PROJECT TITLE

Modern Soil Fumigation Research and Education for Michigan Potato Production

PROJECT SUMMARY

About half of Michigan's potato acreage is treated with soil fumigants through modern subsurface shank injections to control the penetrans root-lesion nematode and dahliae Verticillium fungus. No reliable data have been developed in Michigan on efficacy for this technology. This Specialty Crop Block Grant, funded at $49,000 from the Michigan Department of Agriculture to the Michigan Potato Research Commission for research conducted by Michigan State University compared various treatment rates and injection depths against non-treated control plots. The 2010-2011 research results should lead to recommendations for fumigators and an information set for non-fumigators to use for deciding whether or not to adopt fumigation. Educational materials, including a "Soil Fumigation Field Guide" and a "Potato Nematode Farm Guide" were also produced as part of the project. The project design and associated EPA fumigant re-registration process were presented to the Michigan potato industry at their 2011 annual meeting. The research results and copies of the educational materials will be presented and distributed at the 2012 meeting in February. This process is essential in light of the Environmental Protection Agency's new required inclusion of detailed Good Agricultural Practices (GAP) as part of labels on re-registered fumigants.

Approximately half of Michigan's 40,000 acres in potato production is fumigated. Growers make rough fumigation cost-benefit calculations. Some are willing to sacrifice fumigation and live with lower yields; whereas, others would not operate without fumigant protection. Fumigation that controls the penetrans root-lesion nematodes and dahliae Verticillium fungus has been a significant contributing factor in the doubling of Michigan potato yields in the last half-century to approximately 320 hundredweight per acre.

The fumigant most commonly used is metam sodium. The typical fumigation technique in Michigan is subsurface injection whereby a moving shank digs into the soil and the fumigant is injected through an attached nozzle. The nozzle can be placed at a 12-inch depth for reaching the nematode zone or a six-inch depth that is believed to be effective against dahliae Verticillium. The mechanism can be adapted for injections at both 12-inch and six-inch depths. Shank-injection technology includes backflow control to prevent accidental fumigant discharges.

The rates used in Michigan potato fields are still largely guesswork. No controlled studies have been done with modern injection equipment to determine optimal rates for optimal pest control at the respective depths. Growers face the quandary of wasting money by over-applying the costly fumigants or losing the degree of pest control they need by applying too low a fumigant rate.

While the research results and educational materials will assist Michigan potato growers in evaluation the economics of fumigation, a second year of data will be necessary. Funding for this has been obtained from industry and the work initiated in the fall of 2011. Both of the educational products from this project stress Good Agricultural Practices (GAP). This is an

issue having an impact on the entire Michigan potato industry. Fumigants have been re-registered by EPA. The new labels mandate a Fumigation Management Plan and Post-Application Report. under the Phase I labels that took effect in 2011. It is believed that various GAP will be available for reducing the size of Buffer Zones when the Phase II labels are finalized in the spring of 2012.

PROJECT APPROACH

Two sites on Michigan commercial potato farms (Farm I. and Farm II.) were selected for the study based on grower fumigation experience and site availability. Both sites were selected in part, based on moderate potato early-die risk information provided by the farm. Four treatments, each replicated four times in a randomized block design were established in the fall of 1010. Each plot was four-rows in width and 250 feet in length. The sites were sampled for the penetrans root-lesion nematode and dahliae Verticillium fungus at 0-6 and 6-12 inch soil depths in both the fall of 2010 and spring of 2011. The plots were sampled again in the fall of 2012 at a 0-12 inch soil depth. Both sites were fumigated in the fall of 2010 using grower equipment. At Farm I, the fumigant was shank injected at a 12-inch soil depth. On Farm II, the fumigant was injected at both a 5 and 10-inch soil depth, with 60% of the material being applied at the 5-inch depth and 40% at the 10-inch depth. The variety Snowden was planted in the spring of 2011 at Farm I. and F-2137 at Farm II. The following four treatments were used:

Farm I.

Non-treated control
Metam (18.75 gallons per acre)
Met am (37.5 gallons per acre)
Metam (75 gallons per acre)

Farm II.

Non-treated control
Metam (50 gallons per acre) + Water (20 gallons/acre)
Metam (50 gallons per acre)
Metam(70 gallons per acre)

A subsample of each plot was harvested in the fall of 2011 and the tubers graded.

GOALS AND OUTCOMES ACHIEVED

1. Develop sound research data that will yield recommendations growers can follow to achieve maximum productivity at the least cost in their nematode and Verticillium control. The data will also be available for non-fumigators to evaluate in their own decision-making concerning the advisability of fumigation. The purpose is to enhance the competitiveness of Michigan potato growers through reliance on rigorously designed replicated research.

