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Investigation of Organic Weed Control Methods

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ABSTRACT

Weed control in organic vegetable production systems is critical for profitability; however, there are few tools to manage weeds in organic vegetable production besides plastic mulch and labor-intensive hand weeding. Plastic mulch (PM) creates problems in that it must be disposed of in landfills, which is not in keeping with otherwise environmentally friendly organic agriculture. Corn gluten meal (CGM), an organically acceptable by-product of corn milling, has been shown to be an effective pre-emergent herbicide in the humid climates of the Midwestern U.S. This study was done to evaluate the effects of various rates of CGM versus plastic mulch and hand weeding, two common weed control practices in the arid western U.S., on broccoli production, a high-value cash crop. This study examined weed density, marketable yield and net returns for seven treatments and five replications. The treatments were four rates of CGM, 0.56, 0.84 and 1.12 tons ha^{-1} (single application) and 1.70 tons ha^{-1} (split application), PM, hand weeding and a control. This study was conducted at the Colorado State University (CSU) Western Colorado Research Center at Rogers Mesa near Hotchkiss, CO in 2004 and 2005. All treatments showed significantly less weed density than the control in both years. Marketable yield was significantly higher under PM in 2004 than all other treatments. The 0.56 tons ha^{-1} CGM application had the highest marketable yield in 2005 but only significantly higher than the 1.12 tons ha^{-1} CGM application and the control. In 2004 and 2005, net returns were significantly higher in the PM and 0.56 tons ha^{-1} CGM application than all other treatments. In 2005, net returns were significantly higher in the 0.56 tons ha^{1} CGM application than all other treatments except the split CGM application. Results of this study show that growers can achieve the same or higher net returns using 0.56 tons ha^{-1} CGM as when using PM without the disposal and environmental issues presented by the PM.

INTRODUCTION

Weeds and weed control is one of most crucial aspects of organic vegetable production. Unchecked weeds compete strongly with cash crops for water, nutrients and light and can significantly reduce yield and crop quality (Knott, 2002). Organic vegetable growers spend a significant portion of their production budgets on weed control measures, be it for plastic mulch (PM) or mechanical cultivation coupled with manual (hand hoeing) weed control (HW) in their vegetable crops. Plastic mulch is an opaque, sheet of plastic laid over the beds prior to transplanting that significantly reduces weed growth. The other option is mechanical cultivation, used for weed control between beds, coupled with hand weeding for on-bed weed control. Conventional growers typically spray herbicides to control weeds both on the planting beds and between beds but this is not acceptable in organic production. Weed control is critical to producing adequate yields for profitability by reducing weed competition within the cash crop. Although PM insures virtually 100% weed control it is costly and poses a serious disposal problem as growers typically pull the mulch up after harvest and dispose of plastic in a landfill. Organic vegetable growers usually spend 35-40% of their production budgets on PM or 45% of their production budgets on HW (UCCE, 2002).

There are few organically approved herbicides, but, work has been done at Iowa State using corn gluten meal (CGM) as a pre-emergent herbicide (Bingaman, and Christians, 1995; McDade and Christians, 2001; Bingaman and Christians, 2002a). Corn gluten meal is a by-product of corn milling and can be used in organic agriculture; however, no information is available on the efficacy of CGM in the dry climates of the western U.S. The objectives of this study were: a) to determine the efficacy of CGM as a pre-emergent herbicide in organic vegetable production in the arid climate of the western U.S., b) to determine if using CGM is economically viable compared to the typical organic practices of using either PM or HW and c) to determine if weed control and economic returns using CGM would be sufficient to enable growers to abandon plastic mulch as a weed control measure. Organic vegetable growers would like an alternative weed control option that is as profitable as PM while being more environmentally sound and sustainable.

MATERIALS AND METHODS

A field experiment was conducted in 2004 and 2005 at the CSU Western Colorado Research Center at Rogers Mesa near Hotchkiss, CO. Bingaman, et al., (1995) found that CGM suppresses germination of vegetable seed, therefore broccoli transplants were used for this study. Broccoli (*Brassica oleracea* L. *Italica var.* Waltham) was grown from seed in a greenhouse for five weeks and then transplanted in the third week of May each year and harvested the second week in July. The experiment was a randomized complete block design with seven treatments and five replications. The seven treatments were four rates of CGM, PM, HW and a control plot with no weed control. The four rates of CGM were 0.56, 0.84 and 1.12 tons ha^{-1}, corresponding to ½, ¾ and 1 ton ac^{-1} in a single pre-transplant application, and 1.70 tons ha^{-1} split application treatment (¾ ton ac^{-1} application^{-1}). The split application was applied at half the rate pre-transplant and half the rate one month following transplant. Bingaman and Christian (2002b) found that split applications worked best at weed control rather than a single, pre-transplant application.

