AN ABSTRACT OF THE THESIS OF

Christopher Hilgert for the degree of Master of Science in Horticulture presented on April 24, 2003.

Title: Evaluation of Natural and Synthetic Preemergence Herbicides used in Ornamental Landscapes

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Ann Marie VanDerZanden / Thomas W. Cook

A series of field experiments conducted at the Lewis-Brown horticulture farm at Oregon State University evaluated the performance of four preemergence herbicides in simulated ornamental shrub beds. Two natural products, corn gluten meal (CGM) and meadowfoam seedmeal (MFS), were used along with two synthetic products, prodiamine purchased under the trade name Barricade® 65WG herbicide and Team 2G herbicide containing active ingredients trifluralin and benefin. The efficacy of these products was evaluated on four weed species commonly found in the Willamette Valley of Oregon, *Digitaria sanguinalis* (crabgrass), *Poa annua* (annual bluegrass), *Senecio vulgaris* (common groundsel) and *Medicago lupulina* (black medic). The objective of this research was to determine if these natural products could be used as effectively as their

synthetic counterparts to control weeds. Throughout each field experiment, CGM and MFS provided poor weed control results, and performance of the synthetic herbicides was superior to the natural products. Following each respective manufacturer's label recommendations, prodiamine and trifluralin + benefin provided acceptable to excellent preemergence control of all weed species screened with the exception of *Senecio vulgaris*. MFS provided temporary control of the two broadleaf weeds, but did not prevent either grass species from emerging and establishing. At this time MFS is not a commercially available product, and this research found MFS to be unreliable and impractical for use as a preemergence herbicide in ornamental landscapes. CGM was ineffective against all four weeds even at rates twice the maximum recommended label rate. Following CGM's unsatisfactory performance in four field experiments, further research examining growth and development of *Digitaria sanguinalis* seedlings treated with CGM at the time of planting was conducted in a series of greenhouse experiments. Root length measurements were documented 28 days after treatment (DAT). Foliage was removed 28 DAT, dried for 14 days and weighed. In these greenhouse experiments *Digitaria sanguinalis* increased in both foliar dry weight and root length when comparing CGM treatments to the control. Root length and foliar dry weight increased as CGM rates increased. CGM failed to control *Digitaria sanguinalis* even at rates of up to nine times the maximum recommended label rate.

Evaluation of Natural and Synthetic Preemergence Herbicides used in Ornamental Landscapes

by

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Christopher Hilgert, Author

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CONTRIBUTION OF AUTHORS

Tom Cook assisted with the design of experiments and writing in Chapters 2 and 3. Ann Marie VanDerZanden was involved in writing Chapters 2 and 3.

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General Introduction

Weed control in ornamental landscapes is a continuous challenge faced by homeowners, commercial landscapers, and gardeners. Traditionally, synthetic herbicides, mulch, and manual labor have been used to manage weeds in shrub beds. Researchers are now examining natural products to help homeowners control weeds. Two natural products, corn gluten meal (CGM) and meadowfoam seedmeal (MFS) have undergone testing for use as preemergence herbicides against weedy grasses and broadleaf plants (Bingaman and Christians, 1995; Vaughn, Boydston, and Mallory-Smith, 1996).

Meadowfoam (*Limnanthes alba*) is grown in the Willamette Valley of Oregon as an oilseed crop used in the manufacturing of cosmetics, lubricants, and plastics. The seedmeal remaining after oil extraction contains the glucosinolate glucolimnanthin (Bartelt and Mikolajczak, 1989), which degrades to produce isothiocyanates, nitriles, and thiocyanates (Vaughn, et al., 1996). Some of these products of degradation are toxic to some insect larvae (Bartelt and Mikolajczak, 1989), and fields with MFS incorporated in the soil have shown a reduction in weed populations (Vaughn et al., 1996). Our research examines MFS's potential for use in ornamental landscapes. MFS is not yet commercially available as a preemergence herbicide and due to its limited availability MFS was included in only one replicated experiment.

CGM, the protein fraction of corn grain is patented (US patent 5,030,268) as a natural product used for preemergence weed control in turfgrass (Carrow, Christians, and

Shearman, 1993) and as a fertilizer for established plants. Several dipeptides have been isolated from CGM and identified as root inhibiting compounds causing reduced seedling survival (Liu and Christians, 1994). Roots emerge, development is inhibited, and after a period of water stress the seedlings wilt and die because they do not have an adequate root system (Christians and McDade, 2000).

Prodiamine is sold under the trade name Barricade® 65WG herbicide and is a selective preemergence herbicide that controld many grass and broadleaf weeds in established turf, ornamental landscape beds, and perennial and wildflower plantings. The active ingredient prodiamine [N^3, N^3-Di-n-propyl-2, 4-dinitro-6-(trifluoromethyl)-m-phenylenediamine] is a dinitroanaline that binds to tubulin and prevents cell division as its mode of action (C & P Press, 2002).

Team 2G herbicide contains the active ingredients benefin (N-butyl-N-ethyl-α,α,α-trifluoro-2, 6-dinitro-p-toluidine) and trifluralin (α,α,α-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine) and controls several annual grass species. Trifluralin and benefin are dinitroanilines which bind to tubulin and prevent cell division as a mode of action (C & P Press, 2002).

Over a two year period, our research evaluated the performance of two synthetic preemergence herbicides, prodiamine and benefin + trifluralin, along with two natural products, Concern Weed Prevention Plus with 100% CGM as the active ingredient, and MFS. Field trials were conducted in simulated shrub beds on bare soil and on mulched plots. Four weed species, *Digitaria sanguinalis* (crabgrass), *Poa annua* (annual bluegrass), *Senecio vulgaris* (common groundsel) and *Medicago lupulina* (black medic) were screened as test subjects in a series of four experiments conducted at the Lewis-

Brown horticulture farm in Corvallis, OR during the summers of 2001 and 2002. Field experiments were initially conducted following all product label instructions. After a poor performance in the first field trial, an additional CGM treatment of twice the maximum recommended label rate was applied in three more experiments to determine if this higher application rate would improve CGM's performance as a preemergence herbicide.

