Organic Weed Control Solutions in Broccoli

Project Report to:

Certified Organic Association of BC

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Prepared by:

Jackson Chu, Lena Syrovy and Heather Meberg
E.S. Cropconsult Ltd.
3041 West 33rd Avenue, Vancouver, BC, V6N 2G6
604-266-6560
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Abstract

A need for cost-effective weed control has been identified as a major concern among organic growers. Mechanical cultivation and hand weeding currently provide effective control, however high labour costs make hand weeding increasingly uneconomical. Trials were conducted in transplanted broccoli and cranberry in Delta, BC in 2006 to evaluate two naturally derived herbicides, corn gluten meal (CGM) and vinegar, as potential tools for organic weed management.

The broccoli study consisted of six replications of five treatments: CGM broadcast and incorporated at transplant, at 200g / m^2; vinegar sprayed twice on weeds at 1:2 (1X) and 1:3 (2X) parts water to vinegar; hand cultivation (twice); and an unweeded control. The cranberry study consisted of eight replications of three treatments: CGM broadcast at 200g / m^2; vinegar at the 2X rate, sprayed once on weeds; and an unweeded control. Common weeds in the broccoli study included pigweed (*Amaranthus* spp.), lamb's quarter (*Chenopodium* spp.), chickweed (*Stellaria* spp.), creeping Charlie (*Glechoma* spp.), shepherd's purse (*Capsella* spp.), and lady's thumb (*Polygonum* spp.), while bog blueberry, blackberry, vetch, and juncus were most abundant in the cranberry study.

Broccoli plots were assessed twice for percentage weed cover and number of weeds. An additional study was conducted to determine phytotoxicity to broccoli plants. Cranberry plots were assessed before and after treatment to determine percentage weed cover and phytotoxicity to cranberry plants.

In the broccoli study, a significant treatment X location interaction was observed, as weed cover was higher along the field edge than within the field. Under lower weed

pressure in the middle of the field, vinegar applied at 1X or 2X rates produced similar % weed cover and number of weeds to hand cultivation after one application. The lowest levels of weed cover were achieved with the 2X vinegar treatment. After two applications, all four methods were successful at reducing the number of weeds compared to the uncultivated control.

Along the field edge where weed pressure was higher, no treatments were effective at suppressing weeds on the first sampling date. The two vinegar rates and hand cultivation resulted in fewer weeds along the edge after two applications. The highest percent weed cover and weed counts were found in corn gluten meal plots, while the 2X vinegar rate had lowest weed cover and number.

Significant yellowing, browning or bleaching symptoms were observed on both broccoli and cranberry plants in vinegar-treated plots, indicating phytotoxicity. Thus vinegar will need to be used with care to minimize the risk of crop damage. Further work to examine appropriate timing of vinegar sprays with other weed control options, such as mechanical cultivation, is needed.

Introduction

Weed management is a major concern of organic vegetable crop production. Mechanical cultivation is widely regarded as the most commonly used non-chemical, weed control method (Smith et al., 2000). However, cultivation does not eliminate all weeds and hand weeding is often required, which maybe time consuming as well as cost prohibitive for the grower. Several natural herbicide alternatives have been suggested to be effective in controlling weeds in organic crops, including corn gluten meal and vinegar.

Corn gluten meal (CGM) is a by-product of the wet-milling process of corn and is an animal feed product (McDade 1999). CGM has been found to have several growth-regulating effects on certain monocotyledonous and dicotyledonous weed species (Christians, 1991; Liu & Christians, 1994, 1997; Liu et al., 1994; Gardner et al., 1997; McDade, 1999; McDade & Christians, 2000). CGM inhibits weed germination by preventing the formation of root systems in plants (Christians, 1993). However, it has also been shown to decrease seedling survival in several crops through this same process (McDade & Christians, 2000).

Limited research has also shown that vinegar (acetic acid) may have potential as a natural herbicide (Chadran, 2003; Chadran et al., 2004; Coffman et al., 2004a, 2004b; Radhakrishnan et al., 2002, 2003). Vinegar acts as a contact herbicide, destroying cell membranes resulting in tissue desiccation (Webbler & Shrefler, 2006). However, vinegar is also non-selective and may also damage the crop depending on the application method (Coffman et al., 2004a, 2004b; Radhakrishnan et al., 2003).