Planting beds were 76 cm wide and formed with a bed-shaper/irrigation tape layer that simultaneously installed sub-surface drip irrigation tape at a depth of 15 cm in the midline of the beds. Plots were 9 m long by 4.5 m wide and contained three double row beds. Data was collected from the center double row of each plot. Corn gluten meal (7-0-0) was applied uniformly over the beds at the above-mentioned rates and lightly raked into the soil. For the PM treatment, the plastic mulch was laid down simultaneously with the bed shaping and tape laying operation. Broccoli was transplanted in double rows 45 cm apart with alternating 30 cm in-row spacing using a water-wheel transplanter. Plant populations were 26 900 plants ha^{-1}. Plots were uniformly irrigated on a twice-weekly basis as needed. The same treatments were planted in the same plots areas in both years. The soil is a Mesa clay loam [fine-loamy, mixed, mesic, Typic Haplargid].

In the fall prior to each growing season, (2003 and 2004), the ground was tilled and a winter rye/winter wheat cover crop was planted and irrigated to germinate the cover crop. Approximately one month prior to field preparations the following springs the cover crop was mowed and tilled into the soil approximately 15 cm. Two weeks prior to planting each year soil samples were taken and sent to a soil-testing lab for complete crop nutrient analysis. Pre-plant soil tests of the top 30 cm of soil in 2004 contained 140 kg of inorganic nitrogen (N)(NO_3-N + NH_4-N) ha^{-1}. In 2005, soil test N was 125 kg N ha^{-1}. A commercial organic fertilizer (12-0-0) was applied to the plots to bring the total inorganic N content in all treatments from the CGM and fertilizer to 400 kg N ha^{-1} as recommended by Thompson et al. (2002a).

The HW treatment was hand weeded approximately every two weeks after transplanting until two weeks prior to harvest, a common practice of area organic vegetable growers. Time spent hand weeding was recorded for each plot at each hand weeding to determine labor costs. Weed density (WD) estimates were taken for all plots every 2 weeks, from 2 weeks after transplant until 2 weeks prior to harvest. The WD was estimated by placing a 1 m^2 frame randomly in the center double row of each plot and estimating the percentage of weed cover within the frame.

Each data plot area was harvested twice when approximately 50% of the main crowns were at maturity. Crowns were graded according to USDA broccoli grading standards (USDA, 1943). Marketable crowns and culls were weighed separately to determine marketable yields. Crowns that were not graded as USDA Fancy at the second harvest were harvested as culls and not included as marketable yield.

A simple cost/benefit analysis was done to determine the net return from the various weed control treatments using the following formula:

Net return = (market price x marketable yield) – production costs ha^{-1}* – harvest cost ha^{-1} – weed control cost ha^{-1}).

Where: market price for broccoli ($ Mg^{-1})
marketable yield (Mg ha^{-1})
production costs (land prep., fertilizer and irrigation) ($ Mg^{-1})
harvest cost (cutting, packing, hauling and cooling) ($ Mg^{-1})
weed control cost (for various treatments) ($ Mg^{-1})

* weed control costs were not included in production cost but have been added in separately due to differences in cost among the various treatments (after UCCE, 2002).

The price for organic broccoli used for the analysis was $1.65 kg^{-1} ($0.75 lb^{-1}), the average wholesale price for organic broccoli in 2004 (USDA, 2005). The average hand weeding cost was $1420 ha^{-1} in both years, comparable to costs paid by area organic vegetable growers (Adam Silverstein, personal communication). The cost of the CGM was $250 ton^{-1}.

All statistical analysis was performed at a significance level of $P < 0.1$ to determine least significant differences between treatments (SAS, 1985).

Weather data was taken from a CSU meteorological station within 100 m of the study field. Meteorological data from transplant to harvest is summarized in Table 1.

Table 1. Meteorological summary.

Date	Avg Max Temp Deg C*	Avg Min Temp Deg C	Vapor Press mb†	Avg Solar Rad Lngly‡	Total Prec cm	Avg Wind Run km	Avg Soil Temp @ 5cm Deg C	Avg Min RH§ %	Total Grow DgDy¶	Total Ref ET# cm
2004	29.5	10.2	7.8	601.9	1.1	133.5	17.5	14.6	1036	45.6
2005	29.4	9.5	8.1	634.7	4.3	120.3	16.9	15.6	955	45.3

* Deg C = temperature in degree Celsius.
† mb = millibars of vapor pressure.
‡ Lngly = Langey = 1 gm calorie per sq cm, a measure of solar irradiance on a radiometer.
§ RH = relative humidity measured as a percent.
¶ = Total Growing Degree Day = (high temp + low temp)/2 – baseline. Baseline = 10°C.
# = Reference Evapotranspiration using Pennman-Montieth equation (Jensen, *et al.* 1990).

RESULTS AND DISCUSSION

Results showed a significant year by treatment interaction, therefore, all data was analyzed separately by year.

