VINEGAR AS AN HERBICIDE IN ORGANIC GARLIC PRODUCTION

GRANT NUMBER – FNE03-461

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PROJECT NAME AND CONTACT INFORMATION

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Title - Vinegar as an herbicide in organic garlic production.

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GOALS

My goal was to test the use of vinegar as an herbicide in commercial organic garlic production on my farm here in North Western New York. (Refer to USDA Beltsville, Maryland for original research - http://www.barc.usda.gov/anri/sasl/vinegar.html).

Garlic enjoys a high dollar value return per acre and is an important and useful crop especially for North East US small farmers. As garlic production is especially labor intensive and based primarily on numerous hand operations, it is not attractive to larger operations and no equipment exists to automate its culture, making garlic a size neutral crop alternative for the organic/sustainable small farmer.

The major downside considerations with regard to garlic culture are the considerable number of individual operations (Refer to Garlic Seed Foundation - http://www.garlicseedfoundation.info/) that are necessary for both a marketable crop and the requisite quantity for profitability. Garlic does not compete well with weeds; a small and inferior quality crop is the guaranteed result if appropriate cultivation is not completed in a timely manner.

Weed control is both the most time consuming and the task most necessary in commercial garlic production. Any opportunity to improve in this area would be a major advantage for Northeast farmers to improve quality, increase production and reduce the effort required in this aspect of garlic culture.

FARM PROFILE

I have worked Honeyhill Farm's 50 acres part-time since 1978 having been involved in horses, hay and grain. I have grown and occasionally sold garlic for 12 years on an exploratory basis.

In 2002 I commenced full-time production starting with ¼ acre or 3500 feet of row (7000 plants) and expanded to ½ acre of garlic in 2003. In addition to the garlic, we sell organic mixed vegetables and pastured chickens at farm markets and restaurants.

The soil consists of a gently rolling Ontario Silt Loam with a parent of glacial till consisting of a high limestone base with a plow layer of 13 inches. It has moderate organic matter, drains well and is high in calcium, potassium and phosphorous. The pH was 6.7 at commencement of this research in the Spring of 2003.

PARTICIPANTS

Project lead – Fred Forsburg; owner of Honeyhill Farm.

Principal Advisor – David Stern, President and founder of The Garlic Seed Foundation, Rose, NY. David's extensive knowledge of both garlic and organic growing methods are legend and has been an inspiration to me. David collaborated in many ways especially in steering me toward the right directions and methods for this project. The Garlic Seed Foundation's website is www.garlicseedfoundation.info.

Advisors:

Dr. Andrew Landers, Pesticide Application Technology Specialist, Cornell University. Dr. Landers visited Honeyhill Farm at project inception and instructed me in the proper use of the spraying technology i.e. calibration requirements, suggested droplet size for the herbicide, weather conditions and target species, pressure and nozzle selection. My walking speed was measured, thus determining the volume of product applied.

Dr. Robin Bellinder, Professor of Weed Science, Cornell University. Dr. Bellinder provided information and suggestions as to project establishment and operations. She visited the project upon completion of the testing phase and confirmed that my methods were sound, evaluated the damage to both the weeds and the garlic and supported the success of the stated goals.

James Pricola, Mgr. Sales, Fleischmann's Vinegar. Jim, in support of this research, donated the 10% acetic acid vinegar including delivery. He provided me with extremely useful advice and technical information on the product including an overview on the source of vinegar, its production, storage, composition, available strengths and handling considerations. Jim can be reached at James.Pricola@Fvinegar.com.

Solo – Solo donated to this research the sprayer and associated spraying equipment, nozzles and drift guard. The Solo sprayer was selected because its internal mechanisms are unaffected by the vinegar. Solo sprayers are universally available and spare parts are easy to find. Find Solo information here http://www.solousa.com.

John Newton; Global Agricultural Technology & Engineering (G.A.T.E.) LLC - Source of the CFValve (Constant Flow Valve), an ingenious pressure-limiting device that attaches directly to the spray wand and is impervious to vinegar. G.A.T.E. additionally provided me with a selection of nozzles for use on this project. John's knowledge of the spraying technology and of my specific needs significantly contributed toward the success of this project. Find information on CFValve at www.cfvalve.com/cfvalve_ag.htm

MODIFICATIONS TO ORIGINAL PLAN

My considerations with regard to vinegar strength are effective action, safety and availability. My original intent was to use 5% acetic acid vinegar, as it is safe for use and widely available, however after further consultation, I found that a 5% solution, in most instances, would be ineffective for my needs. After consulting with a chemist, I was persuaded that the more concentrated 10% vinegar would satisfy my safety concerns. Because any commercial use would require large amounts of the product and since I found concentrations of 5-30% easily obtainable in 55-gallon drums I adjusted the plan. I believe these considerations justify the modification.

