Final Report on Proposal to Explore Some Engineered Approaches to Pest Management

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Summary

Studies were conducted to evaluate the feasibility excluding slugs from crops by using copperized fabric barrier. Results showed that slug numbers in protected areas were reduced when compared to areas not protected by the barrier, but that the reduction was transitory.

Several studies were also conducted to evaluate the potential for prolonging survival and infectivity of foliar applied entomopathogenic nematodes. Initial studies focused on measuring microclimatic changes caused by applying aqueous foam to plant canopies. Foam extended the duration of high relative humidity, and foam applied to plant foliage extended humidification and free water retention. Protection with foam improved nematode survival within plant canopies, but total number of live nematodes recovered was less than from controls.

Background

Certain problems in organic agriculture lend themselves to engineered solutions rather than biological solutions. Centuries of agricultural experience show us, however, that certain non-engineered strategies and tactics for pest management have had the greatest return for the time and money invested. Four techniques come to the forefront: crop rotation, cultivar selection, time of planting, and location of planting. These are tried-and-true techniques that rise head an shoulder above all others when it comes to producing crops without relying on massive inputs. Crop rotation seeks to maintain fertility and to disconnect a crop from a soil-borne pest. Cultivar selection allows resistance to pests or competitiveness with weeds. Choice of planting date can prevent the occurrence of a particularly susceptible growth stage during peak periods of risk. Lastly, geographical location seeks to disconnect crops from endemic and persistent pests or environmental conditions.

When market considerations make the integration of the above factors impractical, engineered solutions are commonly employed to produce a crop. Soil amendments can be added, pesticides applied, and cultural and engineered approaches may be employed to nurse crops through adverse conditions. In the context of organic agriculture, we define engineered approaches as machine technology used as farming inputs. Examples of engineered inputs might be mechanized weed cultivation, novel formulation and application of biocontrol agents, mechanical barriers such as floating row covers, mechanization to speed harvest, bird distress recordings, vacuuming, etc. Conservation of natural enemies, green manure rotations, hand weeding, etc, we would not consider examples of an engineered input, although engineering and mechanization may be needed before they are possible.

In this vein, we evaluated two items, a fiber barrier to slugs, and a foam formulation for application of entomopathogenic nematodes (EPNs). Slugs are a relatively common complaint among organic growers (Hoffmann et al. 1997). They tend to be difficult to control and there are few options available. Elemental copper has been shown to be effective, but it is an expensive and labor intensive barrier. In previous experimentation, we have shown that there is potential to use a fabric impregnated with copper dust to deter slugs (unpublished). This may provide a low cost barrier that could be easily applied either manually, or much in the fashion of plastic mulch or row cover.

We also believe it may be possible to protect insect parasitic nematodes on crop foliage, where they would otherwise desiccate and die. If EPNs can be applied effectively to foliar targets, organic growers will have another control option at their disposal. Indeed, EPNs have been shown to have a very wide host range. In reality, that range is severely limited by environmental conditions (Kaya and Gaugler 1993). Thus, there isn't any widespread use of these potentially effective biological control agents. The major deterrent to the success of our proposed technique will be lack of nematode mobility and infectivity when beneath a layer of foam.

We conducted experiments to 1) evaluate a low cost fiber-copper slug barrier and, 2) evaluate the feasibility of a novel organic foam formulation for insect parasitic nematodes. The goals have potential for rapid and economic return on the research. The second objective is riskier, but may help pave the way for greater use of an under-rated biocontrol option

Copper barrier- Currently, there are limited options for controlling terrestrial molluscs in agricultural, urban, and home garden settings. Certain insecticides and inorganic copper salts are effective, but may be undesirable for a number of reasons. A common alternative tactic for deterring terrestrial molluscs is to use elemental copper strips to surround plants, but it is expensive and time consuming. Cost may be reduced by using copper dust rather than foil. In preliminary laboratory trials, copper dust adhering to row cover fabric was effective in reducing damage to test baits. Those trials showed that efficacy may be influenced by exposure time, thus, the distance the slug has to travel over copper may be important.

Foam- Entomopathogenic nematodes have been shown to have a wide host range, encompassing members of nearly all insect orders. However, that host range data comes from laboratory trials. In the field, their range is effectively restricted by their inability to survive the relatively dry conditions in plant canopies (Kaya and Gaugler 1993). Anti-desiccants have been shown to improve nematode survival and persistence, but not sufficiently to warrant their use in foliar applications (Baur et al 1997). Foams, for several reasons, may offer a novel solution for protecting EPNs.