Weed Density

In general, weed pressure was higher in 2004 than in 2005 as exhibited by weed density (WD) in the control treatment in those years (Figure 1 & 2). In 2004, the WD was significantly higher in the control treatment than all other treatments, as would be expected where no weed control treatments were imposed (Figure 1). The WD in the 2004 split application treatment was significantly higher than all treatments except for the control. The reason for the split CGM application not controlling the weeds as well as the other CGM treatments in 2004 is not known, but maybe due to high weed pressure. Bingaman and Christian (2002b) found that split applications worked best at weed control rather than a single, pre-transplant application. The HW treatment and the three single CGM application treatments did not exhibit significant differences in WD over the 2004 season (Figure 1). Although none of the three single CGM application treatments were significantly better at weed control, the CGM treatments did reduce WD by approximately 30% over the control (Figure 1). More importantly, the lowest CGM rate reduced WD as well as at the higher rates, which reduces weed control costs for growers over the higher rates. In 2004, the PM was significantly better at weed suppression than all other treatments except the low rate of CGM (Figure 1). The weeds in the PM treatments are those that grew in and around the opening in the PM where transplants were inserted.

In 2005, the WD in the control treatment was significantly higher than that in all other treatments but approximately 20% lower than in 2004 (Figure 1 & 2). All four CGM treatments gave similar results with the split application treatment showing slightly better weed control efficacy. The CGM treatments had approximately 10% lower WD in 2005 than the control. The reason for less effective weed suppression by the CGM treatments in 2005 than in 2004, even though there was less weed pressure, is not known but may be climate related. High mid-season temperatures in 2005 may have slowed broccoli growth and canopy closure that allowed the weeds to better compete. Also, there was much higher precipitation in 2005 than 2004, which may have reduced the efficiency of the CGM or enhanced weed growth or both (Table 1). As in 2004, the three single application CGM treatments did not show significant differences among them, suggesting that the lowest rate, 0.56 t CGM ha^{-1} is the better choice for growers because of lower costs. The WD for the HW and plastic treatments was not significantly different in 2005. This may be due to cumulative effects of those treatments that aided in the reduction of the soil weed seed bank.

Figure 1. Weed density, 2004.

