Mustard Green Manures for Soil-borne Pest Control

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This document was adapted from the publication *Using Green Manures in Potato Rotations*

Why use green manures?

Potato producers are using green manures to produce better crops by improving the quality of their soils. The physical, chemical, and biological characteristics of soil may all be improved by through green manures.

Physical characteristics such as water infiltration rate (see Table 1), tilth, water holding capacity, and aeration, are generally improved by the addition of organic matter to the soil, be it via manure, green manure, compost, or crop residues.

The chemical properties of a soil can be improved by increasing nutrient and organic matter levels. This too comes from organic amendments to the soil.

The biological characteristics of a soil, such as biomass, biological activity, and biodiversity, can also be improved through green manures. These changes in the soil's biology provide the short-term economic incentive to use green manure crops in potato rotations, especially for soil-borne pest management. Fungal and bacterial diseases, nematodes, and weeds can all be reduced by using a green manure crop.

When used in certain cropping systems (*see Dale Gies System Profile* publication, and Tables 2-4), green manure crops have been able to replace expensive fumigants. However, the degree and duration of these beneficial effects depends on many factors, such as soil texture, climate, tillage practices, and crop rotation. Therefore, the benefits of green manures may differ between systems.

How green manures help manage pests

The effects of green manures on soil-borne pests are the result of several interacting mechanisms. These mechanisms take place in the complex environment of the soil where it is difficult to measure the specific biological processes taking place. Therefore, it is difficult to say which mechanism is most important or how they work in conjunction with each other—we can only deduce which mechanisms may be at work. Still, it is of benefit to review these mechanisms and the strategies that you can take to enhance their effects in your system.

Crop rotation
Before advances in soil microbiology, many green manure and cover crop effects were combined under crop rotation. Crop rotation reduces pest problems by changing the environmental conditions in the field. Each pest has a set of conditions that it prefers. If pests are allowed to have their favored set of conditions for too long, they multiply rapidly and give us problems.

In general, rotating crops with different planting dates (spring vs. fall), different growing habits (annual vs. perennial, tall vs. short, fibrous vs. tap roots) or different susceptibility to pests (grasses vs. broadleaves) prevents any one pest from becoming a problem.

Strategy
Rotate crops that are as different from one another as possible and usually, the longer the rotation the better the pest control achieved. With green manures, grow a crop that is not a host to the pests that affect your main crops.

Competitive exclusion
A second mechanism of some green manure crops has been termed competitive exclusion. This is the mechanism put forward by scientists to account for suppression of *Verticillium dahliae,* the cause of verticillium wilt in potatoes, after a green manure crop.

They have observed that when certain green manures (barley, mustard, rapeseed, sudangrass, and sweet corn) are incorporated before a potato crop, the level of infection by the *Verticillium* is low even with high levels of the fungus still in the field.

Green manure serves as an energy source for beneficial microorganisms. It is suspected that these beneficials out-compete the *Verticillium* for energy and increase in number. Then, after the potato crop is planted, they exclude the *Verticillium* from the area along the potato roots. This area, called the rhizosphere, is the only place where *Verticillium* can infect potato plants, thus exclusion prevents infection.

Strategy
Produce a good green manure crop. The more biomass that is produced the better, as long as it does not affect your ability to establish the following cash crop. This is where fall incorporation can be helpful; large amounts of biomass have longer time to break down before you need to plant your potato crop. However, in some conditions, fall incorporation may also increase wind erosion and winter leaching of nitrate.

For this purpose, dried crop residues do not work as well as fresh green material. Therefore, incorporate the green manure crop while it is still green.

Biofumigation
This term was coined to describe the effects of *Brassica* rotation crops or green manures on soil-borne pests.

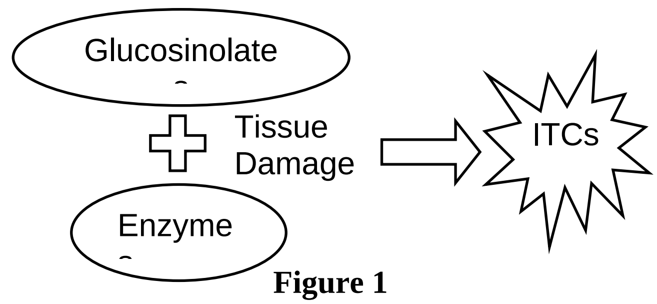

Figure 1

Brassica crops such as rapeseed and mustard contain biologically active chemicals, called glucosinolates. In the soil, certain glucosinolates in the roots of rotation crops, or in the roots, stems, and leaves of green manures, break down into isothiocyanates (ITCs). ITCs can kill or suppress some soil-borne diseases, nematodes, and weed seeds.

