SARE GRANT FINAL REPORT

March 2008

1. **PROJECT NAME and CONTACT INFORMATION:**

Field Trials to Evaluate the Benefits of Biofumigation as Part of a Potato Cropping System in the Northeast

FNE# 06-575

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2. GOALS

Potato growers in the Northeast and the Northwest U.S. contend with similar potato disease and insect pressures. However, the climate and soils between these two regions are very different. Green manures are being researched and used as "bio-fumigants" in potato crop rotations in the Pacific Northwest. Information and research as to how these green manures, specifically mustard, can be used as part of a potato cropping system in the Northeast was not obtainable. Research and field trials are needed to evaluate the potential of successfully using mustard as a bio-fumigant under Mid-Atlantic climate, weather and soil conditions.

The objective of the 2006 SARE Grant was to begin the process of evaluating mustard in a potato-oats rotation, its potential to improve potato quality while significantly reducing pesticide requirements and improving soil tilth. The study of mustard as part of a potato rotation is projected to take several years as there needs to be an assessment of various cultural practices associated with growing mustard in the Northeast. The cultural practice evaluated in the 2006 field trial was to determine the nutrient and fertilization needs of the mustard and the mustards overall effects on nematodes and other soil pathogens.

3. FARM PROFILE:

Glenn R. Hetherington Farms is a 500+ potato, small grain and hay operation near Ringtown, Pennsylvania. Glenn Hetherington began farming full-time in 1978 and is the owner and operator of the farm. The approximately 130 acres of potatoes are varieties grown for their chipping qualities and are all contracted to WISE Foods Inc. for the manufacture of potato chips. The potatoes are harvested in September and October and are stored until February into April when they are delivered to the plant in Berwick, PA.. Oats and timothy/alfalfa hay are used as rotational crops. There are about 130 acres of oats (underseeded with hay) and 120 acres in hay. Approximately 60 acres are enrolled in CREP (Conservation Resources Enhancement Program). There are implemented conservation plans on all the farms acreage.

Since the SARE Grant was approved, two center pivot irrigation systems have been installed one on each of the farms where the field trials are being conducted. One system was installed on the "home" farm and the other on the "homestead" farm. Irrigation of the potatoes in the past has been done by using a solid set hand-moved overhead sprinkler system. This type irrigation system is inefficient as it is too slow to provide adequate moisture in a timely fashion to the potato acreage and it is extremely labor intensive (unable to find people to do this). The center pivot is a more efficient irrigation system, resulting in less water runoff, reduced erosion, and diminished nutrient leaching.

In order to justify the cost of a center pivot system, changes to the present crop rotation are being considered and may change to a two year potato/oats rotation or a potato/oats/potato/oats/hay rotation under the pivots. The oats would no longer be underseeded with hay. This more intensive rotation will probably require more pesticides to control overwintering insects, diseases and nematodes. The planting of mustard as a natural bio-fumigant following the harvest of the oats is expected to significantly reduce pesticide requirements and improve soil tilth.

The study of mustard as part of a potato rotation is projected to take several years as there needs to be an assessment of various cultural practices associated with growing mustard in the Northeast. The cultural practice evaluated in the 2006 field trial is to determine the nutrient and fertilization needs of the mustard and the mustards overall effects on soil tilth, nematodes and other soil pathogens.

4. PARTICIPANTS and COOPERATORS:

Penn State pathologists and Schuylkill County Extension agent George Perry took soil samples from each area of each field using GPS equipment so sampling could be repeated following the test. It was planned that soil samples would be taken from each of the fields, before and after treatment. Penn State pathologists would test for the presence of soil borne diseases. The samples taken in the fall of 2006 confirmed the presence of verticillium. In the spring of 2007, county agent George Perry retired and was not replaced. Therefore, the after treatment samples were not taken and this portion of the test was not completed.

In the fall of 2007, Bob Leiby, Lehigh County Extension Agent, took both plant and soil samples from the areas of fields where the potatoes were exhibiting "early die " symptoms which may indicate the presence of nematodes. The samples were analyzed by Penn State plant/nematode diagnostic service. Results indicated the presence of root lesion nematodes in both samples.

The Pennsylvania Department of Agriculture also sampled both test fields on the farm searching for the "golden nematode". Glenn requested that they also test for the root lesion nematode. PDA confirmed the presence of the root lesion nematode.

5. PROJECT ACTIVITIES:

2006 - three fields were specifically selected for this project.

Home farm: G2W - 8 acres, average field, (Calvin soil)
G13N – 8 acres, tested and confirmed to have root lesion nematodes* (Calvin soil)

Homestead farm: S4B – 7 acres, potatoes in '05 crop year had pink rot** (Leck Kill soil)

* Root lesion nematodes vector with vertillicium wilt (known to be present in this soil) and cause 'early die' in potatoes.