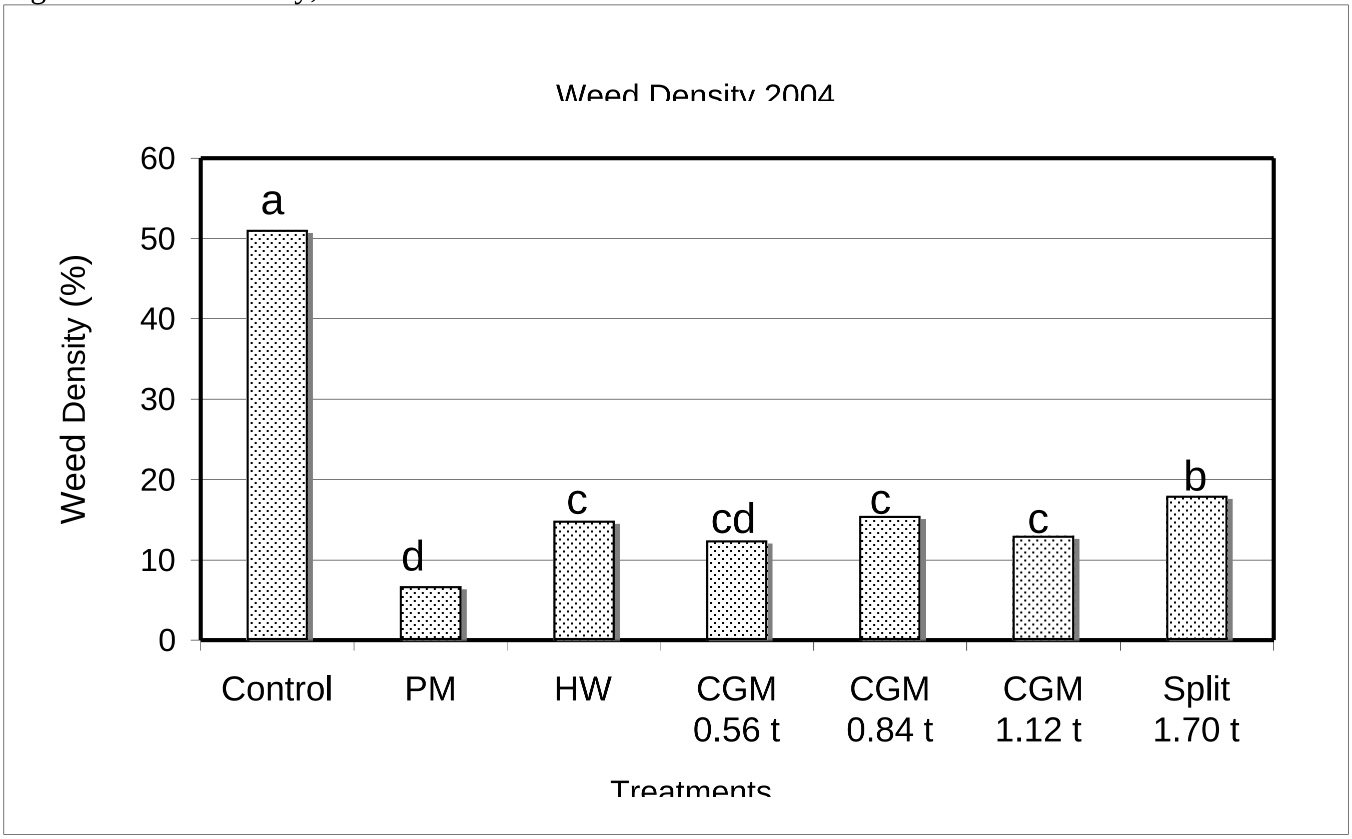
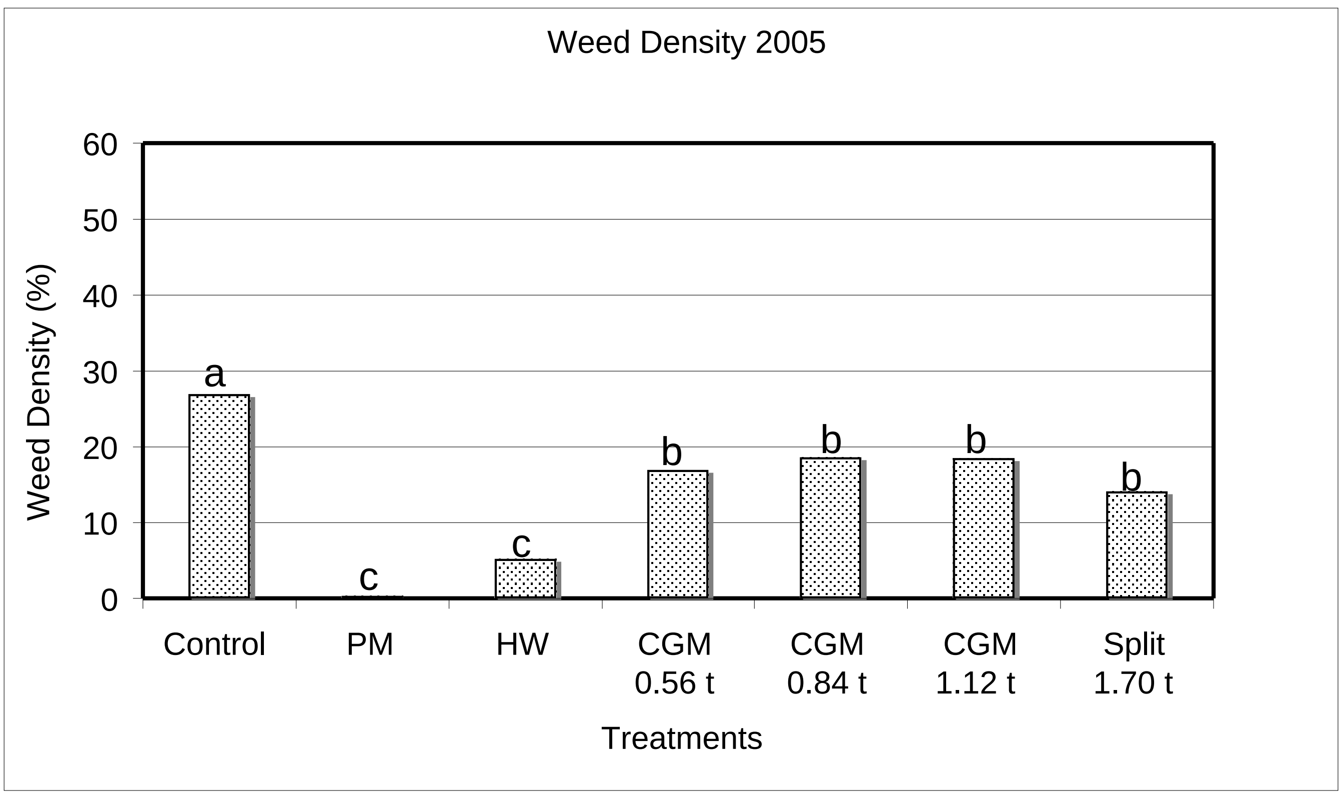


Figure 2. Weed density, 2005.



Marketable Yield

The marketable yields were higher in 2004 than in 2005 for four of the seven treatments even though weed pressure was lower in 2005 (Figure 3 & 4), this is possibly due to more favorable weather conditions in 2004. The average yield in 2004 was 6.7 Mg ha^{-1} and 6.2 Mg ha^{-1} in 2005. A temperature swing from moderate to high temperatures in the middle part of the growing season of 2005 may have had a negative influence on plant growth, leading to the lower yields (Figure 5). However, the 0.56 t ha^{-1} CGM treatment had similar but slightly higher yields in 2005 than in 2004.