Field research was followed by greenhouse research examining growth and development of *Digitaria sanguinalis* seedlings treated with CGM prior to germination in a series of four experiments. The objective of this greenhouse study was to determine if CGM suppressed *Digitaria sanguinalis* growth as a herbicide, or if it stimulated growth as a fertilizer. Because CGM's mode of action involves inhibiting root growth, and thus shoot growth, root length and foliar dry weight measurements were taken 28 days after treatment application. Treatments consisted of CGM rates of 96, 192, and 384 g ai/m^2 in three experiments with additional application rates of 24, 768, and 1536 g ai/m^2 in a fourth experiment. The 96 and 192 g ai/m^2 rates are equivalent to the recommended label rates.

Evaluation of Natural and Synthetic Herbicides used in Ornamental Landscapes

Introduction and literature review

Weed control in ornamental landscapes is a continuous challenge faced by homeowners, commercial landscapers, and gardeners. Traditionally, synthetic herbicides, mulch, and manual labor have been used to manage weeds in shrub beds. Researchers are now examining natural products to help homeowners control weeds. Two natural products recently examined for preemergence weed control are corn gluten meal (CGM) and meadowfoam seedmeal (MFS). Both have undergone testing as preemergence herbicides against weedy grasses and broadleaf plants (Bingaman and Christians, 1995; Vaughn, Boydston, and Mallory-Smith, 1996).

CGM, the protein fraction of corn grain is a natural product used for preemergence weed control in turfgrass (Christians, 1993). Greenhouse screening (Bingaman and Christians, 1995) and field experiments (Christians et al., 1993) indicated CGM reduces emergence of many annual broadleaf and grass weeds. Alaninyl-alanine and four other dipeptides have been isolated from CGM and identified as root inhibiting compounds causing reduced seedling survival (Liu and Christians, 1994). Seedling roots emerge, but development is inhibited. Emerging roots of *Lolium perenne* (perennial ryegrass) seedlings exposed to the dipeptide alaninyl-alnine in petri dishes showed extensive epidermal and cortical necrosis (Unruh, Christians, and Horner, 1997). After a period of water stress, the seedlings wilt and die because they do not have an adequate root system (Christians and McDade, 2000). CGM used in this experiment contained 10.1% nitrogen (A & L western agricultural laboratories, Modesto, CA). This nitrogen rich product when applied to turf stimulates growth of established plants. The fertilizer effect on turf in combination with herbicidal activity make this product promising as a natural weed and feed for lawns.

Meadowfoam (*Limnanthes alba*) is grown in the Willamette Valley of Oregon as an oilseed crop used in the manufacturing cosmetics, lubricants, and plastics. The seedmeal remaining after oil extraction contains a glucosinolate, glucolimnanthin (Bartelt and Mikolajczak, 1989), which degrades to produce isothiocyanates, nitriles, and thiocyanates (Vaughn et al., 1996). Some of these products of degradation are toxic to some insect larvae (Bartelt and Mikolajczak, 1989). Other studies using MFS to control grass and broadleaved weeds have shown variable levels of weed control (O'Brien, 1997; Stanley, 2001; Vaughn et al., 1996).

Prodiamine is sold under the trade name Barricade® 65WG herbicide and is a selective preemergence herbicide that controld many grass and broadleaf weeds in established turf, ornamental landscape beds, and perennial and wildflower plantings. The active ingredient prodiamine [N^3, N^3-Di-n-propyl-2, 4-dinitro-6-(trifluoromethyl)-m-phenylenediamine] is a dinitroanaline that binds to tubulin and prevents cell division as its mode of action (C & P Press, 2002).

Team 2G herbicide contains the active ingredients benefin (N-butyl-N-ethyl-α,α,α-trifluoro-2, 6-dinitro-p-toluidine) and trifluralin (α,α,α-trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine) and controls several annual grass species. Trifluralin and benefin are dinitroanilines which bind to tubulin and prevent cell division as a mode of action (C & P Press, 2002).

Methods and Materials

A series of four field experiments was conducted at the Lewis-Brown horticulture farm in Corvallis, OR during the summers of 2001 and 2002. The experimental design used was a split-strip block with four treatment replications in each of the field experiments. Land was cleared of existing vegetation, tilled, and graded to simulate a shrub bed. Each block was divided into plots 1.5 m x 2.4 m receiving a herbicide treatment. Each herbicide plot was divided by 4 weed species each seeded at 9.6 g/m^2 in strips 0.6 m wide. Herbicide treatments were made the same day as, but subsequent to seeding.

As industry standards, two synthetic products, prodiamine purchased under the trade name Barricade® 65WG herbicide, and Team 2G herbicide containing benefin and trifluralin, were used along with two natural products. CGM was purchased under the trade name Concern Weed Prevention Plus at a local garden center. MFS, which at the time of this research was not yet a commercially available herbicide and had no product label, was donated by Natural Plant Products in Salem, OR.

Experiment 1

Experiment 1 was initiated in June 2001. Treatments included four herbicides each at two rates, prodiamine (0.065 and 0.13 g ai/m^2), benefin + trifluralin (10.64 g ai/m^2 + 5.36 g ai/m^2 and 21.28 g ai/m^2 + 10.72 g ai/m^2), CGM (96 and 192 g ai/m^2), and MFS (1199 and 2398 g product/m^2), four weed species, *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* and *Medicago lupulina*, mulch (0 and 7.6 cm), and no herbicide as the control. Mulch was added to determine if weed control was enhanced when weed seeds were buried. With the exception of MFS, application rates of herbicides were made in accordance with the respective product's label. MFS rates used were at the recommendation of the distributor. Prodiamine was applied using a calibrated liquid herbicide sprayer. Benefin + trifluralin, CGM, and MFS were applied manually using a plastic can with a perforated lid similar to a large salt shaker. Herbicide and seed applications were applied to bare soil but were not mechanically incorporated into the soil.