Aqueous foams can be produced from many substances (Bikerman 1953), and they have unique and interesting characteristics. Aqueous foams are formed by reducing the surface tension of water, incorporating a gas, and allowing it to form a series of bubbles connected by a common film of water. They are wet, persistent, and flow easily. This allows relatively large expansion ratios; that is, a gallon of water can easily yield 50–250 gallons of foam, depending on formulation. As the water drains or evaporates, a solid framework can remain. An example of this would be meringue, made from egg whites. Semi-solid foams made with gelatin remain a bit moist and have a texture similar to plastic food wrap (personal observation). In experiments conducted on foams as a frost protectant (Choi et al. 1999), researchers modified a gelatin foam formulation (Braud 1970) to create a frost barrier that had a good expansion ratio and lasted for several days. Obviously, this also offers some potential to protect nematodes from UV light and desiccation. Nematodes can be either incorporated in the foam, or applied and then covered with the foam. Foams made with CO_2 have been tested for insecticidal activity, and may anesthetize insects, facilitating infection by nematodes. If nematode searching and infectivity are not compromised, foams may offer an ideal medium for foliar applications.

Objectives

1) Test efficacy of novel slug barrier.
2) Create and evaluate a foam protectant for foliar applications of insect parasitic nematodes.

Methods

Slug barrier. Experiment 1. In an experiment conducted at the Dilmun Hill Student Farm, a novel fiber barrier was evaluated for efficacy in preventing slug damage to peas. Agribon® spun-bonded polypropylene row cover was sprayed with adhesive (Super 77, 3M Adhesives Div. St Paul, MN) and dusted with copper powder of mixed particle size. The treated fabric was placed around 6 linear feet of edible pea plants. Controls were peas with no fabric barrier. Because of space considerations, there were only two treated and two untreated plots, arranged in a completely randomized design. Slugs were removed from all plots before counting was initiated. Slugs in each plot were then counted on four separate occasions on 3-4 day intervals.

Experiment 2. A second trial was conducted to compare fabric with copper, fabric alone, copper foil, and no treatment controls. Spun bonded fabric was cut into strips one foot wide and copper was affixed as before, or the fabric was left untreated. The treated and untreated fabrics were placed on bare soil to create a rectangular barrier with a 10-inch x 20-inch expanse of soil in the center. The same configuration was used for 6-inch wide copper foil. Sliced tomato baits were placed on the soil before 10-inch x 20-inch plastic potting trays were inverted and placed on pedestals to provide shade to the exposed soil. Controls were bare soil with inverted trays and tomato baits. Slugs were counted on one, two, three and six days after treatments were placed. Data were analyzed using repeated measures analysis of variance. The experiment was repeated, but hot dry weather prevented slug activity.

Protective foam for entomopathogenic nematodes. Initial studies focused on measuring microclimatic changes caused by applying aqueous foam to plant canopies. Gelatin foam was created using air bubbled through a mixture consisting of water, sugar, gelatin, glycerin, and ammonium lauryl sulfate (Choi et al. 1999). The foam was applied to containers and humidity was measured over time using Hobo® data loggers (Onset Computer Corp., Bourne, MA). Presence of free moisture was visually assessed. Various adjuvants were added to water and the insides of containers were sprayed to determine if a combination of foam and humectants would be necessary to extend nematode activity.

For nematode survival studies, the insect pathogenic nematode *Steinernema carpocapsae* was propagated in *Galeria melonella* (wax worm) supplied by Sunfish Bait Farm (Webster, WI). Daur larvae were collected and held in water at 12C until used. Laboratory studies were conducted on plants in trays. Nematodes were applied to plant foliage and then covered with foam. Over time, nematode survival and recovery were determined by counting under a microscope.

Results and discussion

Slug barrier. In the first experiment copperized fabric barrier was effective in reducing slug numbers, but differences declined over the duration of the experiment. Slug immigration was initially reduced from 50 slugs per six feet of peas to three slugs, but continual immigration and reduced emigration tended to minimize the effect over time, so that after one week, numbers were comparable between copper and no copper (Figure 1).

