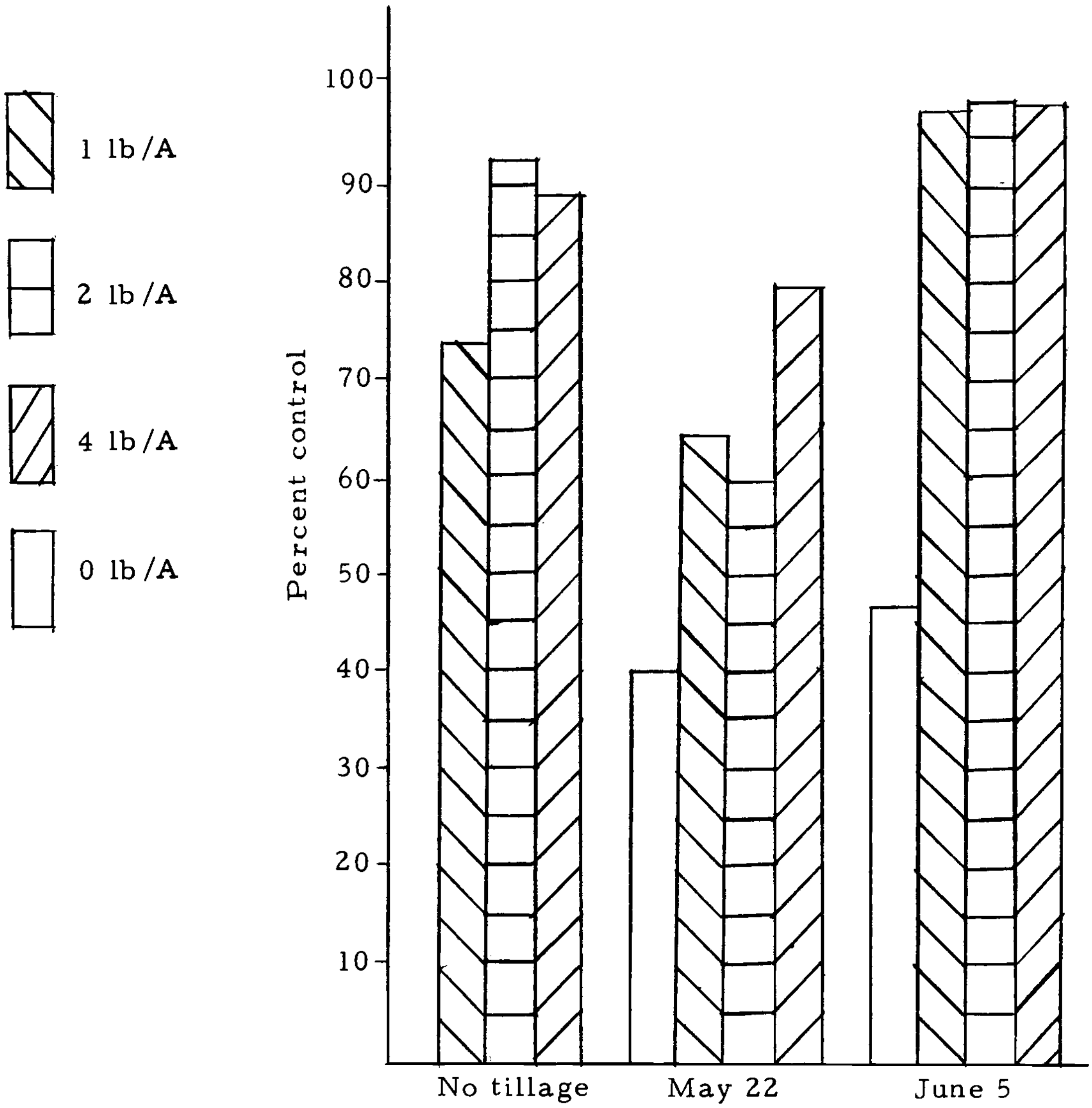

Figure 3. Percent bentgrass control from foliar applications of glyphosate on May 22, 1971, and subsequent tillage on May 22 and June 5. Visual evaluations were made March 29, 1972.

EPTC TRIAL ON ESTABLISHED BENTGRASS

Materials and Methods

The purpose of this experiment was to evaluate the efficacy of EPTC in controlling established bentgrass. EPTC was applied at rates of 0, 3, and 5 lb ai/A on May 22, 1971. The conditions at spraying were those described in the materials and methods section of the MON-0468 tillage trial.

Each plot was tilled once with a tractor-driven field rototiller to a depth of 5 to 6 inches before spraying. After herbicide application, each plot was immediately tilled again in the same manner as the pre-spray treatment.

Visual evaluations of bentgrass control were made on November 29, 1971, and March 29, 1972. Bentgrass control was rated on a scale of 0 to 100 with 0 being no control and 100 being complete kill of all bentgrass in a plot. Evaluations were made independently by two researchers.

Results

EPTC proved ineffective in controlling established bentgrass under the conditions of this experiment (Figure 4 and Appendix Tables 8 and 9). Differences were significant between tilled plots and the untilled checks, but only a slight advantage was found between treated-tilled plots and the tilled check.

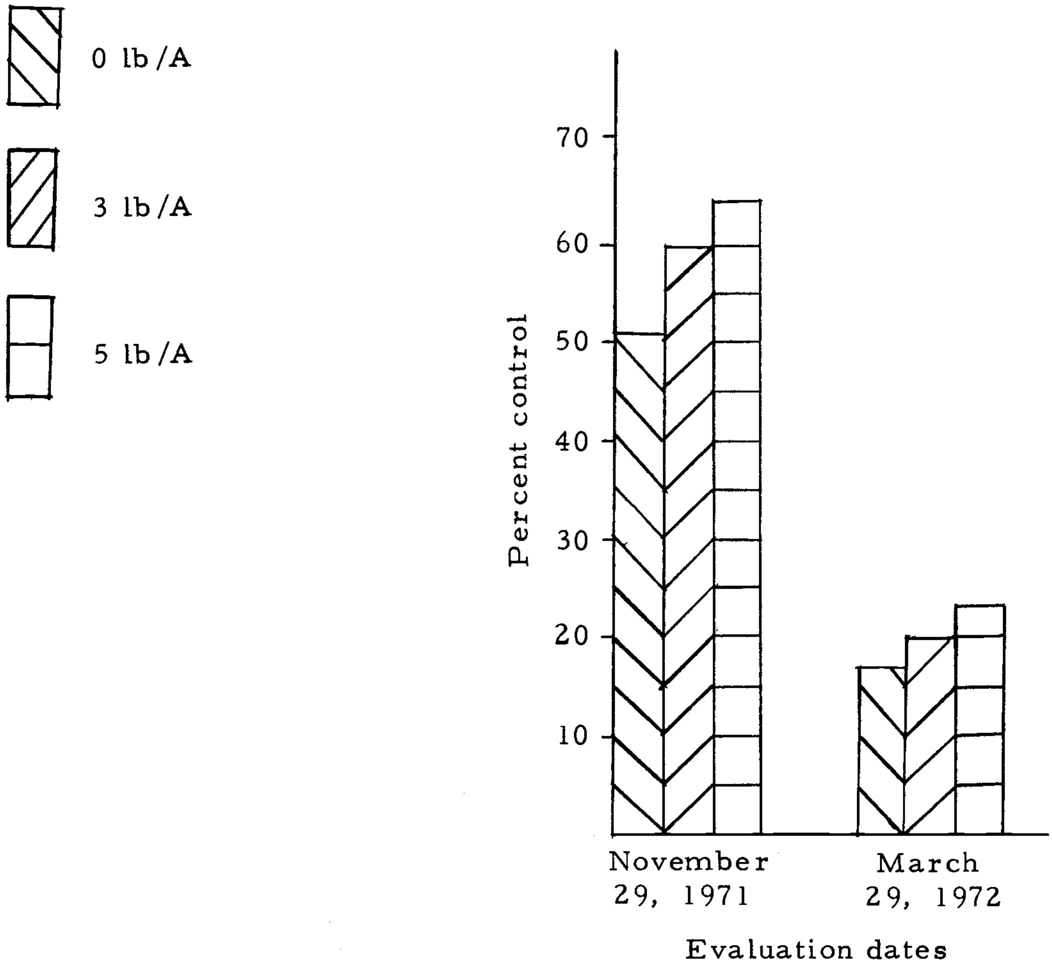

Figure 4. Percent bentgrass control from May 22 applications of EPTC incorporated with a field rototiller. Evaluations were made on November 29, 1971, and March 29, 1972.

GLYPHOSATE SOIL RESIDUAL STUDY

Materials and Methods

Herbicides used in pasture renovation must not remain in the soil in amounts toxic to the newly seeded crop. The purpose of this study was to determine whether phytotoxic levels of glyphosate were present in soil treated with a normal field rate.

Soil core samples (21.1% sand, 27.2% silt, 51.7% clay, 7.2% organic matter)[2] 2 inches deep and 1 inch in diameter were collected from a field experiment in which the mono(dimethylamine) salt of glyphosate was applied at 4 lb ae/A to a mixed weed population with less than 50% ground cover. The core samples from the untreated control plots and the treated plots were collected 2 hours after treatment on April 28, 1971, and frozen in plastic bags at $0^{o}F$ until December 10, 1971. The samples were then thawed, air-dried, sifted through a 0.125-inch mesh screen and mixed thoroughly. Eight 200 gram subsamples were taken from both the control samples and treated samples and placed in 2.75 x 2.75 x 2.75-inch plastic pots for a greenhouse bioassay. Six oat seeds were planted 0.5 inch deep in each of 4 subsample pots of both the treated and untreated samples and six Druchamp wheat seeds were planted 0.5 inch deep in each of the remaining subsample pots; the seedlings were subsequently thinned to four plants per pot.

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[2]Mechanical analysis by Oregon State University soils laboratory.

The pots were placed in watering trays and arranged in randomized block designs. Subirrigation was used as needed and ORTHO-gro® liquid plant food was added once a week to the irrigation water in a ratio of 1 tablespoon per gallon of water. The temperature was maintained at 65-70°F during the day and 65°F at night. Supplemental light was provided. Plant heights of the wheat and oats were determined 32 days after planting. The wheat had five leaves when measured and the oats had four to five leaves.