Experiments 2 and 3

Treatments in Experiments 2 and 3 included two synthetic products at two rates, prodiamine (0.065 and 0.13 g ai/m^2) and benefin + trifluralin (10.64 g ai/m^2 + 5.36 g ai/m^2 and 21.28 g ai/m^2 + 10.72 g ai/m^2); a natural product at three rates, CGM (96, 192, and 384 g ai/m^2); four weed species, *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* and *Medicago lupulina*; and no herbicide as the control. Herbicides and weed seeds were applied to bare soil, and mulch was not used. Experiment 2 was initiated July 22, 2002. Environmental conditions were hot and dry resulting in poor germination of *Poa annua* across all treatments including the control. Experiment 3 was initiated September 25, 2002. *Digitaria sanguinalis*, a summer annual, did not germinate at this time. As a result, analyses of *Poa annua* and *Digitaria sanguinalis* were not conducted for these experiments.

Experiment 4

Treatments in Experiment 4 included three herbicides, prodiamine (0.065 and 0.13 g ai/m^2), benefin + trifluralin (10.64 g ai/m^2 + 5.36 g ai/m^2 and 21.28 g ai/m^2 + 10.72 g ai/m^2), and CGM (96, 192, and 384 g ai/m^2), four weed species, *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* and *Medicago lupulina*, mulch (0 and 7.6 cm), and no herbicide as the control. This experiment was initiated July 12, 2002 on the same land as Experiment 1. Herbicide treatments were applied to the same plots as the first experiment. A third CGM treatment, not included in the first experiment was applied onto plots receiving MFS the previous year. Seeding rates are identical to those in the previous experiments with the exception that they were seeded on top of the mulch used in Experiment 1.

Statistical Procedures

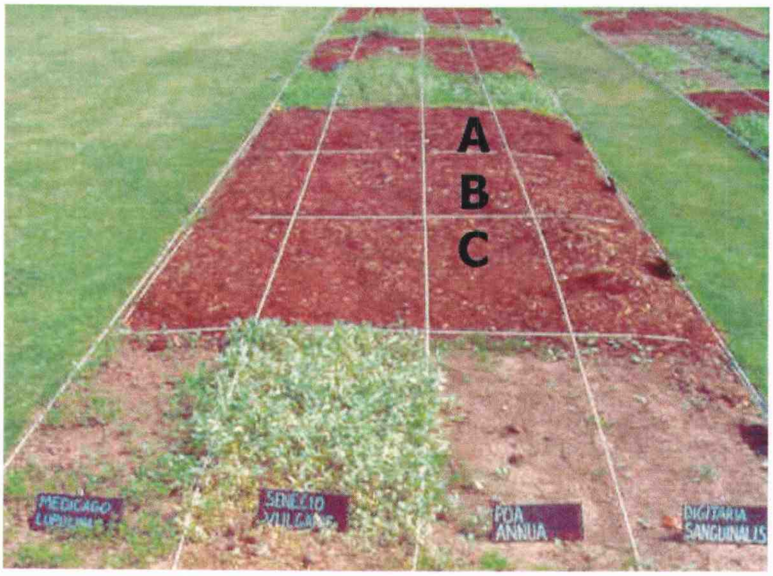
Data were recorded as a percentage of the plot area covered by each weed species for each herbicide treatment. Data in tables were collected 28 days after treatment application. Analysis of variance using the mixed procedure in SAS version 8 (SAS 1990) compared herbicide effects on each weed species separately. Comparisons were made between herbicides for each weed species. No comparisons were made between weed species for a single herbicide. Pairwise differences of all group means were compared using the Tukey-Kramer procedure. A logit transformation {logit = log[(cover + 0.5)/(100 – cover + 0.5)]} was used to convert those data to meet the assumptions of the analysis, particularly the Shapiro–Wilk test for normality. Back-transformed median values are presented, rather than mean values, due to the log-based transformation of those raw data.

Results

Mulch

The shredded hemlock mulch (7.6 cm) applied in Experiment 1 prevented emergence of *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* and *Medicago lupulina*. The buried seeds were prevented from growing with and without herbicides in combination with the mulch (Figure 2.1). For Experiment 1, the mulch factor was left out of the statistical analysis because all mulch treated plots, including the control, produced 0% weed cover. In Experiment 4, there were no differences in weed cover between herbicide applications made onto bare soil or onto mulch.

Figure 2.1 *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* and *Medicago lupulina* seed buried in plots receiving 7.6 cm mulch plus A) Corn gluten meal B) Prodiamine and C) No herbicide



Digitaria sanguinalis Crabgrass

Plots treated with prodiamine at 0.065 g ai/m^2 and 0.13 g ai/m^2 produced plots with 0%-5% *Digitaria sanguinalis* cover. *Digitaria sanguinalis* coverage ranged from 0%-8% when treated with 21.28 g ai benefin/m^2 + 10.72 g ai trifluralin/m^2. Lower rates reduced of benefin + trifluralin *Digitaria sanguinalis* coverage significantly compared to untreated plots (Table 2.1), but it allowed sparse germination within the treated plots. Plots receiving CGM applications of 96, 192, and 384 g ai/m^2 had no herbicidal activity on *Digitaria sanguinalis* as evidenced by cover equal to control plots (Table 2.2). Plots treated with MFS rates of 1199 g product/m^2 and 2398 g product/m^2 had significantly higher cover than plots not treated with herbicide, indicating a stimulating growth effect on *Digitaria sanguinalis* (Table 2.1).