** Pink rot organism lives in soil for several years and will infect '07 potato crop if late season moisture is high.

All three fields were planted to oats in crop year 2006. Half of each field was underseeded with a 75% timothy/25% alfalfa mix at oat planting, the other half of the field was not underseeded. The oats were harvested August 5 to 9 2006. The oat straw was baled between August 8 to 15. The half of each field that was not underseeded with the hay mix was sprayed with Roundup to kill the volunteer oats and weeds on August 25th. During the 8 days from August 26 until September 2nd, it rained 4.3 inches. Due to the wet field conditions it was not possible to plant the mustard until September 11th. On September 8th, half of each field was resprayed with Roundup to kill additional volunteer oats that had sprouted due to significant heavy rainfall.

On September 11, 2006, "Caliente 119" (variety) mustard was planted in the half of each field that had been killed with Roundup. Planting was done using a rented John Deere no-till drill at a seeding rate of 16 lbs/acre.

On September 15, 2006, fertilizer was applied to the portion of each field planted to mustard using a spinner spreader. The area of the field planted to mustard was divided in two sections so that two different rates of nitrogen could be applied. The nitrogen rates were 60 lbs nitrogen/acre and 120 lbs nitrogen/acre. This resulted in each of the 3 experimental fields having the following characteristics.

MUSTARD 60 lbs nitrogen/acre
MUSTARD 120 lbs nitrogen/acre
Mixed Hay with Mocap (applied in 2007)
Mixed Hay (alfalfa/timothy)

On November 29, 2006, the mustard in all fields was roto-chopped.
On November 30, 2006, all chopped mustard was disked using a heavy disk.

In crop year 2007, each field will be moldboard plowed and planted to chipping potatoes. One-half of the sections containing the hay mix will have Mocap applied prior to planting, the other half will not receive an application.

Penn State plant pathologists and Extension agent George Perry took soil samples from each section of each field using a GPS unit so that future sampling can be repeated in the same areas.

2007 ACTIVITIES

Due to economic and marketing (contractual) changes, it was necessary to reduce planned potato acreage for the 2007 crop year. Crop rotation sequence dictated that minimal potato acreage was to be grown on the Homestead Farm. It was decided that insect and disease pressure could be reduced in future years by not growing any potatoes on the Homestead Farm in the 2007 crop year. Therefore, field S4B which had been prepared as part of this study was not planted to potatoes in

2007. This however, afforded the opportunity to continue the mustard/biofumigation trials into crop year 2008, as will be explained later in this report.

Experimental fields G2W and G13N were moldboard plowed on approximately May 1, 2007. Field G2W and G13N were field cultivated and planted to the variety Snowden potatoes on 5/14 and 5/21. These planting dates are 10-14 days later than normal and the soil was very dry. As described previously, one-quarter of each field had Mocap incorporated before planting. Herbicide was applied to G2W on 5/30 and G13N on 6/2. The soil conditions were so dry that .5 inch irrigation was applied by the center pivot to activate the herbicide. Extremely dry conditions continued such that it was necessary to apply another .5 inch before hilling – which includes a CaNO3 application.

Both experimental fields were irrigated with the center pivot system 8 times during the growing season, applying .75 inch each time. In retrospect, a greater amount of water should have been applied with each irrigation. Under normal conditions, .75 inch irrigation water every 5 to 7 days in combination with some rainfall and normal plant canopy development is enough to keep plants growing. But 2007 was far from normal! The problem was that there was no moisture available deep in the ground to migrate up into the root zone. The soaking rains that normally happen in May and June to replenish the soil moisture before the plants become large enough to require much moisture never occurred last year. Also, by July 2007 irrigation became difficult as streams and ponds began to dry up.

PLANNED 2008 ACTIVITIES

Field S4B on the Homestead Farm was scheduled for this study but was not planted in 2007. Half of that field was planted to mustard in 2006. The mustard grew only 6 to 12 inches and was disked in during the fall of 2006 essentially resulting in bare ground. The bare ground was field cultivated several times during 2007 to control weeds. An observation worth noting is that except for bindweed, weed pressure was minimal. Perhaps mustard also has some weed surpression qualities?

On August 19, 2007 fifty pounds (approximately 17 lbs/acre) of caliente mustard was planted after field cultivation using the seed attachment of a standard grain drill. Immediately after planting a 2" soaking rain occurred. The seed germinated almost immediately resulting in an adequate stand (although it appeared less dense than the previous no-till stands). On August 30th, the mustard was fertilized with some leftover potato fertilizer applying 47 lbs nitrogen, 17 lbs phosphorous, and 30 lbs potassium. By October 1st the mustard was 3 feet tall and starting to flower. On October 7th the mustard was roto-chopped and heavy disked three times.