2. Develop educational materials for soil fumigation and nematode management in potato production. Make these materials available and discuss them at Michigan potato industry at grower meetings.

2011 potato tuber yields were general low throughout Michigan. This was reflected in the research yields on both of the farms included in the study. At Farm I., total tuber yields were significantly increased (P = 0.049) through the use of metam (Table 1). The highest yield was 276 cwt/acre, 34 cwt/acre more than yield associated with the non-treated control. The A tuber yield exhibited a positive linear increase from the non-treated control through the highest rate of metam. While there were no statistically significant differences in the J yields associated with the treatments, the highest were from the 18.75 gal/acre and 37.5 gal/acre rates. B tuber yield was significantly (P = 0.030) enhance through application of metam, with the greatest yield being associated with the 37.5 gal/acre rate. The treatments did not appear to have any impact on culls or specific gravities.

Table 1. Specialty Crop Block Grant Metam Research, Farm I. 2011 potato tuber yields (cwt/A).

Treatment	Total	A's[1]	J's	B's	Culls	S. G.
Control	242	183	0.7	57	0.7	1.070
18.75 gpa	269	193	3.5	71	1.2	1.069
37.5 gpa	276	197	3.4	93	0.0	1.071
75 gpa	267	204	1.9	62	0.0	1.070
P	0.049	0.224	0.500	0.030	0.293	0.581

[1]A, B and J refer to tuber size: 1 7/8 in. to 3 ¼ inch in. diameter, < 1 7/8 in. and > 3 ¼ in, respectively.

At Farm II., tuber yields ranged from 389 to 424 cwt/acre, with the highest yield associated with the 50 gal/acre metam rate diluted with 20 gal. of water (Table 2). While the yields were higher on Farm II., compared to Farm I., there were no statistically significant differences in the total, A, J, B or cull tubers associated with the four treatments. Likewise, there were not statistically significant differences in the specific gravities associated with the four treatments.

Table 2. Specialty Crop Block Grant Metam Research, Farm II. 2011 potato tuber yields (cwt/A).

Treatment	Total	A's	J's	B's	Culls	S. G.
Control	389	334	31	29	3.5	1.085
50/20 gpa[2]	424	364	47	19	6.5	1.083
50 gpa	403	343	38	21	3.3	1.083
70 gpa	388	321	46	18	2.0	1.084
P	0.428	0.280	0.693	0.593	0.127	0.161

[1]A, B and J refer to tuber size: 1 7/8 in. to 3 ¼ inch in. diameter, < 1 7/8 in. and > 3 ¼ in, respectively.
[2]50 gal of metam diluted with 20 gal of water an applied at a rate of 70 gal/acre.

The initial population density of penetrans root-lesion nematode at Farm I. was uniformly distributed throughout the research site (P = 0.905 and P = 0.903, Table 3.). The population density at the 6-12 inch soil depth was significantly (P = 0.05) greater than at the 0-6 inch soil depth at the beginning of the experiment. The population density of this nematode remained

low at this site throughout the research period and no differences were detected among the four treatments.

Table 3. Specialty Crop Block Grant Metam Research, Farm I. 2010-2011 penetrans root-lesion nematodes per 100 cm^3 soil.

Treatment	Fall, 0-6 in.	Fall, 6-12 in.	Spr., 0-6 in.	Spr., 6-12 in.	Final 0-12 in.
Control	5	12	1	0.0	2.3
18.75 gpa	5	17	1	0.3	8.0
37.5 gpa	4	13	0	1.0	1.5
75 gpa	5	15	0	0.3	3.0
P	0.905	0.903	0.574	0.352	0.430

Population densities of the penetrans root-lesion nematode were higher at Farm II. than those encountered at Farm I. (Table 4). At the beginning of the research, the population density of this nematode was uniformly distributed throughout the research site (P = 0.970 and P = 0.971). At this time, the population density was significantly (P = 0.05) greater at the 6-12 inch soil depth than at a soil depth of 0.6 inches. In the spring of 2011, the highest population density of the penetrans root-lesion nematode as associated with the non-treated control at a soil depth of 6-12 inches (P = <0.001). At a soil depth of 0-6 inches the highest nematode population density was associated with the 50 gal/acre metam treatment without water. By harvest population densities had increased where the fumigant had been used,

Table 4. Specialty Crop Block Grant Metam Research, Farm II. 2010-2011 penetrans root-lesion nematodes per 100 cm^3 soil.