Poa annua Annual Bluegrass

Prodiamine at 0.065 g ai/m^2 and 0.13 g ai/m^2 prevented emergence of *Poa annua*. Benefin + trifluralin produced plots with weak stands of *Poa annua*, and the higher rate was more effective. CGM applications of 96, 192, and 384 g ai/m^2 failed to reduce *Poa annua* cover when compared to the control. Higher CGM rates were not more effective than lower rates. Plots treated with MFS at 1199 g product/m^2 and 2398 g product/m^2 showed no evidence of herbicidal activity against *Poa annua*.

Senecio vulgaris Common Groundsel

Of the four herbicides used in this trial, none was successful in preventing emergence of *Senecio vulgaris*. MFS at 1199 and 2398 g product/m^2 and prodiamine at 0.13 g ai/m^2

initially stunted the growth of *Senecio vulgaris* seedlings. Seedlings recovered over the duration of this experiment (Figure 2.3). Prodiamine at 0.065 g ai/m^2 had little effect on *Senecio vulgaris* emergence. *Senecio vulgaris* cover in all plots recieving MFS applications was reduced compared to herbicide free plots, but complete control of the weed was not achieved. CGM failed to control *Senecio vulgaris* in these experiments. Because *Senecio vulgaris* is not listed on the label of any of these herbicides, these results are not a reflection of poor herbicidal performance.

Medicago lupulina Black Medic

Prodiamine provided the highest level of control for *Medicago lupulina*, with cover less than 3% at both application rates. Benefin + trifluralin treatments reduced median cover compared to the control, and the higher rate was more effective. MFS provided moderate reduction in *Medicago lupulina* cover initially, but the stunted plants were able to recover. MFS application rates of 1198 g product/m^2 and 2384 g product/m^2 reduced the median plot coverage of *Medicago lupulina* more than 35% compared to the control. CGM at all rates failed to control *Medicago lupulina* in these experiments.

Table 2.1 Median percent plot cover of *Digitaria sanguinalis*, *Poa annua*, *Senecio vulgaris, and Medicago lupulina* from Experiment 1.

Treatment	Rate g/m$^{2\ yz}$	*D. sanguinalis*	*P. annua*	*S. vulgaris*	*M. lupulina*
		% Coverage			
Prodiamine	0.065	1a*	1a	76b	1a
Prodiamine	0.13	1a	1a	35a	3a
BEN + TRI	21.28 + 10.72	13b	16bc	82b	34bc
BEN + TRI	10.64 + 5.36	1ab	8b	85b	32bc
Control	na	55c	43cd	94b	58c
CGM	96	59c	54d	91b	51c
CGM	192	78c	58d	97b	56c
MFS	1199	93cd	42d	27a	22b
MFS	2398	99d	69d	37a	18b

* Using the Tukey-Kramer procedure, groupings within a column assigned the same letter are not significantly different from each other ($\alpha = 0.05$).

[z] Prodiamine, benefin +trifluralin (BEN + TRI), and CGM rates given in g ai/m^2.

[y] MFS rates given in g product/m^2.

Figure 2.2 Plots receiving 1) CGM treatments of 192 g ai/m^2 and 2) prodiamine treatments of 0.13 g ai/m^2. Plot A (*Medicago lupulina*), B (*Senecio vulgaris*), C (*Poa annua*), D (*Digitaria sanguinalis*).

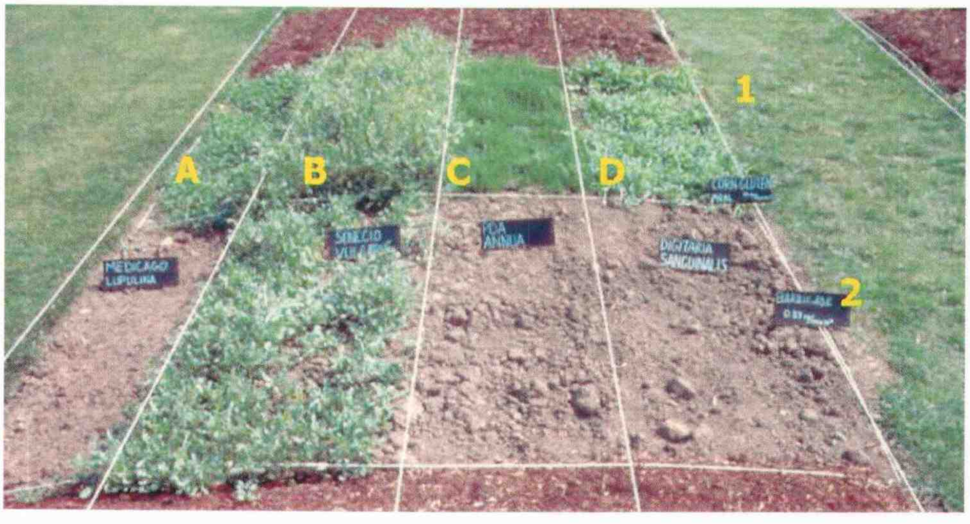


Table 2.2 Effects of synthetic and natural preemergence herbicides on percent plot cover of *Digitaria sanguinalis, Poa annua, Senecio vulgaris, and Medicago lupulina.*