This field is now one-half timothy/alfalfa hay (1 year) and the other half is the disked in mustard. In 2008, the entire field will be moldboard plowed and planted to potatoes. Finally, three was a charm! It took three attempts to grow the mustard to the desired 3 to 4 foot height. We speculate that the reasons the mustard grew well were because it had adequate moisture and temperature (it was a warm September), it was fertilized and it was planted earlier than in previous years. This field should provide a good test in 2008.

6. RESULTS/ACCOMPLISHMENTS:

The major lesson learned by conducting this field trial is that never accept one year of data as the norm. Experiments should be kept simple. Weather provides enough "variables" to decide whether or not a field trial becomes a success or failure.

It appears that mustard does require fertilization in order to achieve the necessary growth. It will take several more years of field trials to narrow down an exact amount. In 2006, the mustard receiving 120 lbsN/acre grew to 12 inches, while the mustard receiving 60 lbsN/acre only reached a height of 6 inches. The presence of the additional nitrogen was not noticeable until the plants reached about 4", then the ones receiving the additional nitrogen grew at a faster rate of speed. This was probably due to the plant roots becoming established and the plants were then able to uptake the additional available nitrogen. In 2007, however, only 50 lbs/Acre of nitrogen was applied and the plants grew 3 feet tall! The difference was that the mustard was planted earlier, on bare ground, and had adequate rainfall with abnormally warm temperatures. The conclusion reached from this is that mustard does require some additional nitrogen along with suitable weather requirements to reach its desired growth.

One of the positive conclusions that can be reached is that the mustard can be successfully no-tilled into the oats stubble. Potato production requires a considerable amount of tillage in the rotation. The literature on the use of mustard recommends the soil be tilled and that a good seedbed should be established in order for the mustard to germinate successfully. Adding yet another tillage operation to the soil was not desirable and using no-till methods were explored. Apparently, using a no-till drill to plant the mustard is something unique to what has been done and it works!

Mustard needs to be planted as early as possible following the oats harvest. It is possible that our growing season following the oats harvest would be too short for the mustard to attain its desired growth. The literature says that mustard should grow 3-4 feet tall to produce adequate biomass in order to be effective. The mustard planted in 2006 grew only 6" (60 lbs N/acre) to 12" (120 lbs N/acre). The delayed planting (9/11/06) date due to the need to bale the oats straw, kill the volunteer oats and extremely wet and cloudy weather was probably too late for allowing for the necessary growth. In general, we had a very cold, wet, sunless September, October, and November. In 2005, the mustard was planted earlier (August) but was not fertilized and an extremely dry August and September resulted in mustard growth much the same or less than 2006. The mustard planted in 2007 was done in mid-August and had adequate moisture and optimum growing temperatures.

An observation worth noting is that mustard may have some weed suppression potential. Except for bindweed, weed populations and pressure in the fields following the mustard appeared to be minimal. If this is the case, then planting immediately following the oats harvest and eliminating the herbicide application may shorten the delay between planting the mustard following the harvested oats.

Disking the mustard does not result in even distribution of the biomass throughout the working soil depth (at least 8" for potatoes) in my type of soil. It may be necessary to plow the mustard into the soil to adequately distribute the biomass. This raises several concerns: it would be an additional tillage practice (requiring additional time and fuel = money), the effects on soil compaction should be considered, and it would create a highly erodible soil situation unacceptable in a conservation plan.

No definitive conclusions can be drawn concerning the bio-fumigation properties of the mustard as it relates to reducing verticillium or nematode populations. No difference was observed between the mustard treated potatoes and the non-mustard treatments.

7. CONDITIONS:

The 2006 growing season contained the most weather extremes of any year that I experienced in my 30 years of farming. Twelve inches of rain fell between June 23rd and June 27th – twice as much as I have ever experienced before during that short time period. Water oozed out of most fields for 5 to 7 days, turning plants yellow. Starting on August 26th, 4.3 inches of rain fell during the next 8 days. The period between those two rain events was extremely dry and we ran the center pivot systems three cycles each. September, October, and November were cloudy, cold, and wet. These weather extremes likely effected the growth of the mustard making firm conclusions difficult. It may be difficult to draw any defining conclusions generated from production or quality data for the 2006 growing season due to weather related quality problems. For example, the quality of my potato crop was so poor (internal brown spot and brown center) that it resulted in rejection of one-third of the crop for chip production.