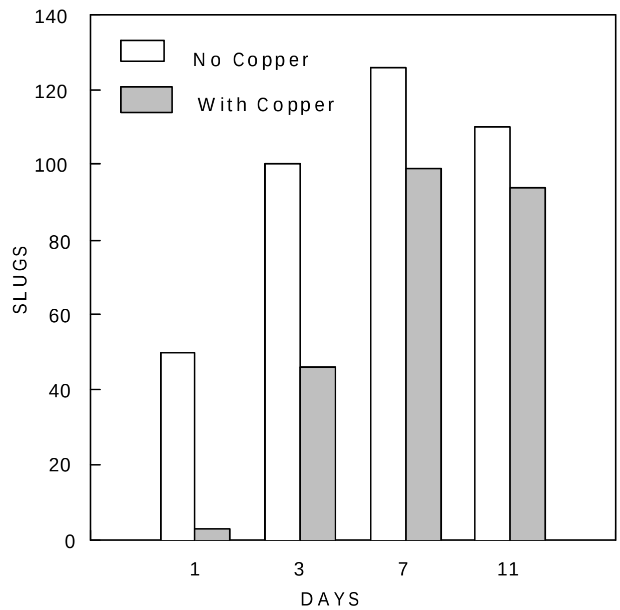

Figure 1. Slug number in peas with and without copperized fabric barrier.

In the second experiment, slug numbers were lowest in areas protected by copper, with little difference between copperized fabric and copper foil (Figure 2). There was a significant treatment by time effect (Wilk's Lambda F = 2.58, P = 0.021. The treatments with no copper showed higher numbers of slugs initially, but declined until all treatments were similar after 6 days. The overall reduction in slug numbers, over time and across treatments, may account for lack of treatment differences after 6 days.

Generally, the results from experiments 1 and 2 indicate the potential for copper-impregnated barriers to reduce slug numbers within a protected area. Other studies should be conducted to determine the optimal width and density of copper necessary to exclude slugs, and whether cost savings could be realized over copper foil

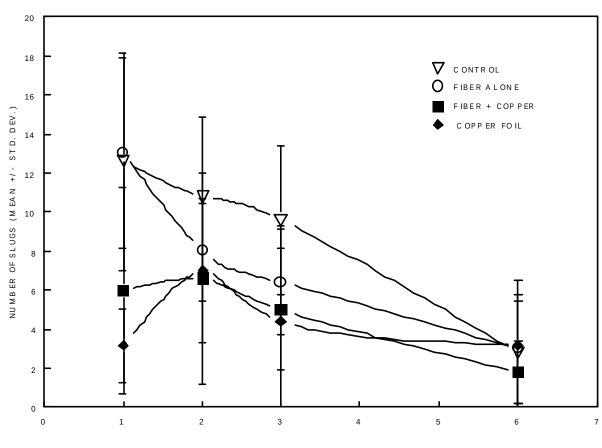

Figure 2. Number of slugs in areas protected by copperized fabric and copper foil.

Foam protectant studies. Several laboratory studies were conducted to evaluate the potential for prolonging survival and infectivity of foliar applied entomopathogenic nematodes. When foam was used to cover a dry 2L plastic container, moisture was initially added to the system, but humidity declined rapidly (Figure 3). Adding 25ml water to the container before covering it with foam kept humidity high for over 32 hours (Figure 4).

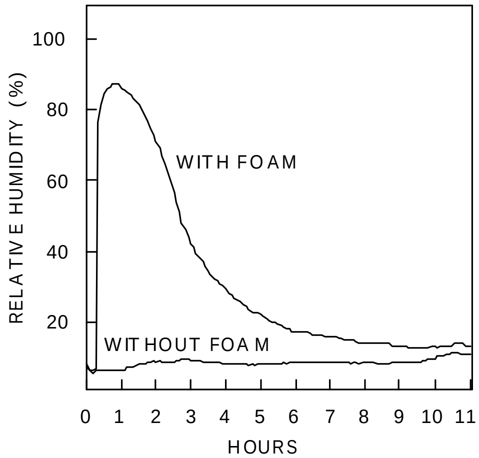

Figure 3. RH in a plastic container covered by foam

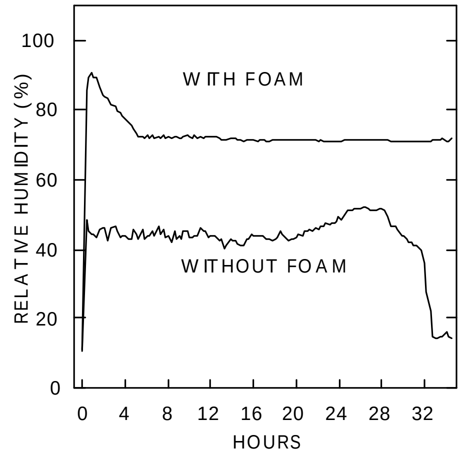

Figure 4. RH in plastic container with water added and covered by foam

Adding 50ml water plus humectant (1% polyacrylamide, Chem-Trol®, Loveland Industries, Inc., Greeley, CO) kept humidity high for over 90h. Humidity in the uncovered moisture was considerably less and plummeted after 60h (Figure 5).