Results

No evidence of herbicide injury was found on either the wheat or the oats grown in the treated soil. Furthermore, plant heights in Appendix Tables 10 and 11 show no significant differences between plants grown in the treated soil and those grown in the untreated control soil. These data suggest that glyphosate has a low level of herbicidal activity in the soil.

SOIL INCORPORATED GLYPHOSATE APPLIED PRE-PLANT TO WHEAT AND OATS

Materials and Methods

In view of the evident lack of phytotoxicity of glyphosate in field soil samples to wheat and oats, an experiment was established to determine if these species would be affected by relatively high rates of glyphosate incorporated into the soil immediately before planting.

A greenhouse soil mix (64.6% sand, 17.5% silt, 17.9% clay, 1.4% organic matter) was sifted through a 0.125-inch mesh screen and air-dried and 210 grams of soil were placed in each 2.75 x 2.75 x 2.75-inch plastic pot. The monoisopropylamine salt of glyphosate was then sprayed onto the surface of the soil in the pots with a motor-driven greenhouse track sprayer. Two passes were made on each of two treatments to give a total of 30 and 60 lb ae/A in 40 gal/A spray volumes. On a weight-weight basis, these rates were approximately 78 and 156 ppm, respectively.

The soil was removed from each pot immediately after treatment, shaken vigorously in a glass jar for 60 seconds to incorporate the herbicide, and placed back in the pots. Seven seeds of oats and Druchamp wheat were planted 0.5 inch deep in separate pots for each treatment. The seedlings were subsequently thinned to five plants per pot. The pots were placed in a watering tray and arranged in a randomized block design with four replications. Subirrigation was used as needed, with ORTHO-gro^R liquid plant food added to the irrigation water once a week at a rate of 1 tablespoon per gallon of water. Supplemental light was provided. Temperature was maintained at 65^{o}F at night and 65-70^{o}F during the day.

Foliage dry weights were determined 47 days after planting; both the oats and the wheat had six to seven leaves.

Results

Stunted growth and some chlorosis and necrosis were observed on most plants grown in the 60 lb/A treated soil, while symptoms were less pronounced with the lower rate. The symptoms were not visible until the plants had three to four leaves.

Figure 5 relates the differences among treatment dry weights of wheat and oats. Although the slight reduction in dry weight with the 30 lb/A rate was not significantly different from the untreated control (see also Appendix Table 12), the 60 lb/A rate caused a significant decrease in the dry weight of both wheat and oats. Although the results indicate that glyphosate has some soil activity at extremely high rates, the activity was slight at 30 lb/A and would be expected to be negligible at normal field rates under the conditions of this experiment.

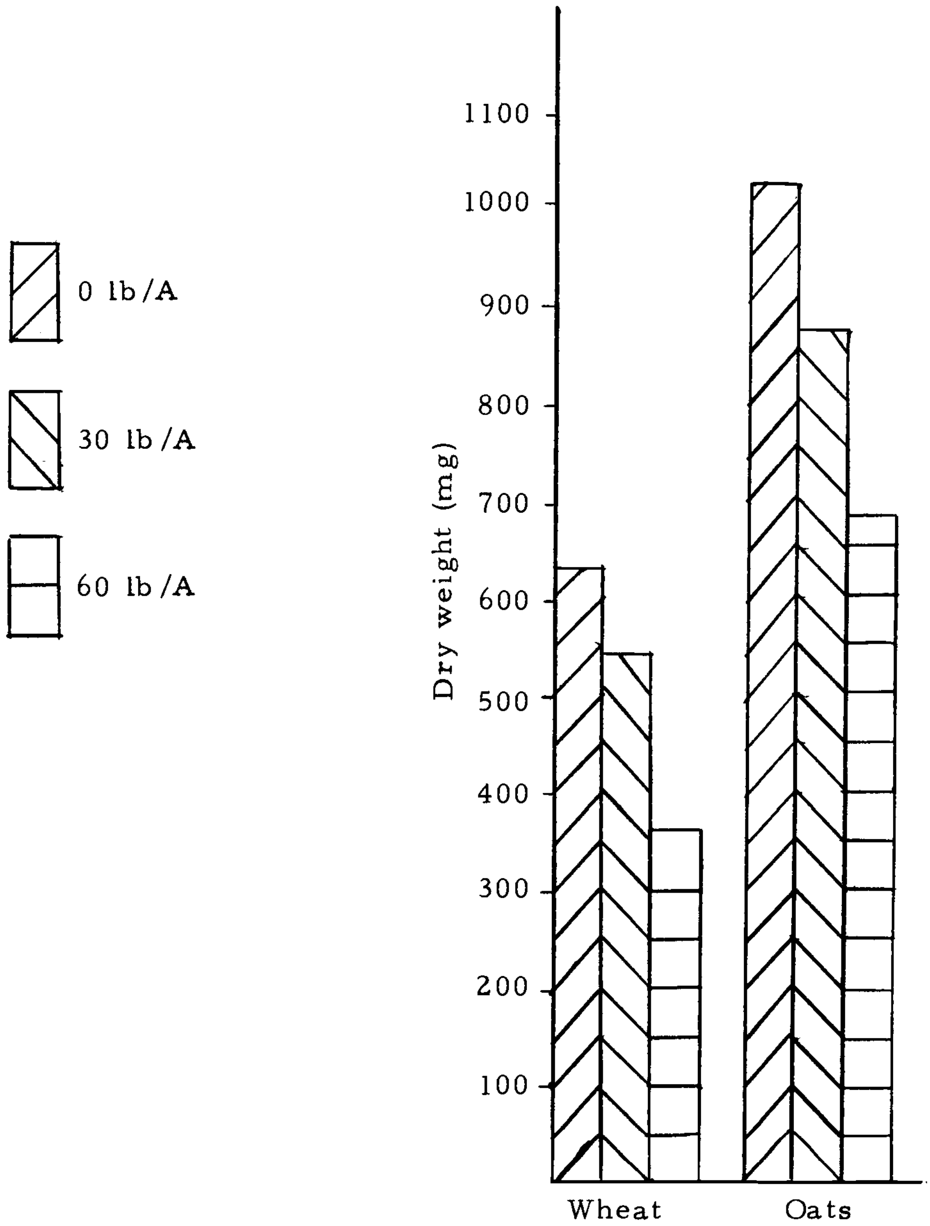

Figure 5. Dry weight of wheat and oats planted in glyphosate treated soil. Plants were harvested 47 days after planting.

PREEMERGENCE APPLICATIONS OF GLYPHOSATE TO WHEAT

Materials and Methods

Since glyphosate appeared to have a low order of soil activity, a study was established to determine the effects of glyphosate preemergence treatments to Druchamp wheat seeds at various stages of germination.

Greenhouse soil mix (64.5% sand, 17.5% silt, 17.9% clay, 1.4% organic matter) was sifted through a 0.125-inch mesh screen, air-dried and placed into 2.75 x 2.75 x 2.75 inch plastic pots at 210 grams per pot. Six Druchamp wheat seeds were planted 0.5 inch deep in each pot and seedlings were subsequently thinned to four plants per pot. The pots were placed in watering trays and arranged in a randomized block design with four replications.

Half the pots were irrigated by gently pouring 30 ml of water onto the soil surface of each pot, and the remaining half was sub-irrigated until moisture started to show on the soil surface. The stage of seed germination at each treatment was determined by examining seeds from three extra pots randomly selected at each treatment. These stages are listed in Table 3.

Treatments of the monoisopropylamine salt of glyphosate included rates of 1.5, 3.0, and 30.0 lb ae/A applied with two passes of a motor-driven greenhouse track sprayer. The total spray volume was 40

Table 3. Stage of wheat germination at three preemergence applications of glyphosate.

Time of treatment	Stage of germination
Immediately after first irrigation	Seeds starting inbibition
One day after planting	Seeds swelled and radicles enlarged but coleorhiza not ruptured.
Two days after planting	Nine seeds had primary roots 12-18 mm long, six seeds had primary roots 4-7 mm long, and three seeds had unruptured coleorhizas

gallons per acre. After each treatment, the pots were returned to the watering trays and the treated surface-irrigated pots received 20 ml of water as before. The amount of water to add had been predetermined so that it would not escape through the bottom of the pots.

The subirrigated pots received no further water after the initial application until the fourth day after planting, when all pots, including the surface irrigated pots, were subirrigated. All further watering was subirrigation as needed with 1 tablespoon of ORTHO-gro^{R} liquid plant food added per gallon of water once a week.

Supplemental light was provided and the temperature was maintained at 65-70^{o}F during the day and 65^{o}F at night. Foliage dry weights were determined 42 days after planting.

Results

The 1.5 and 3.0 lb/A treatments appeared to have little effect on Druchamp wheat. The 1.5 lb/A treatment caused etiolation in the meristematic region of two plants on each of the first two treatment dates when surface irrigated, while one plant became stunted and etiolated when treated with 3.0 lb/A on the first treatment date and surface irrigated. Two plants became stunted and dark green when treated with 3.0 lb/A on the second treatment date and subirrigated. These were the only plants to show visible symptoms of herbicide injury with the 1.5 and 3.0 lb/A rates.

The 3.0 lb/A rate did not affect the wheat on the first application date when subirrigated, and plants in only one replication were affected on this date when surface irrigated.

Figures 6 and 7 and Appendix Table 13 show the differences among dry weights of the various treatments. Only small differences were found among the dry weights of all treatments when surface irrigated, although etiolation of the leaf meristem occurred with the 30 lb/A rate when applied 1 and 2 days after planting. Etiolation and stunting were more pronounced with the 30 lb/A rate when subirrigated, and four plants were killed with this treatment on the second application date and one was killed on the third date.