Treatment	Rate	*D. sanguinalis*	*P. annua*	*S. vulgaris*	*M. lupulina*
	$g/m^{2\ yz}$	% Coverage	% Coverage	% Coverage	% Coverage
Experiment 2					
Prodiamine	0.065	0.5a*	-	63a	0.7a
Prodiamine	0.13	0.5a	-	61a	0.7a
BEN + TRI	21.28+10.72	0.5a	-	95b	45b
BEN + TRI	10.64+5.36	7b	-	98b	61bc
Control	na	88c	-	98b	91bc
CGM	96	92c	-	96b	73bc
CGM	192	95c	-	99b	76c
CGM	384	96c	-	99b	85c
Experiment 3					
Prodiamine	0.065	-	0.5a	69a	3a
Prodiamine	0.13	-	0.5a	58a	0.7a
BEN + TRI	21.28+10.72	-	1a	89b	24b
BEN + TRI	10.64+5.36	-	3a	96b	32bc
Control	na	-	78b	97b	58c
CGM	96	-	81b	96b	46c
CGM	192	-	82b	98b	51c
CGM	384	-	88b	97b	57c
Experiment 4					
Prodiamine	0.065	1a	0.5a	61a	2a
Prodiamine	0.13	1a	0.5a	57a	0.7a
BEN + TRI	21.28+10.72	1a	0.9a	83ab	36b
BEN + TRI	10.64+5.36	5b	5b	95b	61bc
Control	na	88c	83c	99c	77c
CGM	96	91c	85c	96c	66c
CGM	192	94c	88c	89c	68c
CGM	384	93c	89c	91c	73c

* Using the Tukey-Kramer procedure, groupings within a column assigned the same letter are not significantly different from each other ($\alpha = 0.05$).

[z] Prodiamine, benefin +trifluralin (BEN + TRI), and CGM rates given in g ai/m^2.

[y] MFS rates given in g product/m^2.

Discussion

Benefin plus trifluralin provided excellent control of *Poa annua,* and *Digitaria sanguinalis* but was marginal to poor against *Senecio vulgaris* and *Medicago lupulina.* Prodiamine prevented emergence of *Poa annua, Digitaria sanguinalis, and Medicago lupulina* when applied at the low and high recommended label rates. Residual control of prodiamine was observed throughout the 8 week observation period of the experiments (Figure 2.3).

MFS applied at extremely heavy rates stunted the growth of *Senecio vulgaris* and *Medicago lupulina,* but its effects were temporary. After approximately 6 weeks, the plants had recovered. Using MFS as a preemergent herbicide may inhibit growth and establishment of some weeds, but it was unable to control the broadleaf weeds in this study. MFS showed no herbicidal effect on *Digitaria sanguinalis* and *Poa annua.*

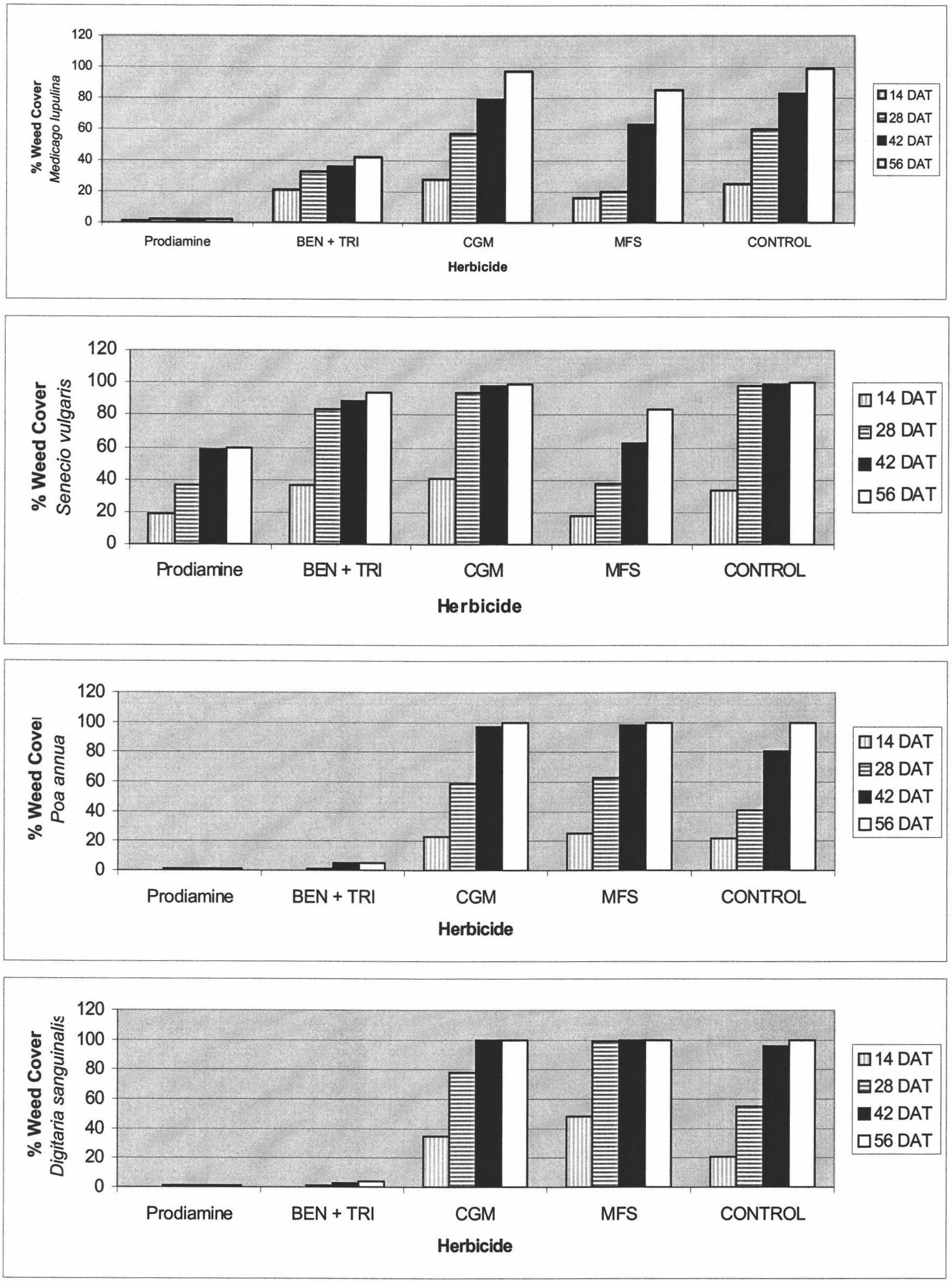
With the exception of *Senecio vulgaris*, both synthetic products were superior to natural products used in these experiments. CGM did not reduce cover of *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* or *Medicago lupulina* even at rates twice the maximum label recommendation. In all cases, weed cover in CGM treated plots was statistically equal to the untreated control. Under the conditions of this experiment, the weeds were not faced with a competition factor, as is the case in turfgrass situations. Increased plant competition might enhance the herbicidal activity of CGM if applied to turf. CGM's poor performance may be due to degradation during the processing, shipping, and, or storage of the product, or for unknown reasons related to the conditions in our experiments. Future research should evaluate CGM's performance as the product ages.