From the outset of the project I found that I was not fully treating the weeds on the side opposite on the row that I was spraying due the use of a drift guard and the angle of the nozzle. I further modified the plan by spraying on one side of the row only on two test plots and spraying on both sides of the row in the other two test plots.

PROJECT ACTIVITIES

Objective – The use of vinegar as a basally directed spray for in-row weed control of garlic.

Design – The experimental plots were set up the in a randomized complete block design. That means replicating every treatment in each block and the plots in the block are non-adjacent.

- In the field trial there were 14 rows of garlic 250 feet in length.
- Row 1 was reserved as a "sacrificial row" I used it to test the effects of direct application of copious amounts of the herbicide on several occasions.
- Row 14 was reserved and used as a buffer for the balance of the market garden.
- I divided the remaining 12 rows into 4 equal blocks, each with a control and test plot.

- In all plots I cultivated only mechanically between-rows.
- In the Control plots I cultivated only manually with a collinear hoe in-row.
- In the Test plots I cultivated only by spraying with the herbicide in-row

Among the four blocks, test and control plots were allocated so that differing soil conditions or available moisture and fertilizer through out the test field did not unduly influence the results. The test plots were laid out in the blocks such that they were non-adjacent.

The goal in spraying is uniform deposition of sprayed product on the target species. As in any spray program, it is important to control droplet size to minimize drift, improve effectiveness of the product, and reduce waste. Droplet size is a function of pressure and nozzle flow rate. The nozzle's droplet size spectrum determines deposition and drift. Large droplets can bounce off leaves and small droplets frequently drift. [Landers, Cornell] I used a medium droplet for the product I was spraying based on the tables found in the TeeJet catalog.

If there is no accurate pressure limiting or controlling mechanism, the droplet size varies constantly with pressure changes in the sprayer and a poor result is certain along with inefficient use of the herbicide. An ingenious device developed by G.A.T.E. Technology eliminates the necessity for an integrated pressure controlling mechanism within the sprayer. Called a Constant Flow Valve (CFValve), weighing less than an ounce and 2" in length, it attaches to the wand of most commonly available sprayers. The CFValve provides a constant flow of fluids regardless of varying input pressure. The flow rate remains constant with accuracy at ±1.5%. [CFValve WebPages]

Travel speed is a critical factor in maintaining accurate application rates and will influence spray deposition. Studies indicate that the higher the speed, the greater the variability. [Landers, Cornell] My travel speed was calibrated at 2 mph; this turns out to be the mid-point of the ideal speed range. Gallons per acre are a function of nozzle flow rate, pressure and travel speed.

With regard to spraying technology I used the red CFValve @ 21.5 psi (1.5 bar) and the TeeJet XR11002VS nozzle from Spraying Systems Company. The spraying equipment I used was a Solo backpack sprayer with a diaphragm pump, standard wand, and drift guard. Solo offers a variety of CFValves in its catalog, as does G.A.T.E. LLC.

Vinegar kills plant life by producing a breakdown of the cell membrane integrity resulting in desiccation of foliar tissue. [Teasdale, USDA-Beltsville] As vinegar is a non-selective herbicide, precautions were employed (drift guard) to avoid the spray contacting the garlic.

Theorizing that the waxy nature of the garlic leaf may provide some protection against the vinegar, I tested the effect of the vinegar weed control on both the immature garlic plant and mature plant in full leaf. As weed pressure is typically low in my area in early May the plants were already at 18" height during the first spray application on May 10. While there

was damage to the leaves in the form of tip burn on lower leaves it later proved to be cosmetic. Later applications of the herbicide seemed to have little visible effect on the more mature garlic.

For optimal effect I attacked the weeds at the 2-leaf (cotyledon) or emergence phase with the herbicide when possible due to the weather (see Conditions section). I sprayed a total of 5 times ending on June 22. Each time I sprayed the test plots, I also manually cultivated the control plots.

Labeled row markers were established and a complete photographic documentation was conducted on all phases of this field trial. These photographs are retained for later examination.

All rows received equal amounts of water and fertilizer and were planted with the same seed stock. I manually cultivated the entire field both in & between rows in April prior to the start of the vinegar trial. This was done to break the crust and to make the surface friable, allow it to drain, incorporate fertilizer and warm the soil.

Soil pH was laboratory tested at the onset and conclusion of this project at 6.7.