The PM treatment resulted in significantly higher yield in 2004 than all other treatments except the 0.56 t ha^{-1} CGM treatment, probably due to significantly lower WD. The lowest marketable yields were found in the control, HW, the highest rate of CGM, and the split CGM application (Figure 3). The three single application CGM treatments had decreasing yields with increasing rates of CGM (Figure 3). It is not known why broccoli shows a yield reduction with increasing CGM rates, as this is the first reported research using CGM on broccoli. Similar results have not been reported. It may be that broccoli cannot tolerate high rates of CGM before yields are negatively affected.

In 2005, the 0.56 t ha^{-1} and split CGM treatments had the highest yields, with the PM treatment not having a significantly lower yield than the split CGM treatment (Fig. 4). It is not known why the yields under the plastic mulch are not higher, but are possibly due to the large temperature swing in the middle of the growing season. Daily high temperatures in mid-June of 2005 were in the 20°C range. One week later the high temperatures were 30-35°C. This abrupt change may have slowed crop growth sufficiently to reduce yields in this cool-season crop, especially under the PM that tends to build up higher soil temperatures.

This data shows that growers can achieve marketable yields with the 0.56 t ha^{-1} CGM treatment as high as with the PM or the split CGM treatment.

Figure 3. Marketable yield, 2004.

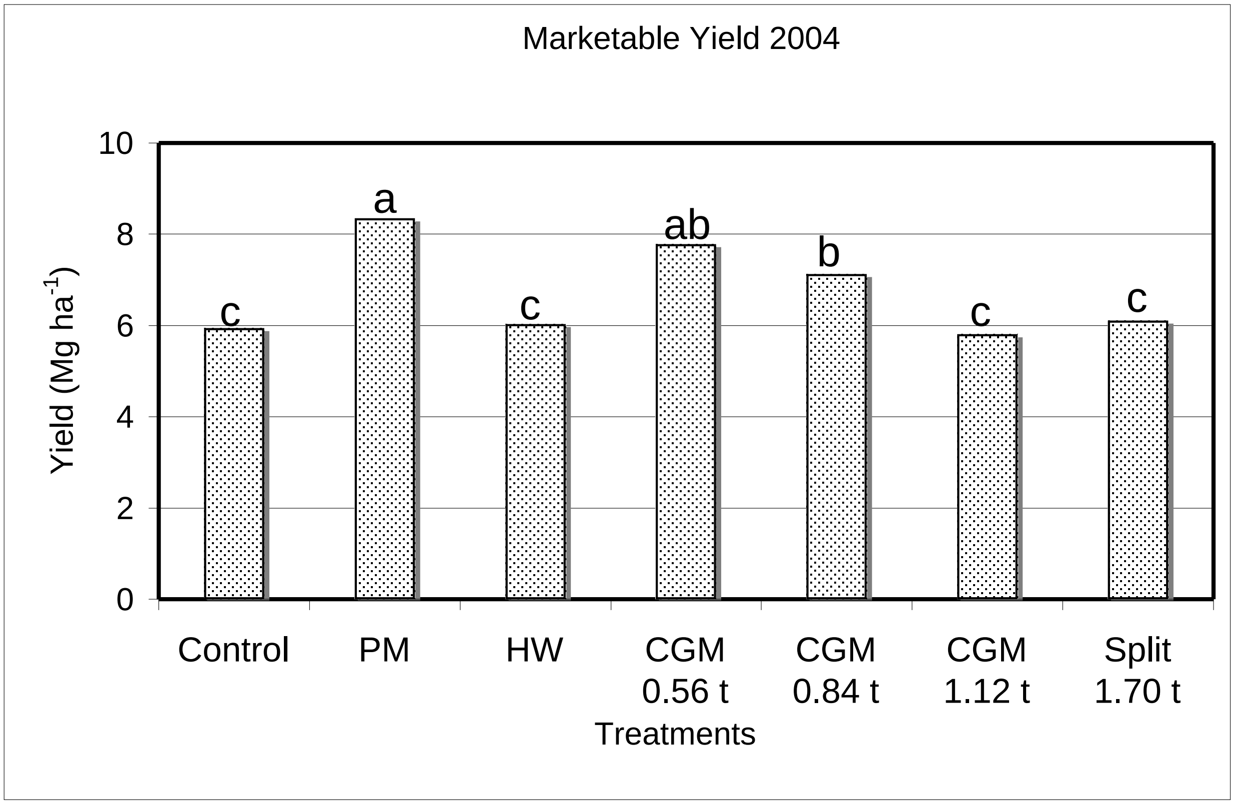


Figure 4. Marketable yield, 2005.