These data indicate that glyphosate is relatively inactive when applied immediately after planting, but that injury increases when

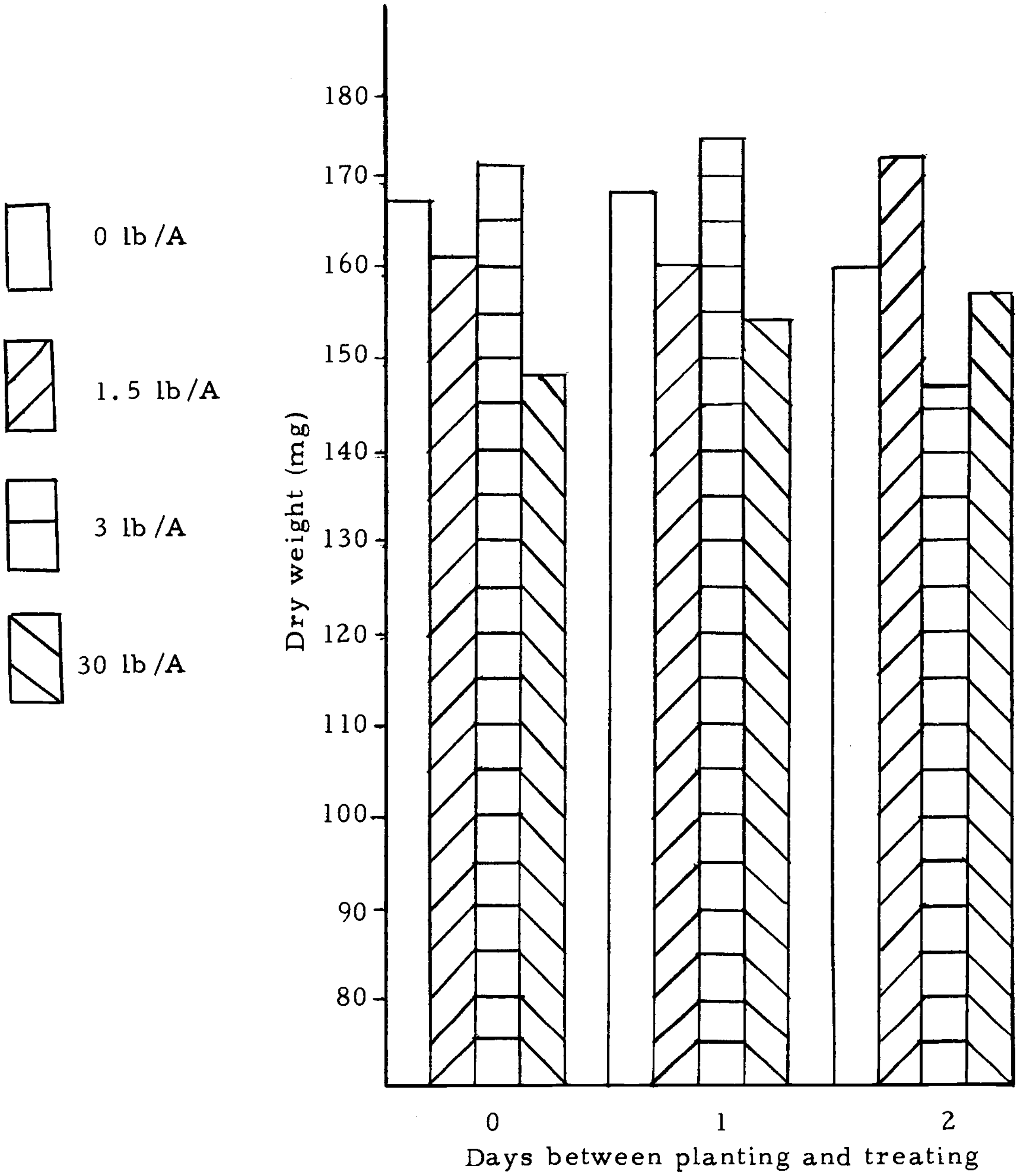

Figure 6. Dry weight of wheat treated preemergence on three application dates with glyphosate and surface irrigated. Yields were determined 42 days after planting.

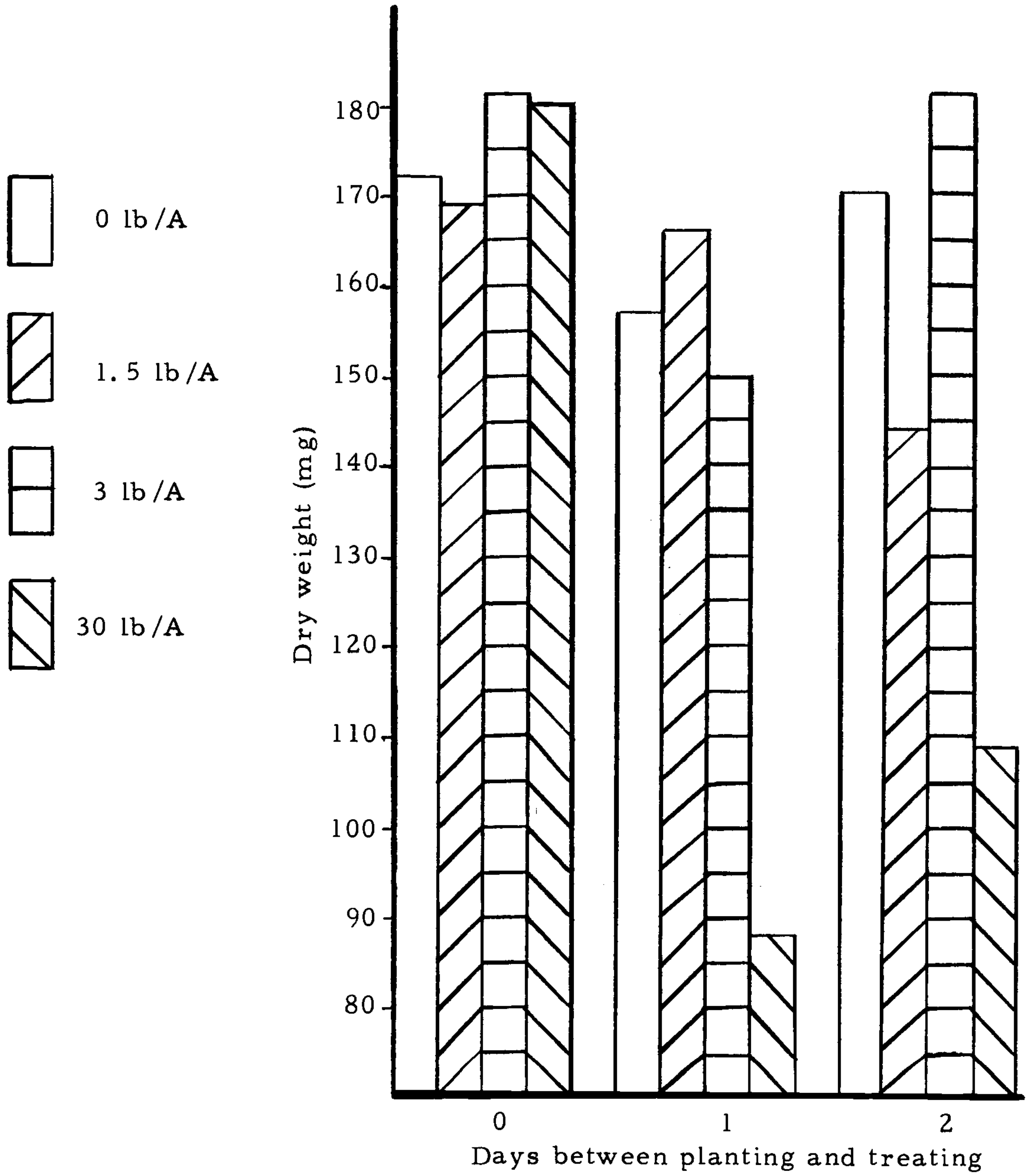

Figure 7. Dry weight of wheat treated preemergence on three application dates with glyphosate and subirrigated. Yields were determined 42 days after planting.

applications are made after germination with the 30 lb/A rate. The difference in foliage dry weights between subirrigation and surface irrigation was not significant, although the 30 lb/A rate caused a greater weight reduction with subirrigation than with surface irrigation.

EPTC RESIDUAL STUDY

Materials and Methods

A study was conducted to determine the residual life of EPTC in the soil after May 22, 1971, field applications. Soil core samples (21.1% sand, 27.2% silt, 51.7% clay, 7.2% organic matter) 1.0 inch in diameter and 6.0 inches deep were collected from each treatment on four dates after EPTC applications of 3 and 5 lb/A. The core samples were divided into 0-3 and 3-6 inch subsamples and placed in plastic bags and frozen at 0^{o}F until December 28, 1971.

On December 28, the samples were thawed, air-dried, and sifted through a 0.125-inch mesh screen. One hundred sixty-five grams of soil from each subsample were placed in each of four 2.75 x 2.75 x 2.75-inch plastic pots and 10 annual ryegrass seeds were planted 0.25 inch deep in each pot. The pots were placed in a watering tray and arranged in a randomized block design with four replications.

Subirrigation was used as needed, and the seedlings were subsequently thinned to eight plants per pot. The temperature varied from 70^{o}F at night to 70-80^{o}F during the day.

Foliage dry weights were determined 15 days after planting.

Results

The dry weights of ryegrass foliage are listed in Appendix Table

14 and are summarized in Figure 8. No visible symptoms of EPTC injury were noted with ryegrass grown in soil collected on July 31 or September 26. However, soil samples from both sampling depths and both treatment rates reduced ryegrass dry weights significantly when collected on May 30, 8 days after treatment. But results from ryegrass grown in treated soil collected on June 12, 21 days after treatment, indicated that phytotoxicity from the 3 lb/A rate had decreased significantly.

A considerable amount of EPTC residue still persisted 21 days after treatment from the 5 lb/A rate. After 2 months, residues from both EPTC rates had decreased to non-phytotoxic levels.