The purpose of this study was to investigate the efficacy of corn gluten meal and vinegar as potential weed management tools for organic vegetable production. In addition, a smaller phytotoxicity study was conducted to examine the potential negative effects of vinegar on the crop.

Methods: Efficacy

Description of study field

The study was conducted in an organic broccoli field in Delta, British Columbia Canada. Broccoli (var. italica) seed was first planted in a seed bed on June 5th and seedlings transplanted in the same field on June 27. Typical weed species found in this field and fields in the vicinity are: pigweed (*Amaranthus* spp.), lamb's quarter (*Chenopodium* spp.), chickweed (*Stellaria* spp.), creeping Charlie (*Glechoma* spp.), shepard's purse (*Capsella* spp.), lady's thumb (*Polygonum* spp.), vetch (*Vicia* spp.), pineapple weed (*Matricaria* spp.), horsetails (*Equisetum* spp.), and various grasses. Although the field was mechanically cultivated as per the growers practice, plots used for this study were flagged off prior to cultivation and were not mechanically cultivated.

Treatments and experimental design

The experiment consisted of five treatments: corn gluten meal, vinegar 2X, vinegar 1X, hand cultivation and control. Each treatment was replicated 6X and divided between two areas of the field (blocks). The two blocks were chosen due to a difference in weed pressures. Block 1 (east edge) had high weed pressure and block 2 (midfield) had lower weed pressure. Plots were 2.5 m long by 2.0 m wide with 1.0 m wide buffer zones between plots (Fig. 1).

Corn gluten meal was applied on June 27 with a manual hand crank fertilizer spreader at a rate of 200g / m^2. The corn gluten meal was then incorporated into the top 0.05 m of soil using a hand cultivator. On July 11th vinegar at both 1x (1 part water: 2 parts vinegar) and 2x (1 part water: 3 parts vinegar) recommended rates were applied via backpack pump sprayers. Vinegar treatments were applied to the plots a second time on July 25. The vinegar treatments were sprayed between rows of open canopy broccoli to mimic application by a boom sprayer. Hand cultivated plots were weeded twice on July 11th and July 25. Buffer areas between plots were also hand weed on these same dates. Treatment details are summarized in Table 1.

Data collection and analysis

The effect of the different weed control tactics was assessed twice first, on July 25 when broccoli plants were still small. The second assessment was done on August 17, when plants were near harvest. Efficacy was measured in two ways: weed cover and number of weeds. A 25cm^2 quadrat was placed randomly in each plot and the percent weed cover in the quadrat was recorded. The number of weeds within the 25cm^2 quadrat was also counted and for each plot we did four separate weed counts in four different quadrat locations. Thus the weed count for each plot represents the total weed count in four 25cm^2 quadrats. For the August 17 assessment only the number of individual weeds above the crop canopy were counted because the crop canopy had closed by this point and weeds had grown to above the canopy. The quadrats were placed on the crop canopy and again counts for each plot were the total of four locations. The effect of weed management tools on weed cover, measured once on July 25, was analyzed using two-way ANOVA (block X treatment). Effect of treatment on number of weeds, counted on

July 25 and Aug 17 was analyzed with two-way repeated measure MANOVA (block X treatment X time).

Methods: Phytotoxicity

A small-scale vinegar phytotoxicity trial was performed on 18 broccoli plants located in the same field as the efficacy study. Plants were located in a single row and were randomly assigned to either the water control, 1X or 2X vinegar treatment. Between each plant there was a 100 cm buffer. Plants were sprayed with the assigned solution to run-off. Phytotoxicity was assessed on August 22, 2006. The proportion of each plant with phytotoxicity symptoms (describe the phytoxicity symptoms) was recorded. Results were compared with a one-way ANOVA.

Table 1. Summary of treatment details for organic weed control efficacy study.