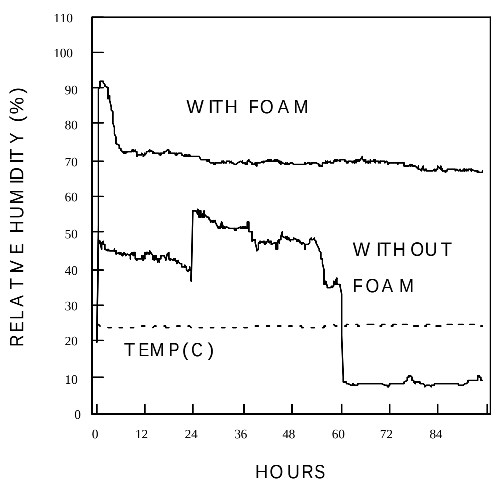

Figure 5. RH over water + humectant with and without foam protectant.

To simulate field application of foam to a plant canopy, bean foliage was covered with foam and relative humidity was measured within. Humidity fluctuated but remained considerably higher than in unprotected foliage (Figure 6).

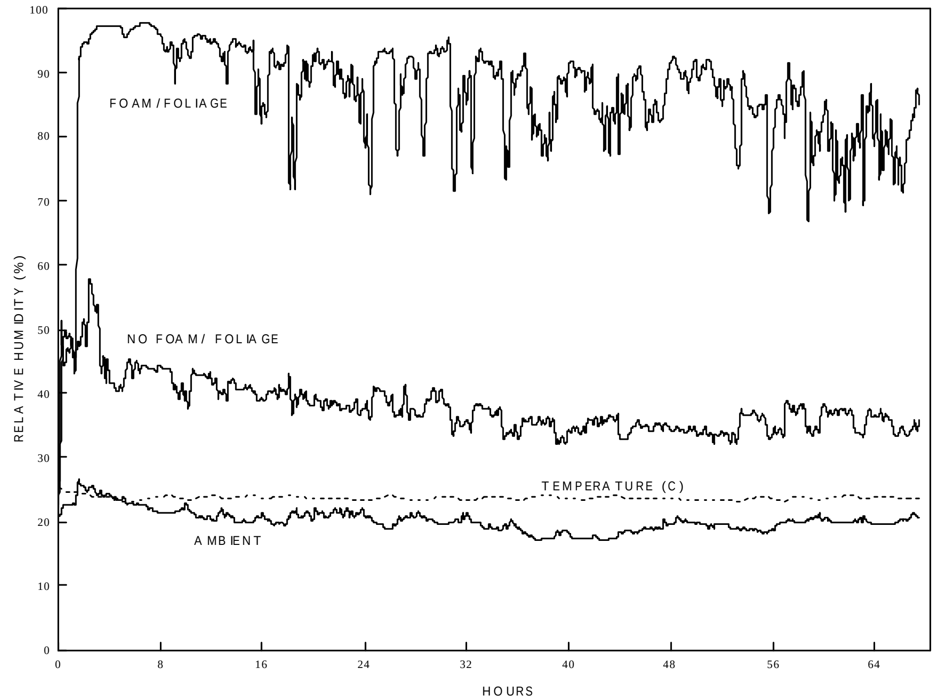

Figure 6. Relative humidity within bean canopies with and without foam protectant.

To evaluate duration of free water presence, 10-gallon aquariums were spritzed with water and covered with wire mesh. The mesh on one aquarium was then covered with foam. Again, humidity was much higher and free water was present approximately 10h longer with foam (Figure 7).

Nematode survival on mustard and pepper foliage was enhanced by foam protection, but recovery of live and dead nematodes was reduced. Survivorship was consistently higher in foam covered foliage, regardless of duration after application (Figure 8). Mixed model analysis of variance (using only 24h and 48h data to balance the design) indicated significance for both fixed effects, treatment ($F_{1,89}$ = 35.53, P = 0.0001) and duration ($F_{1,89}$ = 65.57, P = 0.0001). There was no interaction between the factors. In all trials combined, 4918 nematodes recovered from foam treatments compared to 12,884 in non-foam treatments. Overall survivorship from foam treatments was 62 ± 17% compared to 46 ± 25% without foam. So, even though survivorship was higher with foam, total number of live nematodes recovered was lower (3,049 vs. 5,927). Two possibilities may account for the observation. First, nematodes may have been trapped in the foam and were not extracted and counted. Second, the improved microclimate may have allowed them to migrated to the soil. Further studies would clarify the issue.