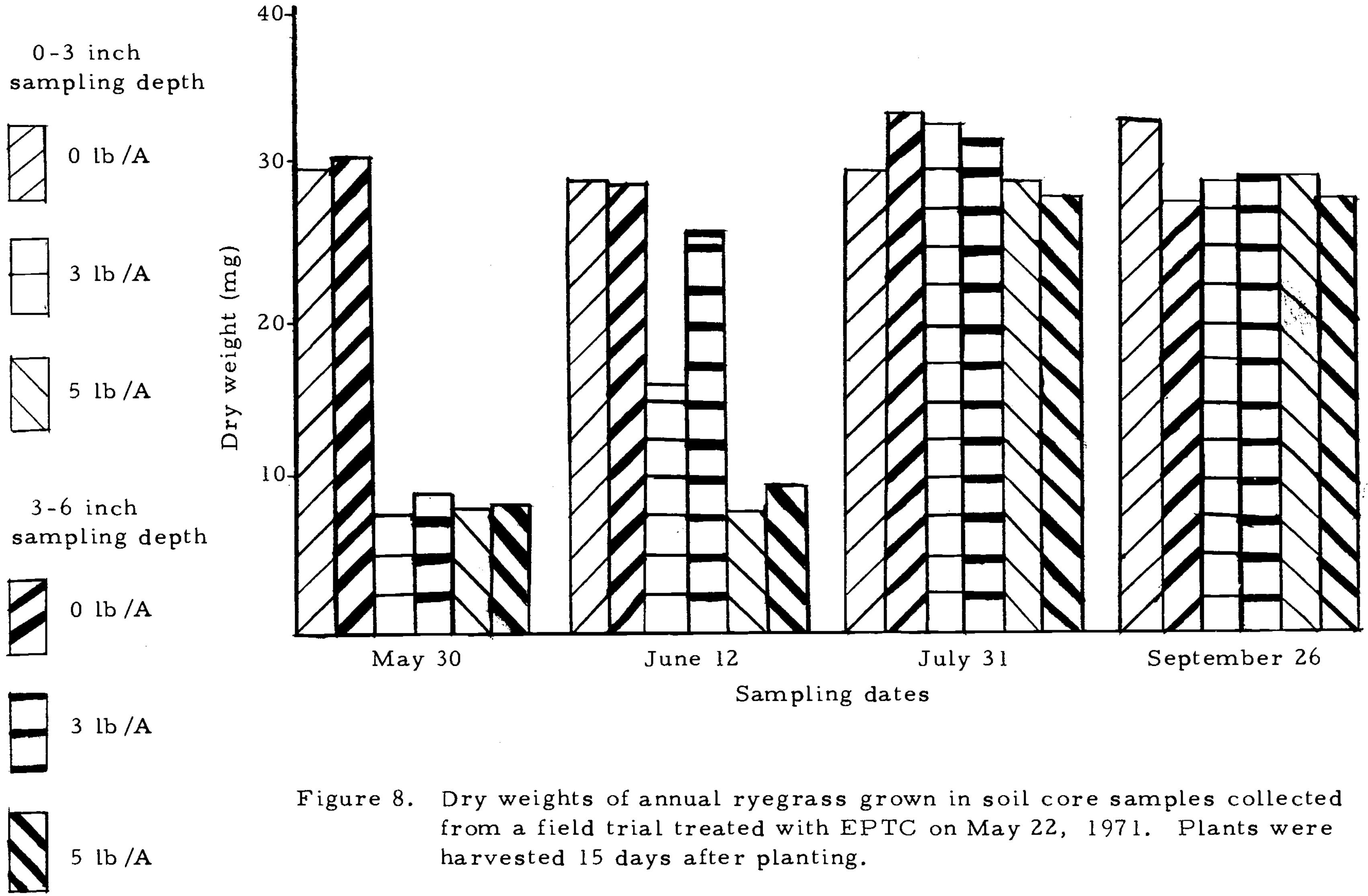

Figure 8. Dry weights of annual ryegrass grown in soil core samples collected from a field trial treated with EPTC on May 22, 1971. Plants were harvested 15 days after planting.

SIMULATED RAINFALL APPLICATIONS FOLLOWING FOLIAR APPLICATIONS OF GLYPHOSATE ON OATS

Materials and Methods

Rain within several hours after application has been observed to cause reduced performance of glyphosate (Baird and Begeman, 1972). To investigate this possibility, the monoisopropylamine salt of glyphosate was applied to oats in the greenhouse and simulated rainfall was applied at predetermined times after glyphosate application.

Eight oat seeds were planted in 2.75 x 2.75 x 2.75-inch plastic pots containing 200 grams of greenhouse soil mix. The oats were grown to the 2-leaf stage and thinned to five plants per pot. Half of the pots were then treated with glyphosate at 0.125 lb ae/A in two passes of a motor-driven greenhouse track sprayer. The total spray volume was 30 gal/A applied at 20 psi.

Simulated rainfall was applied with a spray nozzle held 10 inches above the pot rim. Treatments included washing glyphosate treated and untreated plants immediately, 1, 3, 5, and 8 hours after treatment. The pots were placed on a circular table which was rotated once every 16 seconds by an electric motor. Three millimeters of water, which required 12 rotations of the table, were applied in each washing treatment.

The pots were placed in watering trays and arranged in a randomized block design with four replications. Supplemental light was provided and the temperature was maintained at 65^{o}F at night and 65-70^{o}F during the day. The plants were subirrigated as needed and ORTHO-gro^{R} liquid plant food was added to the irrigation once a week at a rate of 1 tablespoon per gallon of water.

The foliage was harvested 27 days after treatment and dry weights were determined.

Results

The dry weight data are presented in Appendix Table 15 and summarized in Figure 9. The only treatments to show symptoms of glyphosate injury were the 5- and 8-hour washings and the unwashed control. The difference in dry weights between the treated control and the 8-hour washing was small and not statistically significant, but the dry weight of plants washed 5 hours after treatment was significantly higher than both the treated control and the 8-hour washing.

These data indicate that the effects of glyphosate were prevented when 3 mm of simulated rainfall were added 3 hours after treatment and the effects were greatly reduced when simulated rainfall followed herbicide application by 5 hours.

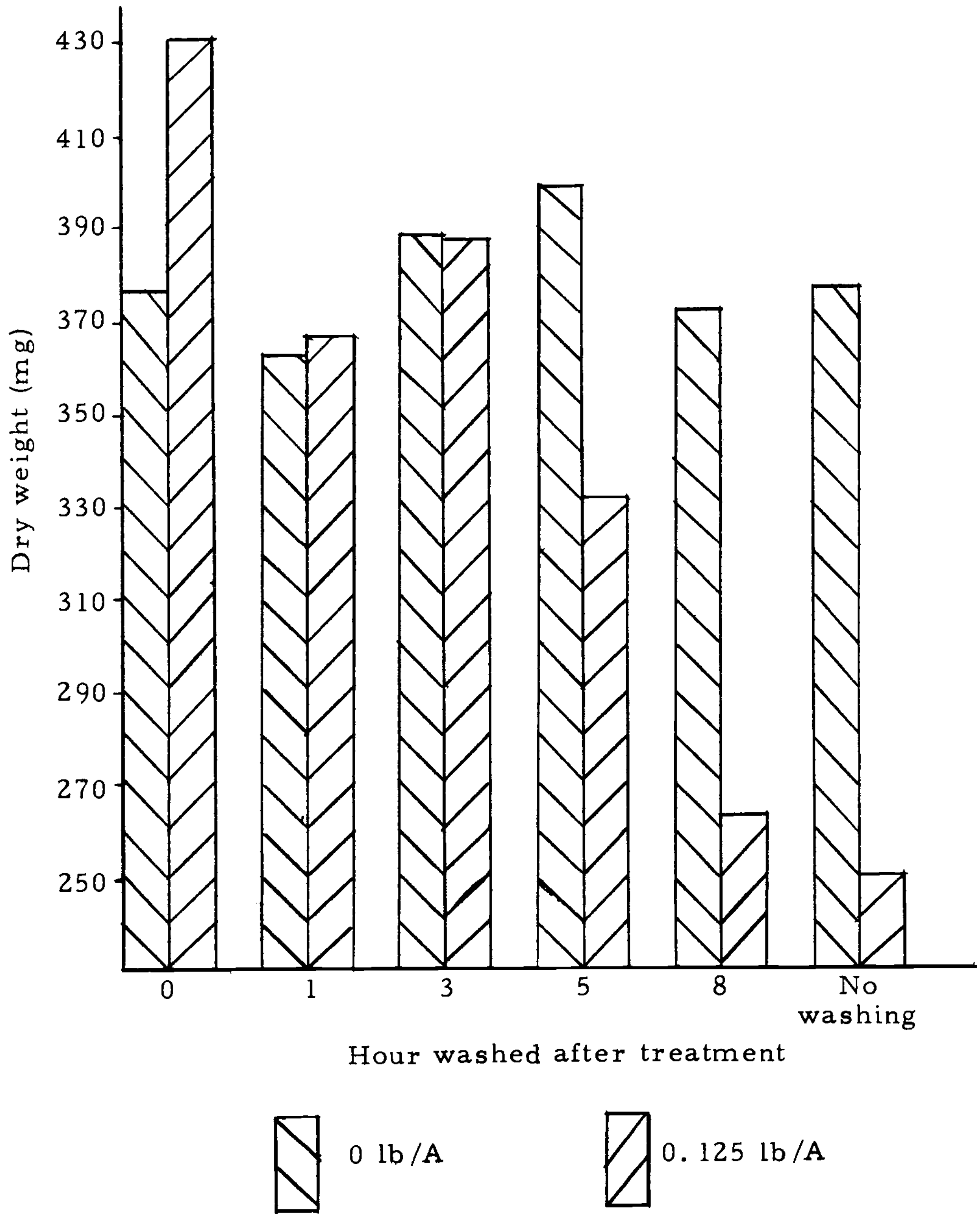

Figure 9. Dry weight of oats treated with foliar applications of glyphosate and washed with 3 mm of simulated rainfall. Oats were treated in the 2-leaf stage and plants were harvested 27 days after treatment.

TRANSLOCATION OF GLYPHOSATE IN OATS

Materials and Methods

Translocation of herbicides or their reaction products is generally considered necessary to kill most perennial weeds. The rate of translocation can determine how fast a particular herbicide will kill a weed, depending on the species, its physiological stage of growth, and environmental conditions.

Oats were used in a greenhouse study to observe the rate of translocation of glyphosate. Four seeds were planted in 2.75 x 2.75 x 2.75-inch plastic pots containing 200 grams of greenhouse soil mix. Supplemental light was provided and the temperature ranged from 65°F at night to 65-70°F during the day. The oats were subirrigated as needed and fertilized once a week with 1 tablespoon of ORTHO-gro[R] liquid plant food per gallon of irrigation water.

The seedlings were thinned to two plants per pot. When the plants had reached the 5-leaf stage, the third leaf of each plant was immersed to within 0.5 inch of the collar in a solution containing 1.0 gram of the monoisopropylamine salt of glyphosate per 125 ml of water. The treated leaves were excised at predetermined times after immersion, which included 3, 6, 9, 20, 45, and 95 hours. The third leaf of the untreated controls was excised 95 hours after immersion of the treated leaves.