Treatment	Application method	Application date(s)	Application rate	Notes
Corn gluten meal	Broadcast	June 27, 2006	200g / m^2	The corn gluten meal was then incorporated into the top 0.05 m of soil using a hand cultivator
Vinegar 1X	Backpack Sprayer	July 11,2006 July 25, 2006	1 part water: 2 parts vinegar	sprayed until run off
Vinegar 2X	Backpack Sprayer	July 11,2006 July 25, 2006	1 part water: 3 parts vinegar	sprayed until run off

Results: Efficacy

Weed cover - Weed cover was higher along the field edge than within the field and the weed control tools performed differently in these two areas, leading to a significant treatment X location interaction (Table 2). When treatment efficacy is examined separately in each area of the field we see that within the field the lowest levels of weed cover are achieved with the 2X vinegar treatment and as expected the unweeded control has the highest cover (Fig. 1). Surprisingly, however, along the field edge the highest amount of weed cover was found in corn gluten meal plots with 2X vinegar treatment resulting in the fewest weeds (Fig. 1).

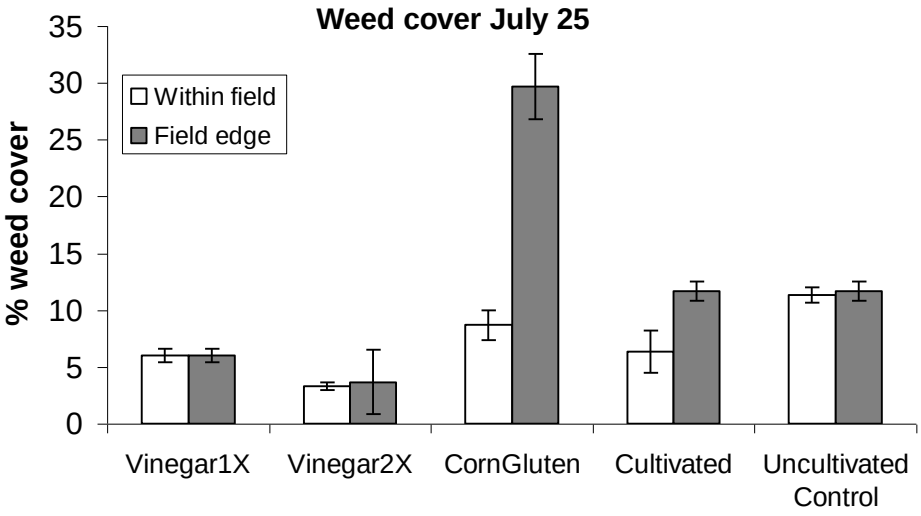

Figure 1. Effect of organic weed control treatments on weed cover in each plot. Each of the 5 treatments was replicated 3 times in the two locations of the field. Each column represents the mean ± s.e. of 3 replicates. None of the plots were mechanically cultivated prior to or during the study, the cultivated treatment was only hand weeded.

Number of weeds - The different weed control tactics did not perform in a consistent manner over the two sampling dates leading to a significant interaction of time X treatment X location (Table 2). When we examined the results separately for each

sampling date we see that early in the summer, weed pressure is higher along edges than within the field, leading to a significant location effect (Table 2). All four weed control tactics are effective in suppressing weeds within in the field, compared to the uncultivated control (Fig. 2). Along the field edge none of the treatments are effective at suppressing weeds compared to the control (Fig. 2). The 1X and 2X rates of vinegar did result in fewer weeds along the edge than hand cultivation (Fig. 2). Later in the season, the number of weeds above the crop canopy is similar both within the field and along the edge (Table 2). Again, within the field all four methods are successful at suppressing weeds compared to the uncultivated control. Further, both vinegar treatments performed as well as hand cultivation (Table 2, Fig. 3). Along the field edge weed counts are highest in corn gluten meal plots; with vinegar and hand cultivation treatments resulting in significantly lower weed counts than the unweeded control (Table 2, Fig. 3).

