PRECISION PLACEMENT OF CORN GLUTEN MEAL FOR WEED CONTROL IN ORGANIC VEGETABLE PRODUCTION

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ABSTRACT

Organic vegetable producers rank weeds as one of their most troublesome, time consuming, and costly production problems. As a result of the limited number of organically approved weed control herbicides, the precision placement of these materials increases their potential usefulness in organic production systems. As a non-selective preemergence or preplant-incorporated herbicide, corn gluten meal (CGM) inhibits root development; decreases shoot length, and reduces plant survival. The development of a mechanized application system for the precise placement of CGM will increase its use in organic vegetable production, especially in direct-seeded vegetables. Our research objective was to develop a mechanized method to uniformly apply CGM to the soil surface in either a solid (broadcast) or banded pattern. An applicator was constructed using a fertilizer box, rotating agitator blades, 12-volt motor, and fan shaped, gravity-fed, row banding applicators. The equipment was evaluated for the application of two CGM formulations (powdered and granulated), three application rates (250, 500, and 750 g m^{-2}), and two application configurations (solid and banded). Field evaluations were conducted on 81-cm wide raised beds at Lane, OK. Differences between CGM formulations affected flow rate within, and between, application configurations. The feasibility of using equipment, rather than manual applications, to apply CGM to raised beds for organic weed control purposes was demonstrated.

Keywords: Precision placement, corn gluten meal, organic, weed control, mechanization

INTRODUCTION

Turfgrass research demonstrated a reduction in creeping bentgrass (*Agrostis palustris* Huds.) establishment after incorporation of corn meal into the top 7.5 to 10.0 cm of the soil surface (Christians, 1993). The experimental treatments compared the effect of soil surface incorporation of the inoculated corn meal (*Pythium* and corn meal), the incorporation of non-inoculated corn meal (corn meal only), and a treatment in which neither the inoculated nor the non-inoculated corn meal was applied or incorporated. Creeping bentgrass was then seeded into each plot. Creeping bentgrass development was not inhibited as a result of the inoculated corn meal, but the fresh non-inoculated corn meal did inhibit bentgrass establishment (Christians, 1993). This unexpected finding generated research questions regarding the role of corn meal in weed control.

Christians (1993) conducted further research to evaluate the weed control potential of applying corn starch, corn gluten meal, corn germ, corn seed fiber, or corn meal to the soil surface with the objective of determining the weed control efficacy of the various corn seed components. The research determined that corn gluten meal (CGM) produced the greatest inhibitory effect and reduced root formation in several weed species, including creeping bentgrass and crabgrass (*Digitaria* spp.).

Corn gluten meal is the by-product of the wet-milling process of corn (Quarles, 1999; Bingaman and Christians, 1995). Chemical analysis of the protein fraction of CGM is approximately 60% protein and 10% nitrogen (Quarles, 1999). CGM (Alliance Milling Company, Denton TX), normally a yellow powder (McDade, 1999), has been used as a component in dog, fish, and livestock feed (Quarles, 1999; Christian 1991, 1995). Corn gluten meal can be purchased in a pelletized form (McDade, 1999) and as a granulated material.

Bingaman and Christians (1995) determined that CGM applied at 324 g m^{-2} reduced plant survival, shoot length, and root development for the 22 weed species tested, whether the CGM was applied to the soil surface as a preemergence herbicide or mixed into the top 2.54 cm as a preplant-incorporated herbicide. Although plant development was reduced for all weeds tested, the extent of susceptibility differed across species. Plant survival and root development were reduced by at least 70% and shoot length by at least 50% for the following weeds: black nightshade (*Solanum nigrum* L.), common lambsquarters (*Chenopendium album* L.), creeping bentgrass, curly dock (*Rumex crispus* L.), purslane (*Portulaca oleracea* L.), and redroot pigweed (*Amaranthus retroflexus* L.). When CGM was applied as a preplant incorporated herbicide, the following weeds had at least a 50% reduction in plant survival and shoot length and at least an 80% reduction in root development: catchweed bedstraw (*Galium aparine* L.), dandelion (*Taraxacum officinale* Weber), giant foxtail (*Setaria faberi* Herrm.), and smooth crabgrass [*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl]. Plant survival reductions were less than 31% for barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] and velvetleaf (*Abutilon theophrasti* Medic.).