The foliage was harvested 2 days after the last excision and fresh and dry weights were determined.

Results

The fresh weights of plants with treated leaves excised 9 hours or longer after immersion were significantly lower than the fresh weights of the untreated control and plants with treated leaves excised 3 or 6 hours after treatment (Appendix Table 16). The fresh weights of plants with treated leaves excised 45 and 95 hours after treatment were also significantly lower than the fresh weights of plants with treated leaves excised 9 hours after treatment.

Although none of the treatments had dry weights significantly lower than the control, there was a tendency for lower weights when excision followed immersion by 20 hours or more (Appendix Table 17). The dry weights of plants with treated leaves excised 6 hours after immersion were significantly higher than the dry weights of all other treatments including the control, and plants with treated leaves excised 3 hours after immersion were significantly higher than those with treated leaves excised 20 or 95 hours after immersion.

Figure 10 shows the general decline in fresh and dry weights when the treated leaves were excised 9 hours or longer after immersion.

The ratios of dry weights to fresh weights are presented in

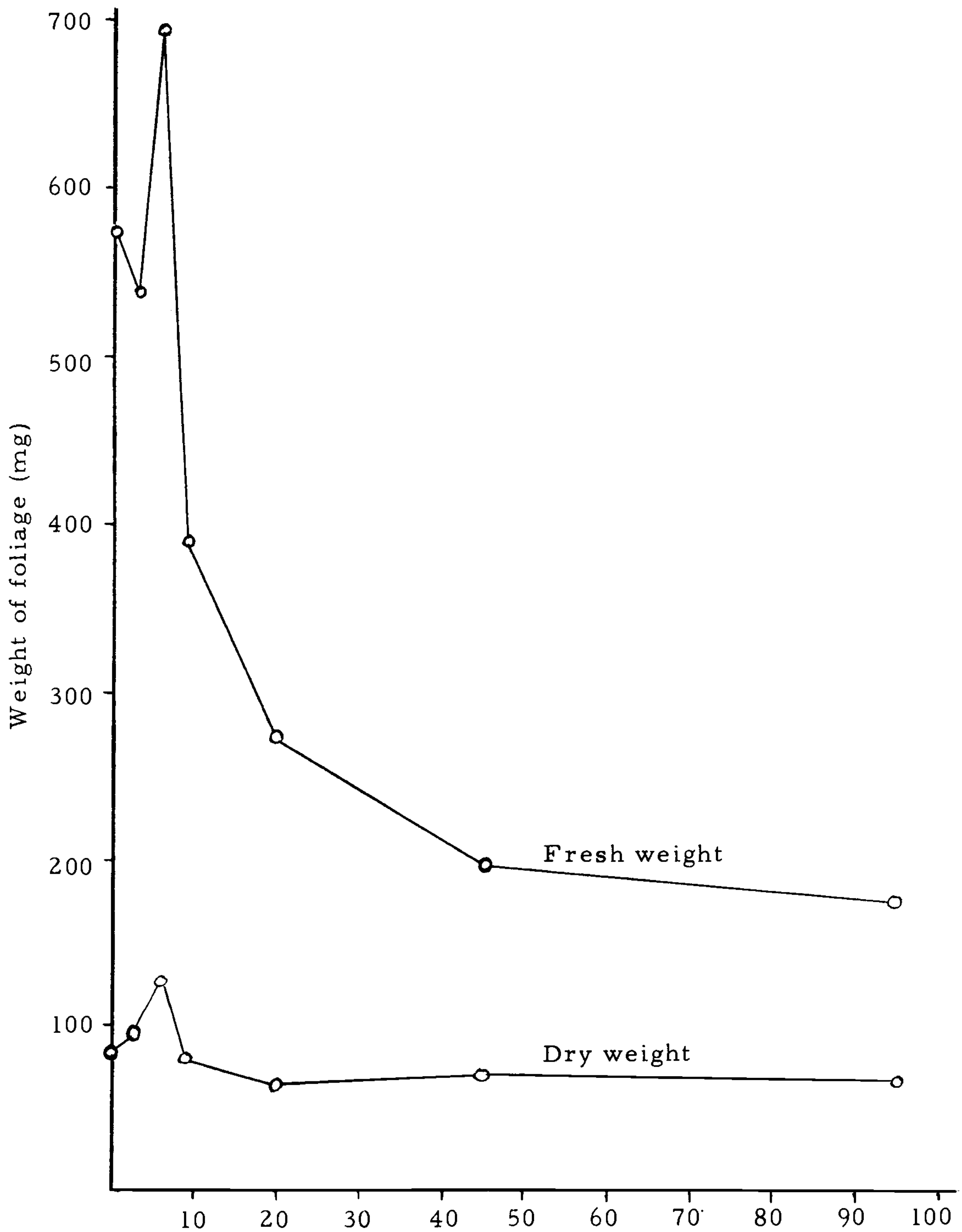

Figure 10. Fresh and dry weights of oat foliage as influenced by treatment of the third leaf with glyphosate and subsequent excision of the treated leaf.

Appendix Table 18 and summarized in Figure 11. The weight ratios for all treatments were significantly greater than the control. There was no significant difference among weight ratios of plants with treated leaves excised 3, 6, or 9 hours after immersion although there was a tendency for higher values with increasing time. The weight ratios of excision treatments 20 hours after application were higher than the previous treatments and lower than the later treatments.

These data indicate that glyphosate or its reaction products may have been translocated out of the treated leaf within 3 hours after treatment and was still being translocated out of the treated leaf 20 to 45 hours after treatment.

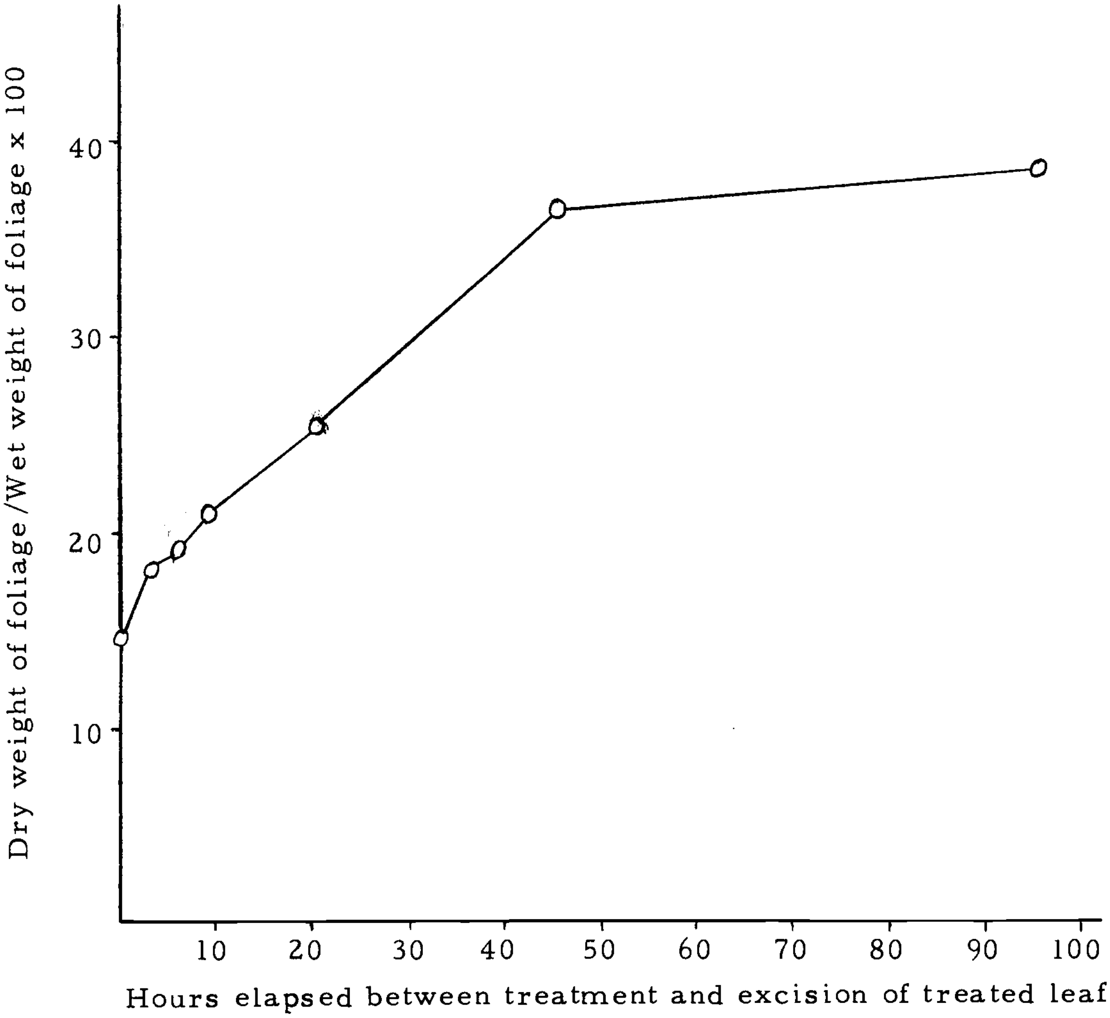

Figure 11. Dry weight of oat foliage (expressed as a percentage of the wet weight) as influenced by treatment of the third leaf with glyphosate and subsequent excision of the treated leaf.

DISCUSSION AND CONCLUSIONS

The results of the glyphosate timing trial indicate that the effectiveness of glyphosate on established bentgrass was influenced more by weather conditions than the stage of bentgrass growth. No significant differences were found among application dates when glyphosate was applied at 4 lb ae/A. This indicates that increasing the rate of glyphosate may help overcome unfavorable weather conditions or less susceptible growth stages.

Glyphosate alone did not completely eliminate bentgrass on any of the application dates. However, tillage 2 weeks after glyphosate application prevented bentgrass regeneration for at least 10 months. The dry summers of western Oregon provide an opportunity to use moisture stress to aid weed control by proper timing of herbicide applications and tillage. Tillage probably improved bentgrass control by increasing the rate of soil drying and disturbing the regenerative organs of the bentgrass.