Table 2.3. Relative effectiveness of preemergence herbicides prodiamine, benefin + trifluralin, corn gluten meal, and meadowfoam seedmeal against *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* and *Medicago lupulina.*

Herbicide	Rate g/m^2	*D. sanguinalis*	*P. annua*	*S. vulgaris*	*M. lupulina*
Prodiamine	0.065	Excellent*	Excellent	Poor	Excellent
Prodiamine	0.13	Excellent	Excellent	Marginal	Excellent
BEN + TRI	10.64+5.36	Excellent	Excellent	Poor	Poor
BEN + TRI	21.28+10.72	Excellent	Excellent	Poor	Marginal
CGM	96	Poor	Poor	Poor	Poor
CGM	192	Poor	Poor	Poor	Poor
CGM	384	Poor	Poor	Poor	Poor
MFS	1199	Poor	Poor	Marginal	Marginal
MFS	3398	Poor	Poor	Marginal	Marginal

*Excellent = less than 10% weed cover; Marginal = 10% - 40% weed cover; Poor = greater than 40% weed cover

Figure 2.3 Residual effect of natural and synthetic preemergence herbicides on four weed species.



*average percent weed cover recorded 14, 28, 42, and 56 DAT

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Greenhouse Experiments Evaluate Foliar and Root Growth of *Digitaria sanguinallis* Treated with Corn Gluten Meal

Introduction

Corn gluten meal (CGM) is sold as a preemergence herbicide marketed for use in turfgrass and ornamental landscapes. CGM contains five dipeptides that have been isolated and shown to cause epidermal and cortical necrosis in emerging roots (Unruh, Christians, and Horner, 1997). In previous greenhouse studies seedling survival was reduced when seeds were exposed to CGM (Bingaman and Christians, 1995) or dipeptides extracted from CGM (Unruh et al., 1997). CGM works by allowing germination of the seed but inhibits growth of the emerging root (Unruh et al., 1997). After a period of water stress seedlings wilt and die due to an inadequate root system (Christians and McDade, 2000). Field and greenhouse research showed a reduction in germination of grass and broadleaf weeds when CGM was applied prior to germination (Christians, 1993; Bingaman and Christians, 1995). Our field research indicated CGM applied up to twice the recommended label rate did not control *Digitaria sanguinalis* (crabgrass), *Poa annua* (annual bluegrass), *Senecio vulgaris* (common groundsel) and *Medicago lupulina* (black medic) seedlings (Chapter 2). CGM is 10% nitrogen by weight, and acts as a fertilizer on established turfgrasses. This raises the question of the method by which weed populations are reduced in turfgrass when CGM is applied. Is it due to herbicidal activity or the nitrogen rich CGM invigorating turf growth that allows fewer weeds to invade? The objective of this research was to document growth response of *Digitaria sanguinalis* seed treated with CGM prior to germination.

Methods and Materials

A series of four experiments was conducted in Oregon State University's greenhouse facilities to examine CGM's effect on *Digitaria sanguinalis*. Foliar dry weights and root lengths of *Digitaria sanguinalis* were measured 28 days after seeding. Plants were grown in soil media in miniature rhizotrons designed to allow observations of the soil profile and visible roots. A reduction in root length and, or foliar dry weight of CGM treated seedlings compared to the control would indicate herbicidal activity. An increase in root length and, or foliar dry weight would be consistent with a fertilizer response.

Rhizotrons used in these experiments were designed and built specifically for this research. Three sides and the bottom of each chamber were made from marine grade MDO fiberboard. The face of each chamber was constructed using 2 removable layers of 3 mm thick plexiglass. The outside layer was black to prevent root exposure to light. The inner plexiglass layer was transparent which permitted visual inspection of root growth in the soil profile. Each chamber held a volume of soil 48 cm deep, 18 cm wide, and 4 cm thick. Soil used was a sandy loam (pH = 6.6, P = 7 ppm, K = 110 ppm, Mg = 547 ppm, Ca = 1729 ppm, Na = 69 ppm). One gram of *Digitaria sanguinalis* seed (45% pure live seed) was applied onto the soil in each chamber and covered with 3 mm peat moss to enhance germination. CGM was purchased at a local retail garden center under the trade name Concern Weed Prevention Plus containing 100% CGM as the active ingredient. Treatments consisted of CGM rates of 0, 96, 192, and 384 g ai/m^2 in three experiments with additional application rates of 24, 768, and 1536 g ai/m^2 in a fourth experiment. The 96 and 192 g ai/m^2 rates are equivalent to the recommended label rates.

Total nitrogen analysis of the CGM used was 10.1% N (A & L western agricultural laboratories, Modesto, CA). The rhizotrons were watered for seven days using a mist spray. For the duration of the experiments, plants were watered twice each week.

Digitaria sanguinalis root length data were collected 28 DAT. The removable plexiglass wall allowed the roots to be seen and measured without being disturbed. Root lengths were measured from the soil level down to a point containing the main mass of the root tips in the rhizotron. At 28 DAT, all above ground foliage was removed and dried in a solar drier at 50° C for 14 days prior to weighing.