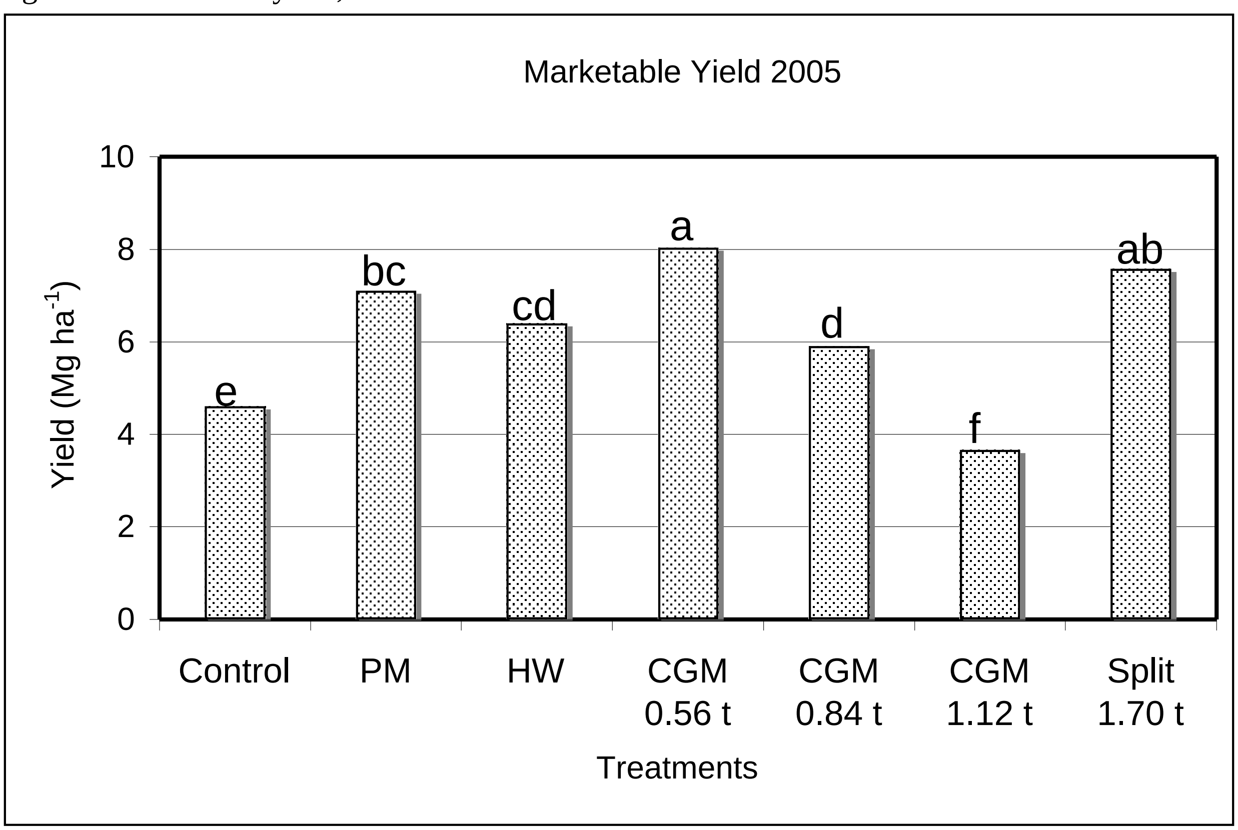
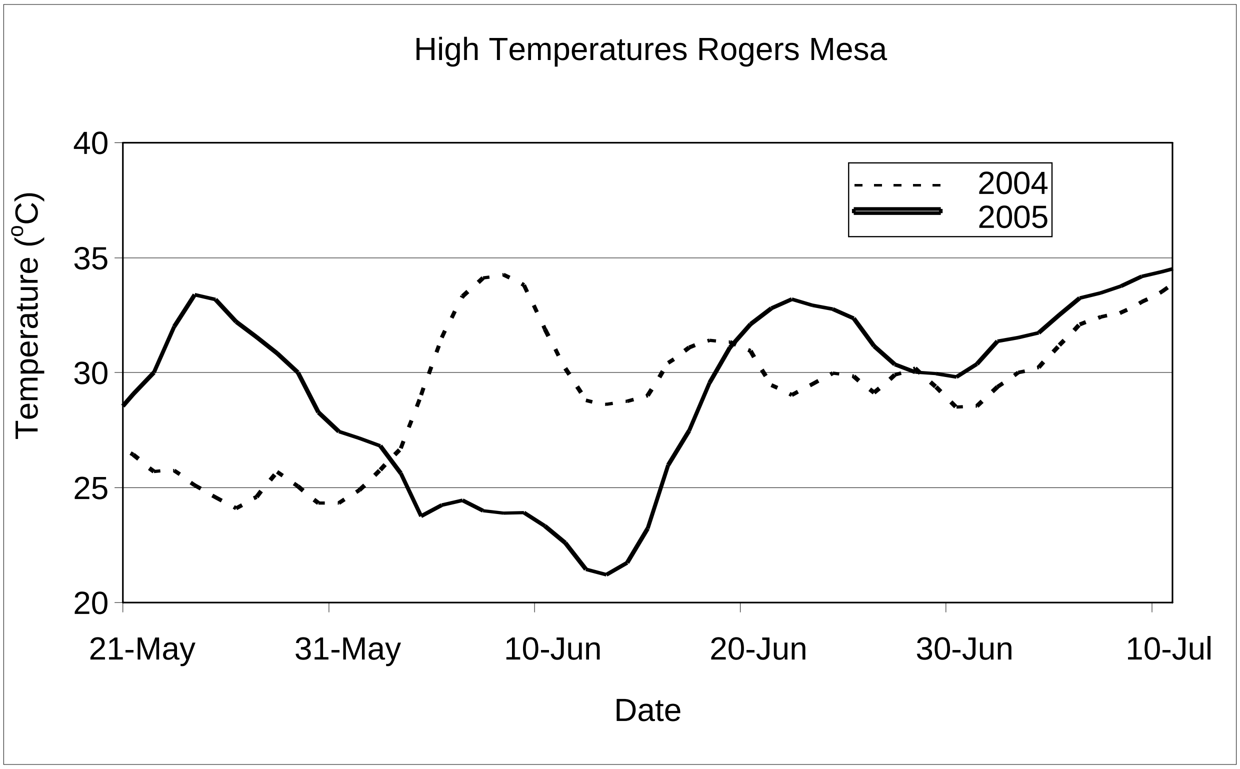