EPTC was ineffective in controlling bentgrass under the conditions of this study, although a greenhouse bioassay indicated that sufficient EPTC to control annual ryegrass was present in soil samples collected 21 days after application.

Rapid inactivation of foliage-applied herbicides in soil allows maximum flexibility in planting a new crop since danger of seedling injury is low. However, low soil residual activity can limit the conditions under which a herbicide can be applied. A greenhouse bio-assay with wheat and oats grown in soil core samples indicated a low level of glyphosate activity in the soil.

When glyphosate was incorporated into soil at high rates immediately before planting, a reduction in dry weights of wheat and oats was observed, although none of the plants were killed. Since injury symptoms were not apparent until the plants had three to four leaves, glyphosate was probably inactivated rapidly or absorbed slowly by the plants.

Freed, Vernetti and Montgomery (1967) listed adsorption, leaching, volatilization, microbial breakdown, and chemical break-down as the five major factors which reduce effective herbicide concentrations in the soil. They also stated that adsorption is greatest in soils high in organic matter and clay. If glyphosate was adsorbed to soil colloids and not rapidly degraded or otherwise inactivated in the rooting zone, greater uptake could have occurred as the root system expanded. Since only a small fraction of the herbicide would have been in the soil solution, uptake, and therefore accumulation of a toxic level in the plant, would have been slow.

Herbicidal activity to wheat also was low when glyphosate was applied to the soil surface after germination. However, glyphosate applied at 30 lb ae/A 2 days after planting reduced the shoot growth of wheat more when subirrigated than when surface irrigated. This indicates that glyphosate may have remained at the soil surface when subirrigated and was subsequently absorbed by the emerging coleoptile and shoot.

The mechanism of inactivation of glyphosate in soils is not clear from the results of these experiments. The most plausible explanation would be either rapid adsorption or degradation.

Etiolation of the meristematic region of young leaves was common in experiments where glyphosate was added directly to the soil. This symptom could be indicative of translocation to an active metabolic sink. Translocation of herbicides can occur in either the xylem or the phloem (Franke, 1967; Robertson and Kirkwood, 1969, 1970). Once in the phloem, some herbicides can move with the photosynthate, possibly by mass flow or protoplasmic streaming (Robertson and Kirkwood, 1970).

The rate of glyphosate translocation from a treated area to other parts of a plant affects the time needed for glyphosate to kill a plant. If translocation is slow, metabolic processes conceivably could inactivate the herbicide before the plant is completely killed. A greenhouse study indicated that glyphosate or its reaction products were translocated out of oat leaves. Sufficient translocation had occurred after 3 hours to cause an increase in the dry weight:fresh weight ratio, which continued to increase for 45 to 95 hours after treatment. The dark green appearance of plants with treated leaves excised 3 hours after treatment was also indicative of glyphosate translocation. Environmental conditions as well as physiological and anatomical differences among species affect herbicide uptake and translocation (Franke, 1967; Robertson and Kirkwood, 1969). Therefore, a direct comparison of oats to bentgrass is not possible. However, only a very brief lag occurred between penetration of the cuticle and translocation of the compound out of the treated oat leaf.

The rate of penetration of phytotoxic amounts of glyphosate into the oat leaf cuticle is obviously dependent on the concentration of glyphosate on the leaf surface. Although translocation from a treated leaf was noted within 3 hours after treatment, results from the simulated rainfall experiment indicate that herbicide injury was prevented when glyphosate-treated oat foliage was washed with water 3 hours after treatment. Five to 8 hours was necessary for a lethal dose of glyphosate to be absorbed into the leaf.

The penetration of water-soluble compounds such as glyphosate into a leaf is limited mainly by the lipid character of wax and cutin layers on the leaf surface (Franke, 1967). Since penetration of a lethal dose of glyphosate takes several hours, rainfall soon after application can reduce its effectiveness.

Glyphosate appears to be an effective short-residual herbicide for controlling bentgrass. Since rototilling following treatment gave essentially complete bentgrass control, future research should concentrate on determining optimum dates and rates when combined with tillage. Experiments involving tillage implements common to pasture renovation, such as the moldboard plow and disc, are also needed.

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Appendix Table 1. The effects of foliage applications of MON-0468 to relative dry weight yields of established bentgrass on six application dates in 1971. (Plants harvested 30 days after the last application.)

Application date	Rate (lb/A)	Percent of the control				
		I	II	III	IV	average
April 19	1	3.0	3.0	5.7	7.9	4.9dc
	2	4.5	13.7	3.0	5.9	6.8d
	4	4.6	0.4	0.1	2.3	1.8ab
May 1	1	0.6	0.2	0.2	1.2	0.6a
	2	0.1	0.1	0.5	1.0	0.4a
	4	0.1	0.3	0.1	1.0	0.4a
May 19	1	1.0	0.1	5.3	1.1	1.9ab
	2	1.0	0.2	0.5	0.1	0.4a
	4	T	0	0.1	0.1	0.1a
May 29	1	0.2	0.9	0.4	0.1	0.4a
	2	0	0.1	0	T	T a
	4	0	0	0	0	0.0a
June 12	1	0.3	2.1	9.1	0.1	2.9cb
	2	0	0.1	0.4	0	0.1a
	4	0	0.1	0.1	0	0.1a
June 26	1	0.1	0.1	0.3	0.2	0.2a
	2	0	0	0.6	0	0.2a
	4	0.1	0	0	0	T a
Control	0	100	100	100	100	100 e

T = Trace

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of variance for data in Appendix Table 1.

Source of variation	d. f.	SS	MS	F
Replications	3	14.87	4.96	3.50**
Rate of MON-0468	2	24.58	12.29	8.67**
Date of application	5	168.35	33.67	23.75**
Rate x date	10	137.43	13.74	9.69**
Error	51	72.32	1.42	
Total	71	417.55		

**Significant at the 1% level.

$LSD_{.05} = 1.7\%$

$LSD_{.01} = 2.3\%$

$S_{\overline{X}} = 0.59$

C. V. = 10.2%

Appendix Table 2. The effects of foliage applications of MON-0468 to established bentgrass on six application dates in 1971. (Percent control determined 5 months (November 29) after the last application.)

Application date	Rate (lb/A)	Percent control I		II		III		IV		average
April 19	1	88	88	84	76	55	65	60	64	72 cd
	2	90	85	62	57	90	86	85	85	80 de
	4	90	88	90	94	93	97	80	84	90 efg
May 1	1	90	86	85	90	65	71	78	86	81 def
	2	95	93	99	99	85	91	75	85	90 efg
	4	95	95	95	91	99	99	85	85	93 efg
May 19	1	50	40	50	50	35	35	25	39	40 b
	2	80	80	80	76	50	46	50	60	65 c
	4	99	99	97	99	99	99	98	94	98 g
May 29	1	92	88	65	60	45	45	60	56	64 c
	2	99	99	90	90	80	76	89	92	89 efg
	4	100	99	99	99	99	99	80	90	96 fg
June 12	1	85	85	60	72	50	40	70	66	66 c
	2	80	80	94	88	80	84	86	90	85 defg
	4	99	99	99	99	94	96	99	97	98 g
June 26	1	99	97	95	97	94	98	99	99	97 g
	2	95	95	99	99	99	99	99	97	98 g
	4	99	99	100	99	99	99	100	100	99 g
Control	0	0	0	0	0	0	0	0	0	0 a

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of variance for data in Appendix Table 2.

Source of variation	d.f.	SS	MS	F
Replications	3	1,309.39	436.46	5.79**
Rate of MON-0468	2	7.723.86	3,861.93	51.27**
Date of application	5	5,850.15	1,170.03	15.53**
Rate x date	10	4,120.43	412.04	5.47**
Error	51	3,841.61	75.33	
Total	71	22,845.44		

**Significant at the 1% level.

$LSD_{.05} = 12.4\%$

$LSD_{.01} = 16.5\%$

$S_{\overline{X}} = 4.34$

C. V. = 10.4%

Appendix Table 3. The effects of foliage applications of MON-0468 to established bentgrass on six application dates in 1971. (Percent control determined 9 months (March 29) after the last application.)

Application rate	Rate (lb /A)	Percent control								
		I		II		III		IV		average
April 19	1	35	35	65	60	15	20	35	30	37 cd
	2	70	70	60	60	60	65	40	35	58 defg
	4	80	75	90	85	75	80	70	75	79 gh
May 1	1	65	70	84	87	65	60	70	70	71 efgh
	2	90	87	90	96	87	90	80	80	88 h
	4	75	70	95	93	85	85	70	70	80 gh
May 19	1	20	25	25	25	10	15	0	0	15 ab
	2	25	35	55	55	45	45	65	60	48 cde
	4	90	92	90	90	95	93	85	85	90 h
May 29	1	34	40	50	60	25	30	60	50	43 cd
	2	95	95	75	80	75	80	80	75	82 h
	4	95	95	90	87	90	95	70	70	86 h
June 1	1	65	65	10	0	55	55	0	10	32 bc
	2	60	65	55	60	85	80	85	89	72 fgh
	4	99	99	85	80	92	94	75	70	87 h
June 26	1	60	60	85	85	30	25	25	20	49 cdef
	2	60	65	85	90	70	75	55	60	70 efgh
	4	90	95	85	80	80	80	90	90	86 h
Control	0	0	0	0	0	0	0	0	0	0 a

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of variance for data in Appendix Table 3.

Source of variation	d. f.	SS	MS	F
Replications	3	1, 593. 26	531. 09	2. 58n. s.
Rate of MON-0468	2	23, 391. 70	11, 695. 85	56. 87**
Date of application	5	6, 095. 39	1, 219. 08	5. 93**
Rate x date	10	5, 626. 93	562. 69	2. 74**
Error	51	10, 489. 05	205. 67	
Total	71	47, 196. 33		

**Significant at the 1% level.

n. s. = not significant

$LSD_{.05}$ = 20. 4%

$LSD_{.01}$ = 27. 3%

$S_{\overline{X}}$ = 7. 17

C. V. = 22. 0%

Appendix Table 4. The effects of foliage applications of MON-0468 to relative yields of trailing blackberry on six application dates. (Plants harverted 30 days after the last application.)