Field studies with three planting dates (3 July 1998, 20 Aug. 1998, and 8 June 1999) demonstrated that CGM incorporated into the top 5-8 cm of soil at 100, 200, 300, and 400 g m^{-2} reduced weed cover by 50, 74, 84, and 82%, respectively, compared to an untreated check at 3 weeks after treatment (McDade and Christians, 2000). Weed cover data collected for purslane, common lambsquarters, redroot pigweed, foxtail (*Setaria* spp.), velvetleaf, and ladysthumb (*Polygonum persicaria* L.), revealed purslane to be the most dominant weed species. In the same experiment, it was also discovered that the 100, 200, 300, and 400 g m^{-2} CGM rates reduced average seedling survival for 8 vegetables by 48, 65, 73, and 83%, respectively. 'Daybreak' sweet corn (*Zea mays* L.) was the least susceptible to CGM, requiring at least 300 g m^{-2} of CGM to produce a significant seedling reduction of 26% compared to the control. CGM applications of 100 g m^{-2} reduced seedling survival by 35% for 'Ruby Queen' beet (*Beta vulgaris* L.), 41% for 'Red Baron' radish (*Raphanus sativus* L.), 59% for 'Maestro' pea (*Pisum sativum* L.), 67% for 'Comanche' onion (*Allium cepa* L.), 68% for 'Black Seeded Simpson' lettuce (*Lactuca sativa* L.), 71% for 'Provider' bean (*Phaseolus vulgaris* L.), and 73% for 'Scarlet Nantes' carrot (*Daucus carota* L. subsp. *sativus*) compared to the control. As a result of the reductions in direct seeded vegetable seedling survival for even the lowest CGM application rate, 100 g m^{-2}, McDade and Christians (2000) advised against using incorporated CGM for direct seeded vegetables.

The wide variations in vegetable production practices, including crop establishment, justify further evaluation of the weed control properties of CGM on additional weed and vegetable species. One limitation to further evaluation of CGM in field vegetable production is the difficulty in achieving a uniform application to the soil surface. The use of equipment to mechanically apply CGM would avoid the difficulty involved with manual application of CGM. Suitable equipment would also enable evaluation of the potential benefits of banded applications for weed efficacy and crop safety of direct seeded vegetables. The objective of this research was to develop and test equipment that would permit either solid (broadcast) or banded application of corn gluten meal.

MATERIALS AND METHODS

An applicator was assembled using various machinery components for the purpose of uniformly applying corn gluten meal to the soil surface in either a solid (broadcast) or banded pattern. A fertilizer box (model 901-4, Gandy Co., Owatonna, MN) measuring 30 cm wide by 23 cm at the top, and 36 cm tall, tapering to a point at the bottom was used as the holding container and metering device for the CGM. The fertilizer box had an approximate capacity of 9 kg of CGM with a 5.08-cm wide, 4-bladed, horizontal rotating agitator at the tapered bottom of the container. Located beneath the rotating agitator blade on the 30 cm base were four circular outlets 6.0 cm apart with an inside diameter of 1.5 cm and an outside diameter of 1.9 cm. Although a sliding metering device could be used to reduce the size of the outlets to decrease the application volume, the applicator openings were unobstructed to maximize the application volume.

A 12-volt motor (model # 9-077746, White's Inc., Houston, TX) with a 60-tooth gear, chain drove a 12-tooth gear attached to the agitator to produce a 24 rpm (revolutions per minute) rotation of the agitator. Tubing with an inside diameter of 1.9 cm was attached to fertilizer box outlets and connected to inlets of fan-shaped gravity-fed row banding applicators (Ro-Bander, Grandy Co.).

The equipment was set in two application configurations, i. e., a solid (broadcast) and a banded application. The solid application configuration employed three 25.4-cm row-band applicators placed side by side to achieve a solid 76 cm wide application. As a result of using three application heads, only three fertilizer box outlets were used to meter the CGM. The fourth outlet was blocked.

The banded application configuration employed four 17.8-cm row-band applicators in sets of two placed side by side, with a 7.6-cm gap in the row center, between the two sets of row-band applicators. The use of four 17.8-cm row-band applicators allowed use of all four-fertilizer box outlets. The fertilizer box, 12-volt motor, and row-band applicators were then attached to a 3-point tractor hitch and tool bar for calibration and field evaluation.

The equipment was evaluated for the application of two CGM formulations (powdered and granulated), three application rates (250, 500, and 750 g m^{-2}), and two application configurations (solid and banded) (Table 1). Within formulation and application configurations, tractor speed was varied to achieve the desired application rates (Table 2). Field evaluations were conducted during the summer of 2004 on 81-cm wide raised beds at Lane, OK.

RESULTS AND DISCUSSION

Differences between CGM formulations affected flow rate within, and between, each application configuration (Table 1). The granulated formulation flowed at a faster rate than the powdered formulation, and the banded formulation flowed faster than the solid application. The granulated formulation flowed easier, without clumping, and faster than the powdered formulation. Regardless of formulation, use of four application box outlets for the banded configuration resulted in a greater application rate than the use of three application box outlets for the solid distribution. It was determined that the CGM powder used with the solid application configuration was inconsistent and unreliable, and not feasible for use with this equipment without further modification. The field evaluation of the equipment did not include the use of the CGM powder applied using the solid application configuration.