Figure 5. In-season high temperatures, Rogers Mesa, 2004 and 2005 (data has been smoothed for clarity).



Net Returns

The net returns for the treatments in this study were significantly higher than those in the studies using conventional practices. This was due to the higher prices paid for organic produce, usually 100% higher, (USDA, 2005) than for conventional produce (Thompson et al., 2002b; Doerge, et al., 1991; and Kowalenko and Hall, 1987). The cost analysis highlights the cumulative results of the effects of the factors in this study. The cost analysis takes into account weeds, which compete with the crop for water, nutrients and light, the cost of weed control and the loss of crop production due to weeds.

The cost analysis shows that for 2004, the PM and low rate of CGM treatments had significantly higher net returns than all other treatments (Figure 6). In a field with high weed pressure the difference in the net returns between the PM and the HW treatment is approximately \$5,000 ha^{-1} because of higher weed control costs and significantly lower yields in the HW treatment. It is easy to understand why organic growers favor the plastic mulch, although the costs are higher the net returns are also significantly higher than in the HW treatment (Figure 5, 6 & 7). The 0.56 t ha^{-1} CGM treatment had significantly higher net returns than the other CGM treatments, the HW and the control. The higher net returns are due to lower weed control costs and higher marketable yields (Figure 5, 6 & 7).

For 2005, the highest net returns were obtained with the low and split CGM rates. As with 2004, the high rate of CGM did not result in significantly higher net returns than in the control because of the offsetting cost of the CGM. The results for the low rate of CGM are consistent for both years of the study and appear to be a viable alternative to PM for growers to get good weed control, high marketable yields and net returns.

Figure 6. Net returns, 2004.