Application date	Rate (lb/A)	Percent of the control				
		I	II	III	IV	average
April 19	1	63.6	96.8	42.9	101.7	76.2
	2	181.8	141.9	106.6	119.0	137.3
	4	0	51.6	70.3	55.2	44.3
May 1	1	160.0	22.6	8.8	100.0	72.8
	2	56.4	67.7	24.2	37.9	46.6
	4	9.1	32.2	12.1	48.3	25.4
May 19	1	9.1	100.0	36.3	6.9	38.1
	2	45.4	0	13.2	19.0	19.4
	4	0	35.5	25.3	12.1	18.2
May 29	1	49.1	51.6	30.8	17.2	37.2
	2	14.5	12.9	13.2	15.5	14.0
	4	14.5	22.6	0	22.4	14.9
June 12	1	105.4	29.0	5.5	55.2	48.8
	2	0	41.9	67.0	55.2	41.0
	4	3.6	61.3	79.1	15.5	39.9
June 26	1	63.6	35.5	12.1	36.2	36.9
	2	40.0	83.9	28.6	39.7	48.1
	4	143.6	29.0	9.9	0	45.6
Control	0	100	100	100	100	100

Analysis of variance for data in Appendix Table 4.

Source of variation	d. f.	SS	MS	F
Replications	3	4, 789. 15	1, 596. 38	1. 41n. s.
Rate of MON-0468	2	6, 390. 99	3, 195. 50	2. 83n. s.
Date of application	5	31, 332. 55	6, 266. 51	5. 54**
Date x rate	10	18, 842. 28	1, 884. 29	1. 67n. s.
Error	51	57, 664. 85	1, 130. 68	
Total	71	119, 019. 82		

**Significant at the 1% level.

n. s. = not significant

$LSD_{.05}$ = 50. 9%

C. V. = 75. 2%

Appendix Table 5. The effects of foliage applications of MON-0468 to relative yields of subterranean clover on six application dates. (Plants harvested 30 days after the last application.)

Application date	Rate (lb/A)	Percent of the control				
		I	II	III	IV	average
April 19	1	197.7	144.1	100.0	153.8	148.9
	2	93.0	8.1	67.4	295.4	116.0
	4	5.5	64.9	32.6	513.8	154.2
May 1	1	71.1	0	16.9	135.4	55.8
	2	13.3	5.4	57.3	1.5	19.4
	4	0.8	4.5	44.9	23.1	18.3
May 19	1	4.7	0	298.9	21.5	81.3
	2	3.1	0	0	4.6	1.9
	4	4.7	0.9	1.1	35.4	10.5
May 29	1	16.4	15.3	30.3	1.5	15.9
	2	0	1.8	0	0	0.4
	4	0	0	0	0	0
June 12	1	13.3	8.1	119.1	0	35.1
	2	0	0	61.8	0	15.4
	4	0	0	2.2	0	0.5
June 26	1	1.6	0.9	3.4	103.1	27.2
	2	14.1	0	74.2	27.7	29.0
	4	100.0	0	1.1	0	25.3

Analysis of variance for data in Appendix Table 5.

Source of variation	d. f.	SS	MS	F
Replications	3	35, 419. 15	11, 806. 38	2. 01n. s.
Rate of MON-0468	2	12, 893. 88	6, 446. 94	1. 10n. s.
Date of application	5	143, 467. 27	28, 693. 46	4. 88**
Rate x date	10	12, 445. 36	1, 244. 54	0. 21n. s.
Error	51	299, 976. 75	5, 881. 90	
Total	71	504, 202. 41		

**Significant at the 1% level.

n. s. = not significant

$LSD_{.05}$ = 109. 3%

C. V. = 182. 8%

Appendix Table 6. The effects of tillage to May 22 applications of MON-0468 on established bentgrass. (Percent control determined 177 days after the last treatment.)

Treatment	Rate (lb/A)	Percent control I		II		III		IV		average
No tillage	0	0	0	0	0	0	0	0	0	0
	1	72	65	55	55	92	88	90	90	76
	2	99	96	95	92	97	94	91	90	94
	4	98	98	99	99	99	97	97	96	98
Tillage on May 22	0	40	35	71	75	49	40	43	50	50
	1	60	60	80	80	89	95	67	60	73
	2	63	60	63	60	72	65	82	85	69
	4	97	95	85	90	74	65	96	95	87
Tillage on June 5	0	50	43	50	50	86	80	55	65	60
	1	99	99	99	100	99	99	99	98	99
	2	99	99	99	98	99	97	99	99	99
	4	99	99	99	99	99	99	99	100	99

Analysis of Variance

Source of variation	d.f.	SS	MS	F
Replications	3	243.54	81.18	0.77n.s.
Rates of MON-0468	3	24,677.21	8,225.74	77.52**
Tillage	2	4,672.57	2,336.29	22.02**
Rates x tillage	6	7,696.64	1,282.77	12.09**
Error	33	3,501.46	106.11	
Total	47	40,791.42		

**Significant at the 1% level.

n.s. = not significant

$LSD_{.05} = 14.9\%$

$LSD_{.01} = 20.0\%$

C.V. = 13.7%

Appendix Table 7. The effects of tillage to May 22 applications of MON-0468 on established bentgrass. (Percent control determined 298 days after the last treatment.)

Treatment	Rate (lb/A)	Percent control								
		I		II		III		IV		average
No tillage	0	0	0	0	0	0	0	0	0	0
	1	70	80	75	70	75	80	70	70	74
	2	85	90	95	95	95	95	95	90	92
	4	80	80	98	95	85	90	95	90	89
Tillage on May 22	0	10	10	60	60	37	42	47	55	40
	1	48	55	70	65	80	70	65	60	64
	2	50	45	65	70	50	40	70	65	57
	4	90	90	80	75	55	60	92	95	80
Tillage on June 5	0	50	40	10	20	70	75	45	50	45
	1	99	98	97	99	97	98	95	97	98
	2	98	99	99	97	98	99	99	98	98
	4	99	98	99	98	98	98	98	97	98

Analysis of Variance

Source of variation	d.f.	SS	MS	F
Replications	3	415.68	138.56	0.91n.s.
Rates of MON-0468	3	27,708.72	9,236.24	60.78**
Tillage	2	5,586.59	2,793.30	18.38**
Rates x tillage	6	6,044.70	1,007.45	6.63**
Error	33	5,014.63	151.96	
Total	47	44,770.33		

**Significant at the 1% level.

n.s. = not significant

$LSD_{.05}$ = 17.8%

$LSD_{.01}$ = 24.0%

C.V. = 17.6%

Appendix Table 8. The effects of soil incorporation of EPTC on May 22, 1971, to established bentgrass. (Percent control determined 177 days (November 29) after treatment.)

Treatment	Rate (lb/A)	Percent control								
		I		II		III		IV		average
No tillage	0	0	0	0	0	0	0	0	0	0
Tillage	0	25	35	60	50	60	60	55	60	51
	3	70	65	68	60	63	65	52	45	60
	5	55	55	69	65	80	75	62	55	65

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	299. 92	99. 97	1. 14n. s.
Treatment	3	10, 591. 55	3, 530. 52	40. 40**
Error	9	786. 52	87. 39	
Total	15	11, 677. 98		

**Significant at the 1% level.

n. s. = not significant

$LSD_{.05}$ = 14. 1%

$LSD_{.01}$ = 19. 5%

C. V. = 21. 4%

Appendix Table 9. The effects of soil incorporation of EPTC on May 22, 1971, to established bentgrass. (Percent control determined 298 days (March 29) after treatment.)

Treatment	Rate (lb/A)	Percent control I		II		III		IV		average
No tillage	0	0	0	0	0	0	0	0	0	0
Tillage	0	10	5	15	20	20	20	25	20	17
	3	15	15	20	25	25	25	20	15	20
	5	20	15	25	25	20	25	25	30	23

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	134.38	44.79	3.58*
Treatment	3	1,278.12	319.53	25.56**
Error	9	112.50	12.50	
Total	15	1,525.00		

**Significant at the 1% level.

*Significant at the 5% level.

$LSD_{.05}$ = 5.3%

$LSD_{.01}$ = 7.9%

C. V. = 23.6%

Appendix Table 10. Height of wheat grown in soil core samples from 0-2 inch depth treated with MON-0468. (Plant heights (cm) were determined 32 days after planting.)

Rate (lb/A)	Subsamples	Plant height (cm)				
		I	II	III	IV	mean
0	1	35.2	37.0	39.5	41.7	
	2	41.3	36.8	33.8	39.8	
	3	32.6	39.5	38.5	40.9	
	4	39.7	39.0	39.5	40.5	
	Avg.	37.2	38.1	37.8	40.7	38.5
4	1	38.3	38.4	34.9	44.0	
	2	33.5	41.2	37.4	40.1	
	3	36.0	38.1	38.0	27.7	
	4	43.1	37.7	41.9	39.5	
	Avg.	37.7	38.8	38.0	37.8	38.1

Analysis of Variance

Source of variation	d.f.	SS	MS	F
Replications	3	14.47	4.82	0.37n.s.
Rate of MON-0468	1	0.95	0.95	0.07n.s.
Rate x replication	3	17.73	5.91	0.46n.s.
Error	24	309.50	12.90	
Total	31	342.64		

n.s. = not significant
C.V. = 9.4%

Appendix Table 11. Height of oats grown in soil core samples from 0-2 inch depth treated with MON-0468. (Plant heights (cm) were determined 32 days after planting.)

Rate (lb/A)	Subsamples	Plant height (cm)				
		I	II	III	IV	mean
0	1	40.2	37.7	35.8	27.5	
	2	37.9	37.0	35.5	35.0	
	3	37.2	36.1	36.2	30.8	
	4	39.8	33.3	38.3	39.4	
	Avg.	38.8	36.0	36.4	33.2	36.1
4	1	37.6	40.0	33.3	38.6	
	2	34.0	38.5	33.1	32.9	
	3	35.9	34.2	34.3	35.8	
	4	36.4	37.2	30.1	40.4	
	Avg.	36.0	37.5	32.7	36.9	35.8

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	42.80	14.27	2.01n. s.
Rate of MON-0468	1	0.88	0.88	0.12n. s.
Rate x replication	3	75.40	25.13	3.55*
Error	24	169.95	7.08	
Total	31	289.03		

*Significant at the 5% level.

n. s. = not significant

C. V. = 7.4%

Appendix Table 12. The effects of soil incorporation of MON-1139 to wheat and oats planted immediately after treatment. (Dry weights (mg) were determined 47 days after planting.)