In conclusion, the potential exists for using these technologies to manage pests on organic farms. Further research will be needed to optimize the techniques before practical application can occur.

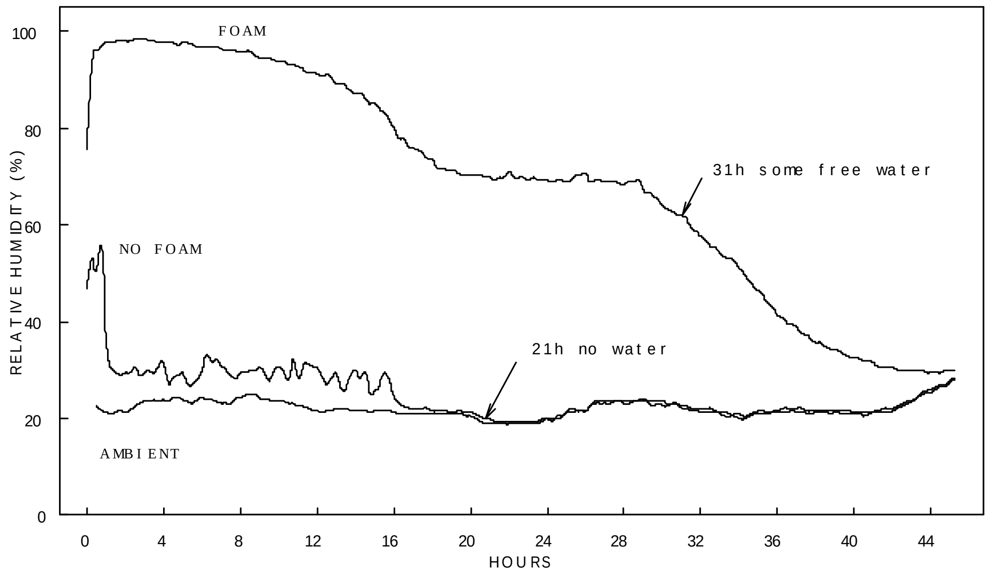

Figure 7. Free water duration with and without foam protectant.

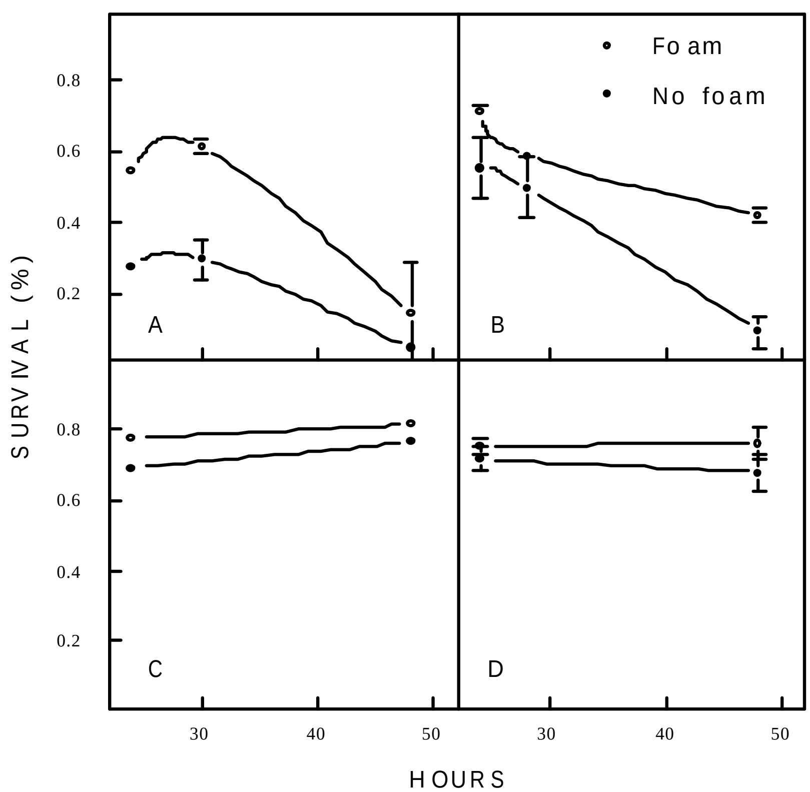

Figure 8. Percentage survival of *Steinernema carpocapse* on plant foliage with and without foam protection (mean ± SEM). Data represent separate trials on mustard (A through C) and pepper (D).

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