Timeline:

Summer-Fall/20002	Field preparation: summer fallow, compost and buckwheat
October 15 /2002	Planting of 14 - 250 foot rows (3500 feet)
March 22/2003	Garlic emergence
April 11/2003	Garlic side dressed with organic fertilizer (Fertrell)
April 14/2003	Manual cultivation on entire field both in-row & between-row
May 1/2003	Garlic side dressed with organic fertilizer (Fertrell)
May 10/2003	Vinegar spray program starts (also on: 5/20, 6/1, 6/15, 6/22)
June 15/2003	Scape removal
July 22/2003	Harvest

CONDITIONS

We experienced very unusual weather during the garlic-growing season here in Western NY. It was unusually cold and wet until mid-June; diminishing, I believe, the vinegar's effect on foliar surfaces and altering my ability to apply it on a regular or as needed basis.

RESULTS

The following are my observations collected during and at the conclusion of this field trial:

In short, the conclusion is that the 10% acetic acid vinegar was very useful in controlling broadleaf weeds in my test plots. The vinegar provided minimal to no control on grasses. This may be the result of the adverse weather conditions experienced during most of this field trial. More research needs to be done in the area of grass control. (See Appendix A & B).

The test plots that were sprayed on both sides of the row were almost totally devoid of broadleaf weeds at the conclusion of the trial in early July. This can be shown conclusively based on the photographic evidence.

With regard to the garlic crop, I saw no difference in plant size, maturity date, quality, yield, bulb size, appearance, or keeping ability between the test plots and the control plots.

On 3 occasions, spaced throughout the season, I liberally saturated the garlic leaves in the sacrificial row (row 1) on all sides with vinegar. While signs of cosmetic damage were evident it grew to the same height, produced scapes, and a bulb on the same schedule and of the same size and quality as the control plots. (a photographic record is retained). Since the research indicates that the vinegar was not harmful to the crop one can be more aggressive in spraying vinegar near garlic plants for weed control purposes.

Regarding vinegar altering the soil pH, this has not been my experience. The soil was laboratory tested at the inception and conclusion of the project with no change in pH value. According to the USDA research project at Beltsville, Md., acetic acid degrades readily in water and has shown little potential for bioaccumulation.

Weed control appeared to be more successful when temperatures exceeded 70 degrees and direct sunlight was available. This would seem to be consistent with the action of the active ingredient (acetic acid) in damaging the foliar tissues and rendering them susceptible to desiccation. We unfortunately experienced few days over 70 degrees prior to mid-June. This aspect on the efficacy of vinegar in weed control needs to be more thoroughly examined in other research.

The bottom line from this field trial is in the substantial saving of labor for in-row cultivation in garlic production. It would require approximately 9 hours to manually in-row weed the ¼ acre thus 36 hours per acre. Given that the garlic is unharmed by the vinegar, one could move over the rows quickly and spray an acre sans drift guard in two hours. Additionally there would be no damage to the plants due to the inevitable *slip of the wrist* when hand cultivating tightly spaced plants.

This represents a 94% reduction in labor!

ECONOMICS

All vinegar is produced from natural fermentation. The common white distilled vinegar I used is made from a source of corn-based ethyl alcohol. This vinegar is available in concentrations of 5-30%. A 55-gallon drum of 10% white vinegar, at the writing of this report, was priced at $1.21 per gallon FOB the Fleischmann's plant in North Rose, NY. A higher strength 20% white vinegar is $2.22 per gallon. [Pricola, Fleischmann's]

In this field trial I used 20 gallons per acre for each application. Five applications on an acre would require 100 gallons of product. It would make good economic sense to purchase the 20% strength and dilute it with water, saving the expense of shipping two drums 10% strength weighing 568 pounds each. One can make 2 drums of 10% from 1 drum of 20% vinegar. The formula is simple for other combinations and is available from Fleischmann's.

The purchase of a single 55-gallon drum of 20% at this writing would cost $122. Thus the cost of each treatment is $24 versus 36 hours of manual labor. Shipping costs must be evaluated separately as these are variables based on shipping distance.

As previously noted, consider the damage done to a small percentage of plants while manually cultivating: My garlic sells at $4/lb. or $1/bulb as the bulbs average 4 oz. If one were to damage only a total of 1% of the plants on an acre during the 5 manual cultivations it would represent a product loss greater than the cost of the vinegar!

ASSESSMENT

Beyond in-row cultivation of garlic, 10% vinegar is useful as a general herbicide around the farm. While the goals of this field trial did not specify ancillary uses of vinegar there is no doubt that it has much wider applicability as an ecological burn-down herbicide. The field trial documents the various broadleaf weeds that were controlled by the herbicide (see Appendix A). While most weeds were controlled in their immature stages, some weeds can be controlled as more mature plants.

Because calibrated spraying technology is assumed here for effective results and due to the tangible concern for safety in the use of acetic acid solutions greater than 5%, the home use of this research may be problematic. USDA-Beltsville research states that acetic acid concentrations over 11% may cause burns upon skin contact and upon eye contact can result in severe burns and permanent corneal injury. Concentrations greater than 11% require professional personal protective equipment to be worn by the applicator.