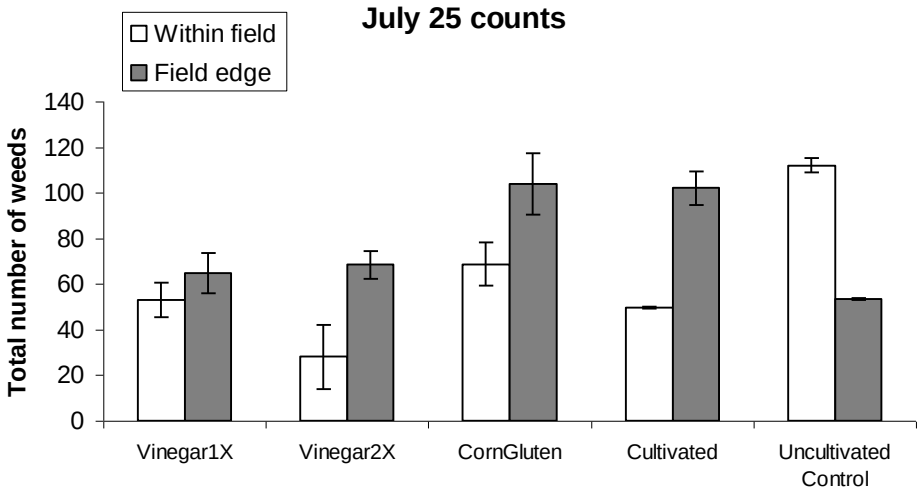

Figure 2. Effect of organic weed control treatments on the number of weeds in each plot following one application of each vinegar treatment and one month after application of corn gluten meal. There were a total of 30 plots, 3 for each treatment in each location. Each column represents the mean ± s.e. of three replicates. None of the plots were mechanically cultivated prior to or during the study, the cultivated treatment was only hand weeded.

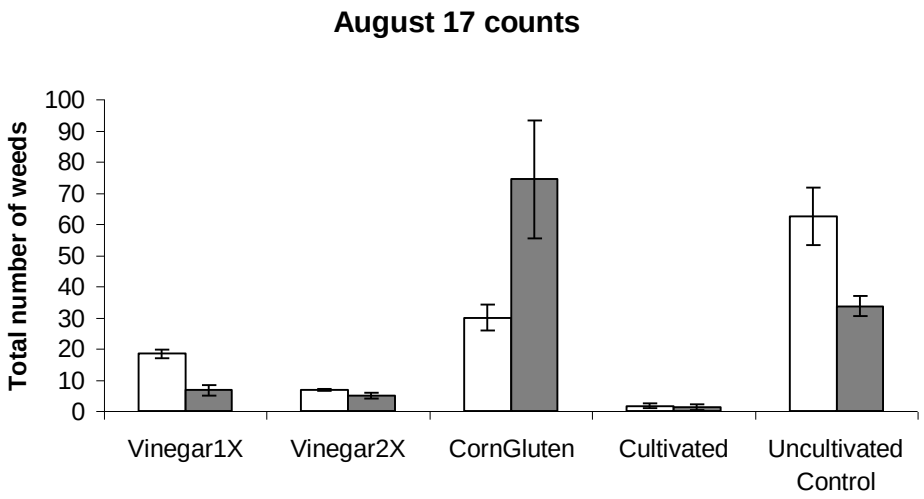

Figure 3. Effect of organic weed control treatments on the number of weeds in each plot following two applications of each vinegar treatment and six weeks after application of corn gluten meal. There were a total of 30 plots, 3 for each treatment in each location. Each column represents the mean ± s.e. of three replicates. None of the plots were mechanically cultivated prior to or during the study, the cultivated treatment was only hand weeded.

Table 2. Summary of statistical results for comparison of different organic weed control methods.

	Treatment	Location (Blocking factor)	Treatment X Block	Treatment X Block X Time
Weed cover (July 25)	$F_{4,20} = 10.16$ $P < 0.001$	$F_{1,20} = 10.19$ $P = 0.005$	$F_{4,20} = 5.66$ $P = 0.003$	N/A
Weed number (July 25 & Aug. 17)			$F_{4,20} = 11.56$ $P < 0.001$	$F_{4,20} = 11.64$ $P < 0.001$
Weed number (July 25)	$F_{4,20} = 7.66$ $P = 0.001$	$F_{1,20} = 9.46$ $P = 0.006$	$F_{4,20} = 14.20$ $P < 0.001$	
Weed number (Aug. 17)	$F_{4,20} = 24.72$ $P < 0.001$	$F_{1,20} = 0.008$ $P = 0.928$	$F_{4,20} = 7.73$ $P = 0.001$	

Results: Phytotoxicity

Both rates of vinegar caused significant yellowing and bleaching of broccoli leaves compared to the water control (Fig. 3 A & B; $p = 0.002$).