Extreme drought and hot is the best way to describe the 2007 growing season. May featured no (as in zero!) measurable precipitation. Both June and July each had only one significant precipitation event – a 2" cloudburst (20 minutes in duration) on 6/27 and 7/29. Immediately following each of these cloudbursts, digging in the potato hills yielded powder dry soil – the water ran off the dry ground before it could soak into the soil. The only decent precipitation event of the entire growing season occurred on August 19th - a 2" soaking rain. However, that was the last significant rainfall until October 11th. The entire growing season was hot and dry resulting in stressed plants and less plant canopy that contributed to soil temperatures being above normal.

OBSERVATIONS:

Hot and dry conditions are known to enhance "early die" in potatoes. Testing confirmed the presence of verticillium wilt and root lesion nematodes in the trial fields. Root lesion nematodes vector with verticillium wilt to cause "early die". "Early die" symptoms were first observed in July in both test fields as well as adjacent potato fields on this farm. No differences in plant vigor between any of the treatments of either field were observed at any time during the growing season. Both the test fields and adjacent fields contained irregular shaped areas where plants were stunted and eventually died earlier than other areas of the field. This is an indication of the presence of nematodes. Testing confirmed the presence of root lesion nematode. Nematode concentration in the earliest die oval area was 3 times greater than the surrounding areas.

Potato plants in all areas of both test fields were mostly (70%-80%) dead by late August. There was no observable difference between treatments. The potatoes were harvested September 20th thru 30th. There were no apparent differences in yield, size, or quality between the treatments. The yield was approximately 100 cwt/acre which is about one-third of what is normally expected.

8. ECONOMICS:

Input comparison

	2008 prices	2006 prices
Fertilizer (100 lb N)	$140	$70
Seed $15 lb/A @ $5.00/lb	$75	$75
Herbicide (Roundup) 1 qt.	$12	$12
Herbicide application	$18	$12
Fertilizer spreading	$10	$10
No-till drill	$24	$16
Rotary chopping	$23	$15
Heavy disking (2X)	$45	$30
Irrigation (2X)	$60	$40
TOTAL	$407	$280

In addition to the obvious economic considerations there are several other concerns worth mentioning. The price of fertilizer has more than doubled in the last two years and the price of fuel has almost doubled. The mustard seed is produced in the Western states and transportation costs have skyrocketed. There are the persistent problems in getting mustard to grow to the desired bulk mass in the potato/oat rotation. If success is achieved in growing the mustard to its desired height the ultimate result is that the treated fields are bare during the winter as a result of having to disk (or possibly plow) the plant tissue into the soil during the fall (when green) to promote its fumigant capabilities. From a soil conservation standpoint, is just isn't a good practice to have so much ground "uncovered" during the winter and early spring months.

Another option for suppressing nematodes in potatoes has recently been approved by the EPA during the past year. During the 2008 growing season the effectiveness of 2 quarts/acre of Vydate CLV in furrow at a cost of approximately $35.00/acre will be evaluated.

9. ASSESSMENT

Caution must be given to conclusions drawn from a one year trial. Initially the mustard appeared to require the addition of nitrogen fertilizer in order to promote adequate growth (120lbs N/acre). From the first year trial we could have easily concluded that mustard would require at least 100 lbs of Nitrogen per acre in order to achieve adequate growth. The 2007 planting grew better with only 50 lbs N/acre. Every year provides a different set of growing conditions. More trials are needed to narrow down the fertilization requirements of the mustard.

Another trial using a reduced seeding rate from the one used in this trial (16 lbs./acre) is suggested. The plants germinated very thick in the rows and it is thought that if the plants had less competition from each other and more room the plants might have grow taller.

No-till planting of the mustard is successful. Similar to the planting in 2005, the mustard seed germinated very well in 2006 using the no-till drill into the oats stubble. The 2007 planting was done on bare ground and yielded better results. It is believed that the results would have been the same if the mustard had been no-tilled. A side-by-side study (all weather conditions being normal) in a field using the no-till planting and conventional planting would be another interesting field trial.

It appears that in order achieve adequate growth of the mustard in our climate it will be necessary to plant it earlier – perhaps too early to fit into a rotation with the oats. The next experiment should entail planting the mustard immediately after the oat/straw harvest instead of waiting for the volunteer oats to germinate and killing them with the Roundup. A post-plant selective herbicide to control volunteer oats would be used if necessary.

Observations of weed populations indicated that mustard may have some weed suppression capabilities. Again, additional field trials would be necessary to document this. If the mustard does indeed inhibit weed growth it may be possible to plant it immediately into the oats stubble without the application of an herbicide.