Statistical Procedures

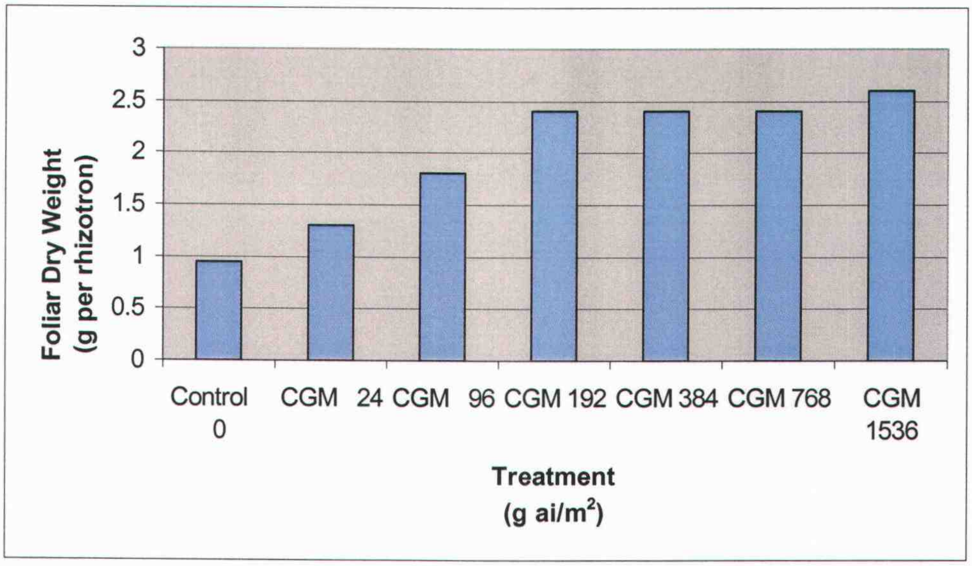
The experiments were completely randomized designs with four treatments and eight replicates per treatment in three repeated experiments. An additional unrepeated experiment contained seven treatments with 4 treatment replications. Analysis of variance (ANOVA) was conducted using Statistix 7.0. Comparison of means was conducted using Fisher's test to project the least-significant difference (LSD).

Results

Foliar dry weight

CGM's recommended label rates (96, and 192 g ai/m^2) provided no evidence of preemergence control of *Digitaria sanguinalis*. Even applications of 1536 g ai/m^2 (9 times the maximum recommended label rate) did not reduce growth, as indicated by increased foliar dry weights. Comparison of means indicated that higher rates of CGM consistently produced greater foliar dry weights of *Digitaria sanguinalis* than lower CGM rates which indicates a nitrogen fertilizer response. All CGM treatments produced greater foliar dry weights than the control in each experiment. Mean foliar dry weight of *Digitaria sanguinalis* from three repeated experiments are presented in Table 3.1. Figure 3.1 displays results from a fourth experiment examining additional rates of CGM.

Figure 3.1 Effects of corn gluten meal on mean foliar dry weight of *Digitaria sanguinalis* 28 DAT.



LSD (0.05) = 0.41

Root length

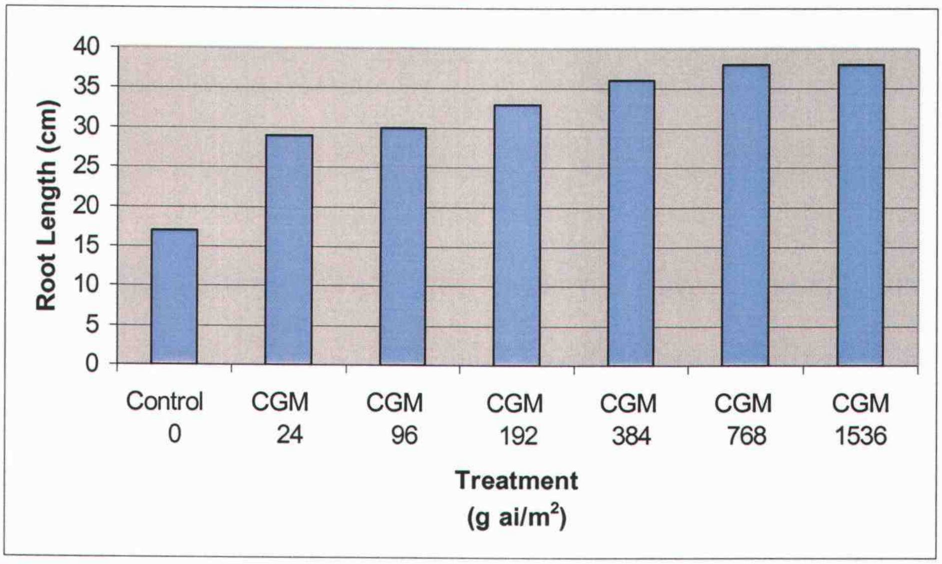
Digitaria sanguinalis root growth was not suppressed in any experiment, at any CGM rate. Root lengths increased as CGM application rates increased (Figure 3.1 and 3.2). The recommended label rates (96, and 192 g ai/m^2) produced plants with longer roots compared to the control, and higher CGM rates produced increased root lengths. Mean root length of *Digitaria sanguinalis* from three repeated experiments are presented in Table 3.1. Figure 3.2 displays results from a separate experiment examining three additional application rates of CGM. Figure 3.3 shows soil profile and root length of *Digitaria sanguinalis* grown in rhizotrons used in these experiments.

Table 3.1 Effects of corn gluten meal on mean foliar dry weight and mean root length of *Digitaria sanguinalis* 28 days after seeding.