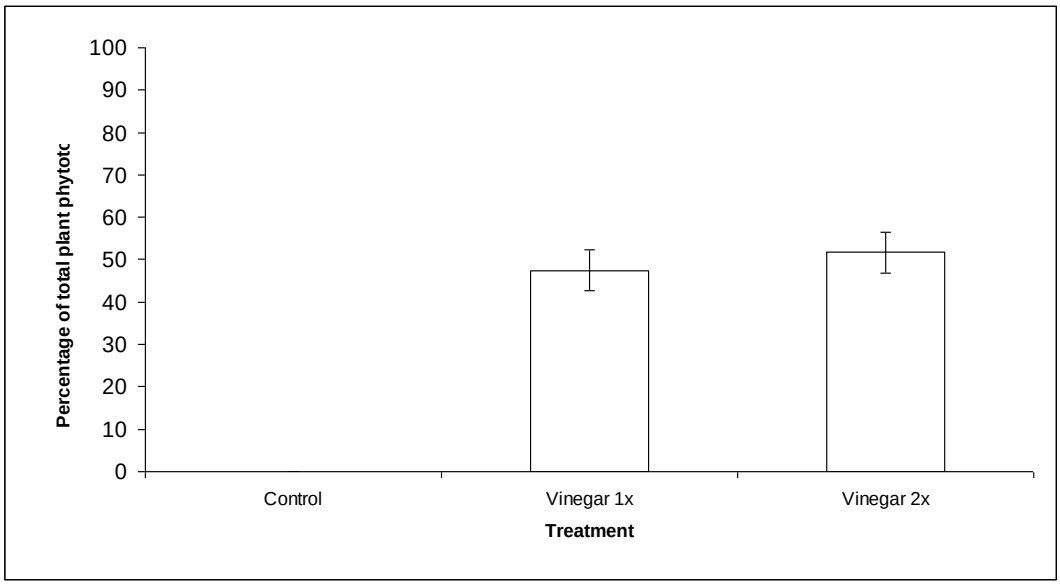

Figure 3A (top) Effect of vinegar treatments on amount of phytotoxicity on broccoli plants (mean ± sem amount of damage per plant). 3B (below) Symptoms of vinegar phytotoxicity on broccoli.

Discussion and summary

The objective of this study was to investigate the efficacy of corn gluten mean and vinegar as a replacement for hand cultivation or weeding for organic production. In an

area with moderate weed pressure such as the middle of the field, weed area coverage and total number of weeds significantly decreased in all treatments compared to the untreated controls after the first product application. In an area with higher weed pressure, like the field edge, efficacy was not apparent after the first application of vinegar or indeed after one session of hand cultivation. However by the second assessments weed counts were much lower in vinegar treated or hand-weed plots than the uncultivated control plot along the edge. Thus in areas of higher weed pressure multiple vinegar applications may be required. However, a single vinegar application may have been sufficient along the field edge had the field been mechanically cultivated as well. Given its phytotoxic effects on the crop (Fig. 3B), vinegar use should be used with care to minimize the risk of crop damage, e.g. application when windy or when crop is larger.

Although corn gluten meal did appear to suppress weeds within the field, the product had the opposite effect on weed growth along the field edge. Since corn gluten meal is a source of nitrogen (Nonneck & Christians 1997) it may have contributed to weed growth in the higher moisture soils of the field margin. Since corn gluten meal acts by inhibiting root growth (Christians 1991) it may only be effective in drier soils where germinating roots face additional stresses. Another limitation of corn gluten meal is that it is not effective on already established weeds.