Clearly there is need for further testing of vinegar as an herbicide in the field and in the laboratory. Dr. Robin Bellinder, one of my advisors, is in the process of commencing additional laboratory and field trials of which I am listed as a co-operator.

ADOPTION

The flat fan (110 degree) nozzle I used for the project directed much of the herbicide into the area between the rows where it was wasted, as this area is already cultivated via mechanical means.

In my attempt to reach optimum deposition of the herbicide I attempted to get as close to the garlic plant as possible. But walking a row with a 30" wand extended from my hand with a spray guard perpendicular to the garlic row I found it difficult to avoid the garlic stems with the drift guard and it would bounce off the stem. The result was a misdirected nozzle, missing the intended target, and causing me to modify my cadence, thus slowing the process. This was most frustrating and tiring at the same time. I turned the guard 90 degrees to run parallel with the row but still had a problem with the guard hitting the stems.

In consideration of the above two issues I will initiate these improvements in my 2004 garlic production:

- I will acquire a special directed spray nozzle that will focus the spray only into the area between the plants (in-row). This may also allow a reduction in volume per acre of sprayed product.

- I will remove the drift guard as it is no longer necessary, per findings that indicate the vinegar spray did not harm the garlic plants. I will attempt to construct a wheeled device that will hold the wand while directing the spray more accurately and at the optimum height.

It would be inappropriate to assume similar results if the technology and methods used by others were not equivalent to that used in this field trial. Furthermore, it is not the intent of this report to provide instruction on the use of spraying technology and methods, as herbicide application is an entire topic unto itself. My findings are based on my experiences with the technology selected on the recommendations of experts for my conditions and usage. Therefore, I am not recommending that one embark on a project such as this without a working knowledge of proper spraying principles and appropriate technology.

Finally there is the matter of whether it is actually legal to spray vinegar on crops. There is a legal fine point in here; any material claiming to kill weeds by default becomes an herbicide. Legal minds will need to resolve this issue. As of this writing, OMRI has informed me that vinegar is approved for use in organic production.

OUTREACH

The results of the research will be published in the official publication of the Garlic Seed Foundation, *The Garlic Press*. This publication is national in scope and reaches a majority of market garlic growers in the Northeast. The Garlic Seed Foundation, based in Rose, NY, was founded in 1984 and has over one thousand members nationally, most in the Northeast.

I intend to submit the results to market gardening publications for their evaluation and publication. As I do not think this application is appropriate for home use, I do not plan on submitting to publications that cater to the home gardening readership.

APPENDIX A – BROADLEAF WEEDS

The10% acetic acid vinegar controlled all broadleaf weeds identified in the field trial.

Note - Most weeds were controlled in their cotyledon or seedling stage. Many weeds can be controlled even as mature plants but may regenerate from root reserves e.g. thistles, dandelion.

The following is a list of broadleafs identified in this field trial that were controlled; they represent both annual and perennial species:

- Bull Thistle
- Canada Thistle
- Common Ragweed
- Catchweed Bedstraw
- Dandelion
- Field Pennycress
- Field Pepperweed
- Goldenrod
- Henbit
- Milkweed
- Oxeye Daisy
- Pigweed
- Purple Deadnettle
- Queen Ann's Lace
- Sowthistle - Annual & Perennial
- White Heath Aster
- Wild Mustard

APPENDIX B - GRASSES

The10% acetic acid vinegar did not fully control any of the grasses identified in the field trial. Common Foxtail however was more affected by the herbicide while Barnyard Grass, as an example, was unaffected by the vinegar.

- Barnyard Grass
- Common Foxtail – partially affected
- Fall Panicum
- Quackgrass
- Smooth crabgrass – significantly affected in seedling stage
- Timothy

REFERENCES

Weeds of the Northeast; Uva, Neal and DiTomaso, Cornell University Press.
This book was indispensable in this research and deserves a place on the bookshelf of all farmers, gardeners and agricultural researchers.

Growing Great Garlic, Ron Engeland, Filaree Productions.
The organic garlic production guide for the small farmer.

Technically Speaking About Vinegar, Fleischmann's Vinegar
Useful information especially on composition, handling, storage and strength calculations.

Dr Andrew Landers, Cornell University:
Knapsack Sprayers – General Guidelines For Use
Selecting the correct nozzle to reduce drift
Selecting a nozzle to give desired flow rate

Agricultural Applications of Vinegar, Radhakkrishnan, Teasdale, Coffman; USDA-ARS, Beltsville, Md. The foundation of my field trial was based on this research material.

TeeJet Catalog, Spraying Systems <http://www.teejet.com/ms/teejet>
Everything you would ever want to know about nozzles, etc.

Respectfully submitted,

Frederick N. Forsburg, 1/15/2004