Treatment	Fall, 0-6 in.	Fall, 6-12 in.	Spr., 0-6 in.	Spr., 6-12 in.	Final 0-12 in.
Control	22	50	0.5	32.5	42
50/20 gpa[1]	18	41	0.0	0.5	18
50 gpa	21	49	10.5	0.0	15
70 gpa	19	40	3.0	1.0	17
P	0.970	0.971	0.070	<0.001	0.693

[1]50 gal of metam diluted with 20 gal of water an applied at a rate of 70 gal/acre.

Population densities of the dahliae Verticillium fungus were higher in the soil on Farm I., compared to Farm II. (Table 5. and Table 6.). The population density appears to be slightly higher at a soil depth of 6-12 inches, compared to a 0-6 inch soil depth. There were no detectable differences in the population densities of this fungus among the treatments at any of the sampling dates or soil depths at Farm I.

Table 5. Specialty Crop Block Grant Metam Research, Farm I. 2010-2011 dahliae Verticullium fungal colonies per 10 grams of soil by wet sieving.

Treatment	Fall, 0-6 in.	Fall, 6-12 in.	Spr., 0-6 in.	Spr., 6-12 in.	Final 0-12 in.
Control	6.8	3.5	9.3	13	3.8
18.75 gpa	1.8	8.3	5.8	5	1.8
37.5 gpa	4.5	5.3	9.3	8.3	2.5
75 gpa	5.5	3.8	8	9	5.0
P	0.627	0.686	8.063	0.343	0.468

Population densities of the dahliae Verticillium fungus at Farm II. Were low at all sampling dates (Table 6). At the beginning of the experiment, the distribution of this fungus throughout the experimental site was more uniform at a soil depth of 6-12 inches than at a 0-6 inch soil depth. There were no detectable significant differences in the population densities among the four treatments.

Table 6 Specialty Crop Block Grant Metam Research, Farm II. 2010-2011 dahliae Verticullium fungal colonies per 10 grams of soil by wet sieving.

Treatment	Fall, 0-6 in.	Fall, 6-12 in.	Spr., 0-6 in.	Spr., 6-12 in.	Final 0-12 in.
Control	1.3	2.5	0.3	0.3	3.8
50/20 gpa	0.8	2.3	2.0	2.0	1.8
50 gpa	2.8	2.0	0.5	0.5	2.5
70 gpa	1.8	2.0	1.0	1.0	5.0
P	0.426	0.983	0.608	0.938	0.468

Grower meetings and development of two field guides were used to fulfill the educational component of the project. The first educational session was held at the 2010 Michigan Winter Potato Meeting in Mt. Pleasant. The soil fumigation component consisted of three presentations. The first described this project, the second reviewed the Michigan atmospheric admissions research that resulted in significant changes in the EPA proposed buffer zones, and the third was a review of the Good Agricultural Practices (GAP) that will be part of Phase II fumigant labels The field guides were to be published in time for the 2011, Great Lakes Expo, but this was not possible since EPA did not meet the fall 2011 deadline in regards to Phase II labels. A soil fumigation session was held at 2011 Great Lakes Expo. It was extremely well attended! There were presenters from EPA, private business and Michigan State University. The general consensus was that the first year of implementation of the Fumigant Management Plans went very well. It is very likely that this was the case because of the leadership by the Michigan Potato Industry Commission in regards to pre-implementation educational programs. The most significant new items discussion at the session related to the fact that two separate postings for each fumigated site are required under the new labels. One is for the treated area and the other for the buffer zone. They have separate requirements in regards to entry periods and posting take-down. The second related to Good Agricultural Practices (GPA). There are three separate types of GAP associated with potato production: 1) those used for formal farm GAP certification, 2) those will be used in Phase II labels for buffer zone size reductions, 3) and those recommended by Michigan State University for superior fumigation results.

Immediately before the December 31, 2011, end of this project, the two field guides were published. The first is entitled, *Potato Soil Fumigation: A Field Guide to Fumigant Management plans, With Special Reference to Potato Early-Die in Michigan (2011 Review Edition)*. Because of the project completion deadline and the fact that EPA will not have Phase II labels available. A limited number of review copies were produced and a second edition will be published as soon as Phase II labels are available. It was originally intended for this publication to have co-authors from Oregon and Florida. After discussion with these individuals, it was determined that there were enough differences in the fumigation practices in these regions to focus solely on Michigan. A copy is included as part of this report as Appendix A.