In summary our study demonstrated the following:

- Vinegar applied at 1X or 2X label rates performed as well as hand cultivation for weed suppression after one application in the mid-field area where there was lower weed pressure. Along the field edge where weed pressure was higher, two applications of vinegar were required to effectively suppress weeds. However if

fields are mechanically cultivated prior to transplanting or seeding, then a single vinegar application may be sufficient to manage weeds, even in areas with high weed pressure.

- Vinegar did result in crop damage, yellowing and blanching of leaves. Because of phytotoxicity issues further work should examine timing of vinegar sprays with other weed control options, such as mechanical cultivation
- Corn gluten meal did not appear to perform as well as hand cultivation. Along the field margin where soil moisture was high, the addition of corn gluten meal resulted in higher weed counts compared to the uncultivated control.

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Organic Weed Control Solutions in Cranberries

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Abstract

A need for cost-effective weed control has been identified as a major concern among organic growers. Mechanical cultivation and hand weeding currently provide effective control, however high labour costs make hand weeding increasingly uneconomical. Trials were conducted in transplanted broccoli and cranberry in Delta, BC in 2006 to evaluate two naturally derived herbicides, corn gluten meal (CGM) and vinegar, as potential tools for organic weed management.

No significant differences in weed coverage were observed in cranberry plots on the assessment date two weeks after treatment.

Corn gluten meal did not appear to perform as well as hand cultivation in the studies presented. Along the broccoli field margin where soil moisture was high, the addition of corn gluten meal resulted in higher weed counts compared to the uncultivated control. Dependency on soil moisture conditions and inability to control established weeds may limit CGM application.

Significant yellowing, browning or bleaching symptoms were observed on both broccoli and cranberry plants in vinegar-treated plots, indicating phytotoxicity. Thus vinegar will need to be used with care to minimize the risk of crop damage. Further work to examine appropriate timing of vinegar sprays with other weed control options, such as mechanical cultivation, is needed.

Introduction

Cranberries (*Vaccinium macrocarpon*) are an important crop in the Lower Mainland of BC. While organic and non-chemical solutions to insect pest control have been developed, there are currently no effective organic weed management tactics, other than hand weeding which is expensive. Two naturally derived herbicides, corn gluten meal and vinegar, are potential tools for organic weed management.

Corn gluten meal (CGM) is a by-product of corn processing (McDade 1999). Previous research has shown CGM to have several growth-regulating effects on various weed species (Christians, 1991; Liu & Christians, 1994, 1997; Liu et al., 1994; Gardner et al., 1997; McDade, 1999; McDade & Christians, 2000). CGM inhibits weed germination by preventing the formation of root systems in plants (Christians, 1993). However, it has also been shown to decrease seedling survival in several crops through this same process (McDade & Christians, 2000). Vinegar (acetic acid) may also have potential as a natural herbicide (Chadran, 2003; Chadran et al., 2004; Coffman et al., 2004a, 2004b; Radhakrishnan et al., 2002, 2003). When applied as a foliar spray, vinegar acts as a contact herbicide destroying cell membranes resulting in tissue desiccation (Webbler & Shrefler, 2006). This process is non-selective and may damage both weed and crop depending on the application method (Coffman et al., 2004a, 2004b; Radhakrishnan et al., 2003).

In this study we compared the performance of corn gluten meal and vinegar for weed control in an established cranberry bog. In addition to weed control, phytotoxicity on cranberries was also evaluated.

Methods

Location of field plots and treatments applied

The study was conducted in a cranberry (var. stevens) field located in Delta, British Columbia. The field was a well established bog approximately 6 years old. Common weeds such as bog blueberry, blackberry, vetch, juncus, and various grasses all appeared in various patches throughout the field. Because weed pressure was patchy in this field, we located plots in two areas with relatively similar initial weed levels. 12 plots were located in each area of the field and were randomly assigned to one of the three treatments, CGM, vinegar or control. Each plot was 1m2 and a 1-meter buffer separated plots.