Species	Rate (lb/A)	Dry weights (mg) I	II	III	IV	average
Wheat	0	703	668	578	552	625
	30	495	534	489	636	538
	60	399	246	362	437	361
Oats	0	900	986	1162	1019	1017
	30	860	683	836	1092	868
	60	882	566	582	691	680

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	51, 323. 83	17, 107. 94	1. 54n. s.
Rates of MON-1139	2	366, 461. 08	183, 230. 54	16. 48**
Species	1	721, 054. 67	721, 054. 67	64. 84**
Rate x species	2	6, 146. 08	3, 073. 04	0. 28n. s.
Error	15	166, 800. 17	11, 120. 01	
Total	23	1, 311, 785. 83		

**Significant at the 1% level.

n. s. = not significant

$LSD_{.05}$ = 159

$LSD_{.01}$ = 220

C. V. = 15. 5%

Appendix Table 13. The effects of preemergence applications of MON-1139 and two irrigation methods to Druchamp wheat. (Dry weights (mg) were determined 42 days after planting.)

Days between planting and treating	Rate (lb/A)	Dry weights (mg)				
		I	II	III	IV	average
		Subirrigation				
0	0	136	169	172	212	172
	1.5	150	153	172	200	169
	3.0	168	214	170	172	181
	30.0	163	221	128	209	180
1	0	149	128	224	126	157
	1.5	150	146	193	174	166
	3.0	116	164	128	192	150
	30.0	30	142	58	125	88
2	0	144	150	172	212	170
	1.5	173	140	136	129	144
	3.0	179	174	164	207	181
	30.0	132	58	173	74	109
		Surface irrigation				
0	0	162	158	156	192	167
	1.5	170	132	218	125	161
	3.0	177	127	181	198	171
	30.0	88	128	183	194	148
1	0	150	152	185	185	168
	1.5	170	115	174	179	160
	3.0	171	175	152	196	174
	30.0	161	146	194	116	154
2	0	163	153	153	173	160
	1.5	174	142	192	180	172
	3.0	155	182	129	122	147
	30.0	205	169	77	178	157

Analysis of variance for data in Appendix Table 13.

Source of variation	d. f.	SS	MS	F
Replications	3	5, 321. 36	1, 773. 79	1. 61n. s.
Irrigations	1	536. 76	536. 76	0. 49n. s.
Date of applications	2	3, 983. 77	1, 991. 89	1. 81n. s.
Rate of MON-1139	3	11, 328. 36	3, 776. 12	3. 42*
Irrig. x date	2	6, 713. 27	3, 356. 64	3. 04n. s.
Irrig. x rate	3	4, 321. 11	1, 440. 37	1. 31n. s.
Date x rate	6	4, 657. 73	776. 29	0. 70n. s.
Irrig. x date x rate	6	9, 850. 73	1, 641. 79	1. 49n. s.
Error	69	76, 109. 89		
Total	95	122, 822. 99		

*Significant at the 5% level.

n. s. = not significant

$LSD_{.05}$ = 47 mg

C. V. = 21. 0%

Appendix Table 14. Dry weight (mg) of annual ryegrass grown in soil core samples collected on four dates in 1971. EPTC was applied on May 22, 1971. (Yields were harvested 15 days after planting.)

Sampling date	Rate (lb/A)	Depth (inches)	Dry weight (mg) I	II	III	IV	average
May 30	0	0-3	31	35	30	23	29.8cd
		3-6	24	30	38	30	30.5cd
	3	0-3	7	9	6	7	7.5a
		3-6	11	4	10	10	8.8a
	5	0-3	7	12	9	4	8.0a
		3-6	6	11	10	6	8.2a
June 12	0	0-3	28	28	35	26	29.2cd
		3-6	27	32	30	27	29.0cd
	3	0-3	18	14	18	15	16.2b
		3-6	34	19	27	28	26.2c
	5	0-3	10	8	8	6	8.0a
		3-6	5	13	10	10	9.5a
July 31	0	0-3	24	34	34	27	29.8cd
		3-6	29	37	34	34	33.5d
	3	0-3	35	34	28	34	32.8d
		3-6	32	33	30	32	31.8cd
	5	0-3	28	33	30	26	29.2cd
		3-6	24	28	33	28	28.2cd
September 26	0	0-3	38	37	28	30	33.2d
		3-6	30	28	23	30	27.8cd
	3	0-3	33	29	32	23	29.2cd
		3-6	34	27	31	26	29.5cd
	5	0-3	29	34	29	26	29.5cd
		3-6	27	29	26	30	28.0cd

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of variance for data in Appendix Table 14.

Source of variation	d. f.	SS	MS	F
Replications	3	88.78	29.59	2.44n. s.
Depth of soil samples	1	12.76	12.76	1.05n. s.
Rate of EPTC	2	2,274.33	1,137.17	93.69**
Date of sampling	3	4,080.36	1,360.12	112.06**
Depth x rate	2	46.08	23.04	1.90n. s.
Depth x date	3	108.20	36.07	2.97*
Rate x date	6	2,079.17	346.53	28.55**
Depth x rate x date	6	140.58	23.43	1.93n. s.
Error	69	837.47	12.14	
Total	95	9,667.74		

**Significant at the 1% level.

*Significant at the 5% level.

n. s. = not significant

$LSD_{.05}$ = 4.9 mg

$LSD_{.01}$ = 6.5 mg

C. V. = 14.6%

$S_{\overline{X}} = 1.74$

$\overline{\overline{X}} = 23.9$

Appendix Table 15. The effects of simulated rainfall on the herbicidal activity of foliar applied MON-1139 to oats.

Hour washed after treatment	Dry weight (mg) I	II	III	IV	average
	MON-1139 1/8 lb/A				
No washing	184	305	244	267	250a
0	444	394	471	410	430c
1	357	379	364	366	366bc
3	413	373	350	412	387bc
5	205	390	301	428	331b
8	210	330	233	281	263a
	MON-1139 not applied				
No washing	356	393	384	373	376bc
0	353	368	403	380	376bc
1	384	337	394	331	362bc
3	334	402	350	467	388bc
5	405	381	389	417	398bc
8	415	395	380	294	371bc

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	8, 025. 50	2, 675. 17	1. 68*
Rate of MON-1139	1	19, 758. 08	19, 758. 08	12. 38**
Washings	5	53, 051. 25	10, 610. 25	6. 65**
Rate x washing	5	50, 171. 17	10, 034. 23	6. 29**
Error	33	52, 659. 00	1, 595. 73	
Total	47	183, 665. 00		

**Significant at the 1% level.

*Significant at the 5% level.

$LSD_{.01}$ = 78 mg

$LSD_{.05}$ = 68 mg

$S_{\bar{X}}$ = 19. 9

C. V. = 11. 2%

Appendix Table 16. The effects of excising a MON-1139 treated leaf on the fresh weight of oat foliage. (Foliage was harvested 6 days after herbicide application.)

Hours excised after treatment		Fresh weight (mg)								
		I		II		III		IV		average
Control	95	496	917	565	533	420	615	554	466	571dc
	3	657	535	531	461	510	371	734	478	535c
	6	734	485	328	774	912	866	649	777	691d
	9	198	244	202	398	497	627	368	560	387b
	20	179	350	130	170	412	346	272	316	272ab
	45	347	154	177	149	170	224	122	217	195a
	95	146	181	319	153	199	196	101	92	173a

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	78,030.71	26,010.24	1.78n.s.
Treatments	6	1,933,129.93	322,188.32	22.05**
Replications x treatments	18	370,757.79	20,597.66	1.41n.s.
Error	28	409,185.00	14,613.75	
Total	55	2,791,103.43		

**Significant at the 1% level.

n.s. = not significant

$LSD_{.05} = 124$

$LSD_{.01} = 167$

$S_{\overline{X}} = 42.6$

C. V. = 30.0%

Appendix Table 17. The effects of excising a MON-1139 treated leaf on the dry weight of oat foliage. (Foliage was harvested 6 days after herbicide application.)

Hours excised after treatment		Dry weight (mg)								
		I		II		III		IV		average
Control	95	72	131	91	75	63	90	77	65	83ab
	3	100	104	96	79	98	68	126	92	95b
	6	138	121	73	160	151	141	112	116	126c
	9	37	63	44	67	100	121	74	132	80ab
	20	56	84	41	67	71	68	56	62	63a
	45	120	57	80	64	67	54	43	71	70ab
	95	61	76	110	53	78	70	41	36	66a

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	1,180.05	393.35	0.73n.s.
Treatments	6	23,468.86	3,911.48	7.25**
Replications x treatments	18	11,699.57	649.98	1.21n.s.
Error	28	15,102.50	539.38	
Total	55	51,450.98		

**Significant at the 1% level.

n.s. = not significant

$LSD_{.05} = 24$

$LSD_{.01} = 32$

$S_{\overline{X}} = 8.2$

C.V. = 34.0%

Appendix Table 18. The effects of excising a MON-1139 treated leaf on the ratio of dry weight to fresh weight of oat foliage. (Foliage was harvested 6 days after herbicide application.)

Hours excised after treatment		Dry weight/Fresh weight x 1000 I		II		III		IV		average
Control	95	145	143	161	141	150	146	139	140	146a
	3	152	195	181	171	192	183	172	192	180b
	6	188	249	223	207	166	163	173	149	190b
	9	188	260	218	168	201	193	201	236	208b
	20	313	240	315	394	172	196	206	196	254c
	45	346	370	452	430	394	241	353	327	364d
	95	419	420	345	346	392	357	406	391	384d

Means followed by the same letter do not differ significantly at the 5% level.

Analysis of Variance

Source of variation	d. f.	SS	MS	F
Replications	3	17,378.93	5,792.98	5.87**
Treatments	6	417,799.43	69,633.24	70.60**
Replications x treatments	18	50,345.57	2,796.98	2.84**
Error	28	27,618.00	986.36	
Total	55	513,141.93		

**Significant at the 1% level.

$LSD_{.05}$ = 32.2%

$LSD_{.01}$ = 43.4%

$S_{\overline{X}}$ = 11.1

C. V. = 12.7%