The second educational publication is entitled, *Potato Nematodes: A Farm Guide to Nematode Diagnostics and Management*. Both educational documents will be introduced to the Research Committee of the Michigan Potato Industry Commission at their meeting on January 12, 2012. As described in the original project proposal, they will be used as part of the soil fumigant educational session at the Michigan Winter Potato Meeting in Mt. Pleasant on February, 16, 2011. It was originally intended for the nematode document to have co-authorship with an individual from Wisconsin. Because of the constraints in regards to the delay in Phase II labels, this was not possible. It is hoped that Dr. Ann MacGuidwin, of the University of Wisconsin will be a co-author of the second edition of this publication. A copy of this document is attached to this report as Appendix B.

BENEFICIARIES

The beneficiaries of this block grant funding were Michigan Potato Growers attending the 2011 and 2012 Winter Potato Conference and other educational sessions where the application of fumigants using Good Agricultural Practices and modern application techniques were explained. Because fumigation is not limited to potato fields other farm operations also benefited where information generated by this research was presented. These meetings include the Great Lakes EXPO, Decision Makers Tour, 2011 (Feb.) MSU Extension Fumigation meeting. Not fumigating potato fields with high nematode populations prior to potato production is believed to be a practice that is self-limiting. Potato yields will continue to decline as the population of nematodes increase. Soil fumigation at 20, 40 and 60 gallon per acre has to increase marketable tuber yields by 17.5, 29 and 40 cwt, respectively, to cover the cost of fumigation. Due to extreme heat in late July 2011, a reduction of 18 cwt per acre was reported by the USDA National Agricultural Statistics Service state wide. Given the unusual growing season it is not possible to determine what the yield benefit would have been due only to a fumigation application. The field research component of the project is being repeated in 2012. Funding for the project has been obtained from TKI, a manufacturer of metam and also a beneficiary of the 2010-2011 grant. While each crop has its specific weather related impact on yields it is safe to say that the decision to make a fumigation application is driven by historical results and not a year to year yield comparison. The benefit of the educational effort provided by this grant is that growers and residents in rural communities began thinking in terms of optimal treatment, best practices, use of modern technology and safety of rural residents.

LESSONS LEARNED

Potato-Dearly Die is a key limiting factor in Michigan potato production. Soil fumigation is frequently used for managing this infectious disease. During two decades of research at the Montcalm Potato Research Farm with metam, increases in tuber yields from application of this chemical were always in the 100-200 cwt/acre range. The equipment used in these studies, however was different than the modern soil fumigation equipment used on today's potato production systems. In one case, it was demonstrated that while the 35 gal/acre rate was adequate for control of the penetrans root-lesion nematode and early-die, the 75 gal/acre rate was necessary for reducing population densities of the dahliae Verticilium fungus. In recent years, however, there have been a number of cases where Michigan potato growers failed to obtain major tuber yield responses. In general, potato yields in Michigan in 2011 were lower than usual. This was the case for both Farm I. and Farm II. used in the current research project. The reason for this is unknown. At both sites, early-die symptoms were relatively mild and did not appear until later in the growing season than normal. Yield response to what would be considered optima fumigation was only 34 cwt. /acre at Farm I. and 35 cwt. /acre at Farm II. This mandates that the research be repeated under a different set of environmental conditions. Funding from private industry has been obtained to do this and the research was initiated in the fall of 2011 at three commercial potato production enterprises in Michigan.

Key findings/discussion associated with the research are:

1. The rates of fumigant used must be specific for the type of equipment used and other associated management practices used on each farm. Excellent penetrans root-lesion nematode control was obtained at Farm II. This could not be adequately accessed at Farm I. because of low initial, growing season and final population densities of this nematode.

2. When the fumigant was injected at a 12-inch soil depth at Farm I., there was a linear increase in tuber yield with increasing fumigant rates from 18.75 to 75 gallons per acre. At this site, however, the greatest yield increase was with B size tubers, indicating that the crop may not have completely matured properly.

3. When the fumigant amount is split and is injected at two soil depths, 5 and 10 inches (60% at the 5 inch depth and 40% at the 10-inch depth) dilution with water appears to the necessary. This was reflected in both tuber yield and nematode control. The width of the blade at the base of the shank may have a bearing on this. The blade used for the 12-inch injection was wide and that used for the split injection was significantly narrower.

4. In Michigan, the dahliae Verticillium fungus is uniformly distributed through the 0-12 inch soil depth profile. The population density was not greater at the 0-6 inch soil depth, compared to a soil depth of 6-12 inches. This is logical because of the types of tillage, crop rotation systems used in addition to various environmental stresses.

The Michigan potato soil fumigation education program appears to have been successful and on a good future trajectory. Growers seem to be very interested in the GAP approach to both their overall farm and soil fumigation technology. It is believed that the 2012 Michigan soil fumigation research will provide significant additional practical information in regards to this topic.

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