CGM was applied with a manual hand crank fertilizer spreader at a rate of 200g / m^2 covering the entire $1m^2$ of each CGM plot. The vinegar was applied via a backpack sprayer at a rate of 1 part water to 3 parts vinegar. Weeds in each vinegar treatment plot were spot sprayed until runoff. Because plot assignments were random, some plots did not have any weeds in them and therefore were not treated. Thus the total number of replicates for each treatment was 8 for CGM, 5 for vinegar and 8 for control.

Data collection and statistical analysis of results

On August 4, 2006, initial levels of weed area coverage were recorded prior to application of the treatments on the same date. Weed area coverage was determined by the visual assessment of area covered by percent in each 1 metre square plot. Weed area coverage was assessed 14 days after treatment on August 18, using the same methods as the pre-treatment assessment. Phytotoxic symptoms on cranberry foliage was also

assessed on August 18. Data were analyzed using standard statistical tests (ANOVA) using JMP® version 5.0.1.2. (SAS Institute, 2005).

Results

Prior to treatment weed coverage was similar in both locations of the field, where the study was conducted ($F_{1,22} = 0.063$, $p = 0.81$) thus we were able to pool data collected from both areas of the field for analysis of post-treatment results. Two weeks after application, there were no differences in weed coverage among the three treatments (Fig. 1; $F_{2, 21} = 0.973$, $p = 0.394$). Symptoms of phytotoxicity were apparent in the vinegar treated plots only (Table 1, Fig. 2).

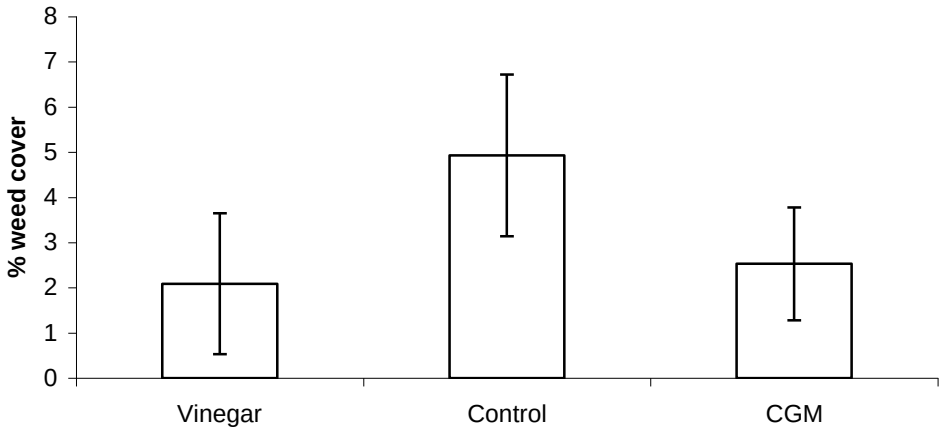

Figure 1. Effect of weed control treatments on mean (±sem) percent weed cover in $1m^2$ cranberry plots.

Table 1. Effect of weed control treatment on cranberry phytotoxicity

treatment	number of replicates	phytoxicity: percentage area of $1m^2$ (mean ± sem)
Unweeded control	8	0
Corn gluten meal	8	0
Vinegar	8	14.47 ± 5.15

Figure 2. Phytotoxicity as a result of vinegar foliar spray.

Discussion/Summary

Weed control in an already established cranberry bog is challenging for several reasons. First any product sprayed on weeds can potentially damage the cranberries, as was the case with the vinegar treatment in this study. Second many weeds in an established cranberry bog are perennial. A single vinegar spray was not sufficient to suppress these weeds; however repeated applications of vinegar with a wiper applicator may be more effective in controlling established perennials over the course of a season. Since the main mode of action of CGM is inhibition of root growth it is not surprising that this product had no effect on weeds with well established root systems. Further,

CGM must be incorporated into the soil to reach the germinating roots weed seeds. Soil incorporation is challenging in an already established bog.

While the results of this study indicate that neither corn gluten meal nor vinegar by spray application were effective for weed management in an already established field, both may be potential tools for weed management in newly planted cranberry fields. Further, a product like vinegar may require repeat applications, by wiping, or higher rates in order to suppress perennial weeds in a well established bog.

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