Treatment	Dry Weight g/rhizotron			Root Length cm/rhizotron		
Control	0.9*	2.5	0.7	17	34	18
CGM 96 g ai/m^2	1.8	3.1	1.1	30	39	21
CGM 192 g ai/m^2	2.4	3.7	1.4	33	44	23
CGM 384 g ai/m^2	2.4	4.6	2.0	35	43	26
LSD (0.05)	0.4	0.4	0.3	4.7	2.9	2.8

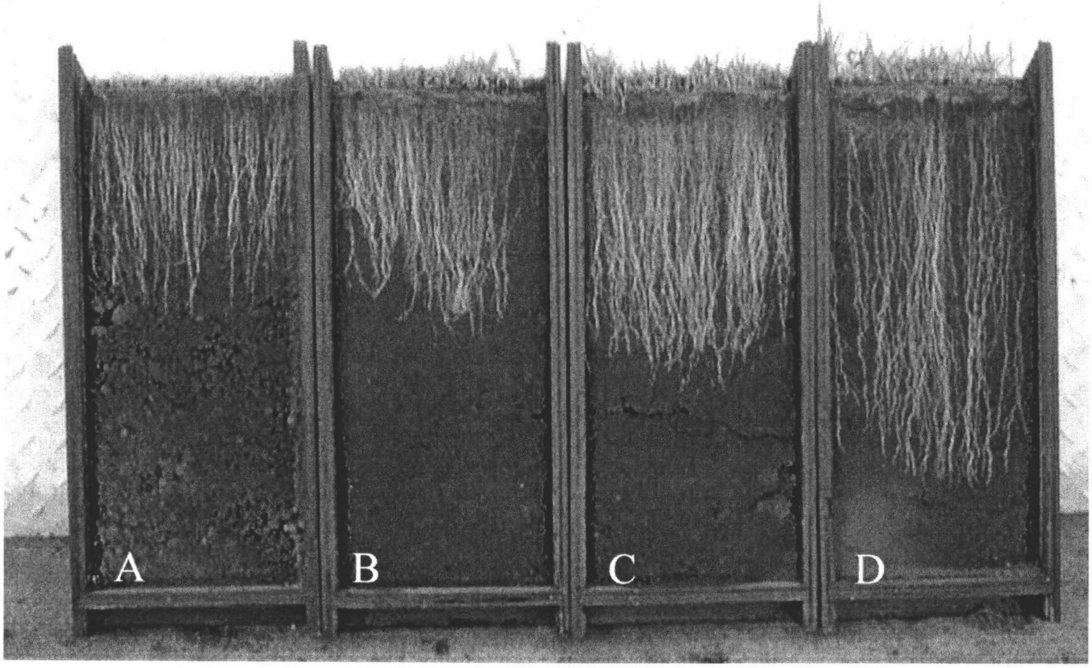
*Each column represents results from one of three repeated experiments with 8 treatment replications each.

Figure 3.2 Effects of six rates of corn gluten meal on mean root lengths of *Digitaria sanguinalis* 28 DAT.



LSD (0.05) = 4.7

Figure 3.3. Rhizotrons receiving A) CGM 0 g ai/m^2, B) CGM 96 g ai/m^2, C) CGM 192 g ai/m^2, and D) 384 g ai/m^2 showing root systems of *Digitaria sanguinalis* 28 DAT.



Discussion

In these experiments the recommended product label rate was ineffective at controlling *Digitaria sanguinalis*. In contrast, growth of *Digitaria sanguinalis* treated with CGM was consistent with a fertilizer response. In three repeated experiments, root lengths and dry weights increased as CGM rates increased. To determine if higher rates would provide effective control, an additional experiment containing CGM treatments up to eight times the maximum label rate was conducted. Even at the highest application rate of 1536 g ai/m^2, no inhibition of growth was observed. Results of these experiments are consistent with a fertilizer response.

Although other research reduced germination of annual weeds treated with CGM, our research showed no herbicidal activity. CGM may be attractive because of the minimal safety risks posed by this natural product, but it failed to inhibit growth or emergence of *Digitaria sanguinalis* in these experiments. The CGM used in these experiments was purchased at a local retail nursery. Our research indicates the product may have shelf life problems due possibly to breakdown of the active ingredient during storage and handling. Additional research is needed to evaluate effects of storage on activity of this product.

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Conclusion

With the exception of *Senecio vulgaris*, both synthetic products provided weed control superior to the natural products used in field experiments. CGM did not reduce cover of *Digitaria sanguinalis, Poa annua, Senecio vulgaris,* or *Medicago lupulina.* In all cases, weed cover in CGM treated plots was statistically equal to the control. It was clear that when used in simulated shrub beds, CGM was not effective in reducing emergence of weed species screened in this research. MFS applied at extremely heavy rates stunted the growth of *Senecio vulgaris* or *Medicago lupulina*, but its effects were temporary, and use of this product at such extreme rates is impractical. MFS was ineffective in controlling *Digitaria sanguinalis* and *Poa annua.* These results show that using MFS as a preemergence herbicide may inhibit germination and establishment of some weeds, but is unable to provide adequate weed control.

Although natural products are appealing because of low safety risk and minimal environmental impacts, both natural products used in our research were failed to control weeds. Additionally, the minimum recommended label rate of CGM cost is \$52.00/1000 ft^2 based on the retail price of CGM purchased for this research. This cost is over 52 times the suggested retail price of BAR, (\$0.93/1000 ft^2) and over 25 times the cost of TEAM (\$1.75/1000 ft^2). MFS did impact the growth of two broadleaf weeds, but effects were temporary. The synthetic herbicides BAR and TEAM provided excellent preemergent weed control of three common weed species found in the Willamette Valley of Oregon.

The interest in environmentally friendly products has lead to the release of natural products to the home gardening market. This research demonstrated two such products were ineffective as preemergence herbicides. In greenhouse research CGM actually stimulated root and shoot growth as evidenced by increased root length and foliar dry weight of treated plants when compared to the untreated control. Because of their poor performance, this research does not support use of CGM or MFS as preemergence herbicides. It appears that synthetic products offer the most reliable, cost effective preemergence control of *Digitaria sanguinalis, Poa annua,* and *Medicago lupulina*.

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