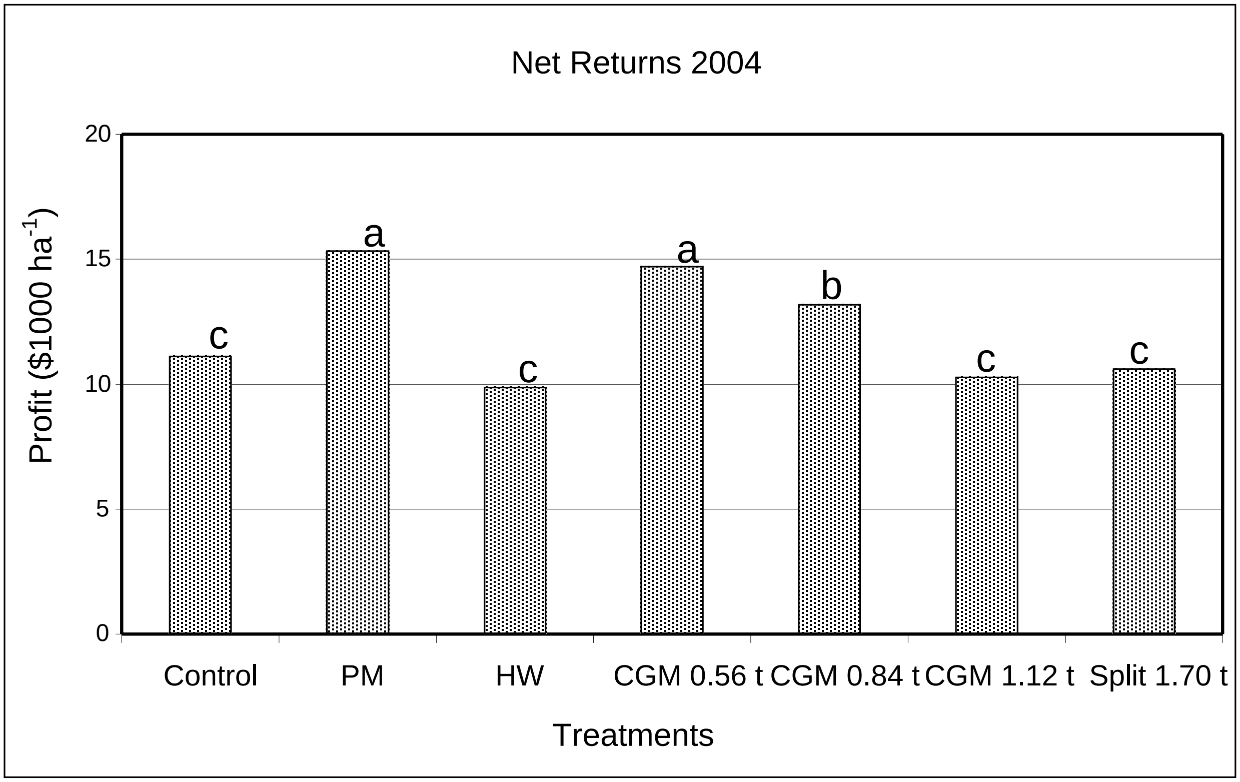
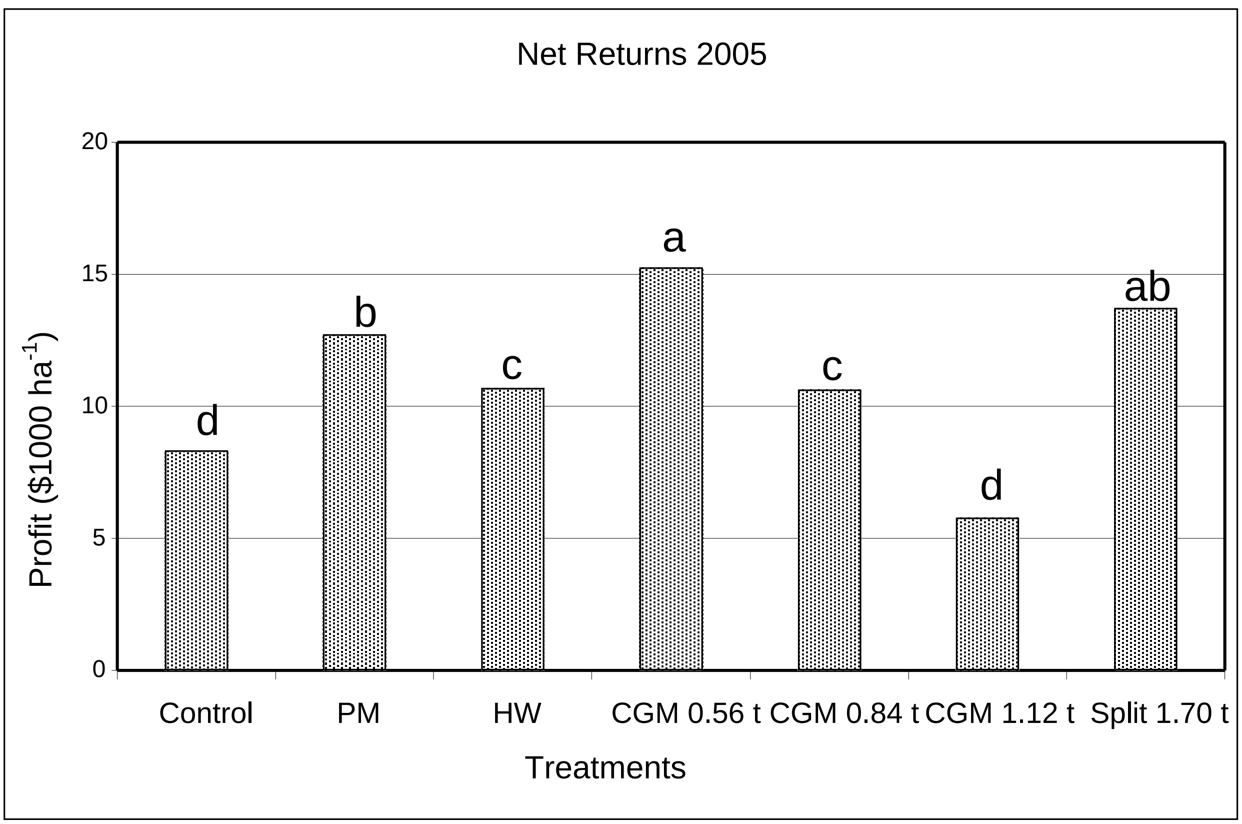


Figure 7. Net returns, 2005.



CONCLUSIONS

The data from this study shows that CGM is an effective weed suppressor in organic broccoli production in the arid West, with the lowest rate of CGM performing as well as the PM and better than higher rates of CGM with lower costs. Corn gluten meal can be as cost effective as PM without the disposal problems inherent in using PM. The net returns using the lowest rate of CGM make it an attractive alternative to other weed control methods for broccoli.

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