In field evaluations the equipment setup to distribute the CGM granulated formulation proved to be the most reliable and precise delivery system of the three application rates (250, 500, and 750 g m^{-2}) for both application configurations compared to the powdered CGM formulation applied in the banded configuration. The powdered formulation did not flow easily or consistently through the application system. To improve the delivery of powdered CGM, the equipment could be modified by increasing the outlet size for the application box, by increasing the internal diameter of the tubing connected to the outlets, or by adding a device to vibrate, or further agitate, the powder as it flows from the outlets through the tubing to be dispersed by the row-band applicators. During the field evaluations, manual tapping of the row-band applicators did help the flow of the powdered material through the system.

Table 1. Application parameters for corn gluten meal formulations, three application rates, and two application configurations.

CGM formulation	Application configuration	Flow rate	Outlets used	Individual head width	Application width	Empty strip width
		g min^{-1}	#	cm	cm	cm
Granulated	Banded	1720	4	17.8	71	7.6
Granulated	Solid	1418	3	25.4	76	0
Powdered	Banded	1132	4	17.8	71	7.6
Powdered [z]	Solid	-----	-----	-----	76	0

[z] The distribution of the Powdered formulation in the Solid application configuration was inconsistent and unreliable, and its use was determined to not be feasible without further equipment modifications.

Table 2. Tractor speeds for application formulation and configuration combinations.

CGM formulation	Application configuration	Tractor speed [z] for application rates		
		250 g m^{-2}	500 g m^{-2}	750 g m^{-2}
		---------------- km h^{-1} -----------------		
Granulated	Banded	0.54	0.27	0.19
Granulated	Solid	0.44	0.22	0.15
Powdered	Banded	0.35	0.17	0.12
Powdered [y]	Solid	----	-----	-----

[z] Tractor speeds were rounded to the nearest 0.01 km h^{-1}.

[y] The distribution of the Powdered formulation in the Solid application configuration was inconsistent and unreliable, and its use was determined to not be feasible without further equipment modifications.

Precise placement of the powder for the banded configuration was further hampered by wind gusts that tended to blow the CGM powder away from the targeted soil surface and into the desired CGM-free strip intended for vegetable direct seeding. This inadvertent misplacement of the CGM powder had the potential to interfere with direct seeded vegetable survival which are planted between the banded applications. Potential solutions to decrease wind interference include attaching small wind shields to each row-band applicator, attaching small shields only on the sides nearest the desired CGM-free area, attaching large wind shields on either side of the equipment as a whole, or completely enclosing the group of row-band applicators in a shielded system. During field evaluations, the use of a 46 cm x 46 cm wind shield attached to each side of the equipment at ground level decreased wind interference of powder application. The use of individual shields on the row-band applicators nearest the CGM-free center strip also decreased drift of the powder CGM.

The feasibility of using equipment, rather than manual applications, to apply corn gluten meal to raised beds for organic weed control purposes was demonstrated. A number of equipment alterations will increase the efficiency and potential usefulness of the mechanical applications of corn gluten meal. Future equipment developments and evaluations should focus on increasing the application rate in order to decrease the time needed for field applications. The granulated formulation worked well at all application rates and application configurations. The powdered corn gluten meal did not flow easily, and its delivery was inconsistent and unreliable when used in the solid application configuration. If equivalent weed control efficacies are found between the two corn gluten meal formulations, the granulated formulation would be the suggested formulation to use in this equipment.

REFERENCES

Bingaman, B. R. and N. E. Christians. 1995. Greenhouse screening of corn gluten meal as a natural control for broadleaf and grass weeds. HortScience 30:1256-1259.

Christians, N. E. 1991. Preemergence weed control using corn gluten meal. U.S. Patent No. 5,030,268 p.63-65.

Christians, N. E. 1993. The use of corn gluten meal as a natural preemergence weed control in turf. Intl. Turfgrass Soc. Res. J. 7:284-290.

Christians, N. E. 1995. A natural herbicide from corn meal for weed-free lawns. IPM Practitioner 17(10):5-8.

McDade, M. C., 1999. Corn gluten meal and corn gluten hydrolysate for weed control. M.S. Thesis, Iowa State University. Dept. of Horticulture, Ames.

McDade, M. C, and N. E. Christians. 2000. Corn gluten meal – a natural preemergence herbicide: effect on vegetable seedling survival and weed cover. Amer. J. Altern. Agricult. 15(4):189-191.

Quarles, W. 1999. Corn gluten meal: a least-toxic herbicide. The IPM Pract. 21(5/6):1-7.