There is a concern that heavy disking alone does not adequately mix the mustard biomass into the working soil depth. If moldboard plowing would be necessary in a two year rotation (potato/oats-mustard), the entire farm would be without soil cover over the winter. This is unacceptable from a conservation and a soil erosion standpoint. A suitable cover crop has yet to be found that can be planted in the fields where potatoes have been harvested. Stone picking after harvest is not completed prior to November 10th and this is too late for most traditional cover crops to become established. Soil compaction with the additional soil tillage operations and equipment passes over the field should also be considered.

Another possibility to consider would be to remain on a three year rotation (maintain the year of hay). The hay provides additional root mass and organic material that provides much needed organic matter to the soil. The benefits of the addition of the hay organic matter may outweigh the benefits provided by the mustard. The mustard could be planted in fields where disease and insect pressure is the greatest. If the mustard biomass is effective in reducing disease and insect pressure, it is worthwhile to pursue a way to use it in a potato rotation.

As previously stated, more years of field trials are necessary just to learn what the cultural requirements are for growing mustard in our climate. As far as ascertaining the biofumigation properties are concerned, it may require the resources of a University to make this determination.

10. ADOPTION

The 2007 growing season has driven home the realization that, considering the current economics of potato production, the root lesion nematode/verticillium wilt problems existing on the Home and the Homestead Farm must be addressed. Traditional fumigation methods are not a likely solution due to the shaley soils. The application of Mocap appears not to be effective for the suppression of verticillium wilt. I had hoped to be able to shorten the potato rotations under the irrigation systems to more efficiently use the available water and mechanization for the growing of my primary crop. Instead I need to consider stretching the rotation in order to not plant potatoes in those fields with high nematode and disease pressure. Perhaps a stretched rotation into which mustard could be incorporated or wheat/mustard prior to potatoes would prove to be beneficial.

The use of mustard in the rotation does have some limitations. One of the main concerns is the fact that it needs to be incorporated into the soil during the fall leaving the soil without cover over the winter. In our trials the mustard was only disked in during the fall. We do not know how much the mustard must be incorporated into the soil in order for it to be the most effective. In our trials the mustard was only disked in during the fall. A trial where the mustard is moldboard plowed into the soil to maximize incorporation of the green material should be done to compare its effectiveness with that which is only disked.

11. OUTREACH

The original plans for outreach relied primarily on the meeting activities of County Agent George Perry. Due to his retirement, outreach activities were greatly curtailed. However, the Pathology Department at Penn State, under the direction of Dr. Barbara Christ, began conducting their own field trials with mustard at Rock Springs Research Farm during the summer of 2007 as part of an experiment to observe its properties as they relate to the reduction of soil borne diseases and nematodes. We hope to learn the results of their trials and have shared the results of ours with them.

12. REPORT SUMMARY

The objective of the 2006 SARE Grant was to begin the process of evaluating mustard in a potato-oats rotation, its potential to improve potato quality while significantly reducing pesticide requirements and improving soil tilth. The study of mustard as part of a potato rotation is projected to take several years as there needs to be an assessment of various cultural practices associated with growing mustard in the Northeast. The cultural practice evaluated in this field trial was to determine the nutrient and fertilization needs of the mustard and the mustards overall effects on nematodes and other soil pathogens.

We were able to determine some of the cultural requirements of growing the mustard for this purpose in our area. Mustard needs to be planted as early as possible following the oats harvest. It was observed that the mustard appeared to have some weed suppression properties. Perhaps it could be planted immediately following the removal of the oats stubble and forgo the herbicide application thought to be required. It germinates easily but requires adequate moisture in order to grow to its desired height of 3 plus feet. It appears fairly drought tolerant but it just does not grow. Mustard can be successfully planted with a no-till drill but seemed to grow more vigorously when planted on tilled soil. Mustard was successfully grown (in this particular field) to its desired 3 foot height when seeded at 16 – 17 lbs/acre with an application of 50 pounds of nitrogen/acre along with adequate moisture and sufficient growing season that had abnormally warm temperatures.

We were unable to draw any definitive conclusions as to whether or not mustard planted into a potato rotation will have a suppressive effect on soil borne diseases such as verticillium wilt and nematodes.

As is expected, we have more questions than we have answers! It will take several more years of trials and observations in order to draw any definitive conclusions as to the benefits of planting mustard in a potato rotation. Hopefully Penn State will continue with their mustard trials at the Rock Springs Research Farm and we will be able to compare notes and learn from their research field studies.

Thank you for your support for this project on our farm.

Sincerely,

Glenn R. Hetherington

Martie

Glenn and Martie Hetherington