There are many types of glucosinolates, some of which produce different types of ITCs, which vary in their toxicity to different pests. Methyl ITC is the active chemical produced when metham sodium, a common synthetic fumigant, is applied to the soil; hence the name biofumigation when ITCs are produced by plants.

In the laboratory, these chemicals have suppressed growth of silver scurf, white rot, powdery scab, and pink rot. Field tests have shown mixed results and research is ongoing.

Strategy
First, select species and varieties that produce large amounts of biomass with a high concentration of glucosinolates. Generally, the concentration of glucosinolates peaks just before flowering, however, biomass continues to increase until the plants begin to dry. The time of incorporation for maximum biofumigation is not yet known.

Second, to produce ITCs, the glucosinolates must be exposed to specific enzymes, which are normally separated from the glucosinolates in the plants *(see Figure 1 above*). Current practice is to chop the green manure before incorporating to insure that this mixing occurs. A high-speed flail chopper, such as those used by some grass seed and asparagus growers, may be the best implement for this. Finally, ITC production is greater in wet soils than in dry soils, so if possible, irrigate following incorporation.

Induced resistance?
This mechanism is also called organic matter-mediated disease suppression. Similar to competitive exclusion, it occurs when beneficial organisms are stimulated by the addition of organic matter to the soil. Some of these beneficials then secrete chemicals that come in contact with plant roots and induce resistance in the plant. In some cases, resistance may be induced to insect borne diseases.

This is an effect similar to that of the harpin protein, which is sold in a product called Messenger®.

Because we know so little about this mechanism's components, there is no clear strategy for enhancement. Incorporating a green manure crop may or may not provide the active organic matter in the soil that this mechanism depends upon. Research is ongoing.

Interaction of pest control mechanisms

We have identified four potential mechanisms that could reduce soil-borne pest problems. However, you may have noticed that these mechanisms act in ways that may counteract each other. For instance, biofumigation is killing microorganisms while competitive exclusion depends upon increasing the number of certain microorganisms. What really happens in the soil is complex and presently beyond our ability to observe. That is the bad news. The good news is that the quality and quantity of your crop yield, balanced by the cost of production, will give you a good idea of the benefits of green manures in your cropping system.

Factors to consider

Goals for a green manure
Before you add a green manure crop to your rotation, you should decide what you want it to achieve. It may be that you want to control a certain nematode, a disease, a problem weed, or just improve the soil's tilth. Once you have decided on a primary goal, then your management decisions should be made to maximize those effects that take you towards that goal. Often you may have secondary goals, but because there are different ways to manage green manure crops, you should always have your primary goal in mind.

Your field's combination of pests
Goal setting should consider the unique mixture of crops, soils, and pests on your farm or even in each field that you manage. Because certain green manures will be better in certain situations, you should investigate the advantages and disadvantages of each type of green manure crop and try those that seem to best fit your situation.

Green manure management
Success or failure in reaping benefits from a green manure crop can be a matter of management details. Factors such as planting method, planting date (see Table 5), seeding rate, fertilization (see Table 6), weed control, and incorporation method and timing can all help or hinder your goals. Before you buy any seed, make sure you have all the information available on the green manure you have chosen. See the resources at the end of this publication.

Cost (see Table 7)

Green manure crops, in certain situations, can be costly. However, green manures produced by using the cheapest seed, residual soil nutrients, and minimal irrigation will not normally produce satisfactory results, especially in terms of pest management.

When looking at the cost of green manures and comparing them to the benefits, it is important to consider *all* the benefits. While it is relatively easy to figure out the benefits if you can reduce or eliminate pesticide applications, it is far more difficult to estimate the benefits of improving soil physical characteristics, or other long-term benefits.

Also, remember that some of the money you spend on a green manure crop would also have been spent if you did not grow the green manure. This is the case with fertilizer applied to green manures as much of it will be recycled into following crops, thus reducing the amount of fertilizer needed.

Management and labor requirements

When considering a green manure, take into account the time and labor required to obtain good results. Will you have these resources available when they are needed? Do you have other activities at that time of year that may keep you from paying due attention to the green manure crop? You may have to supply additional machinery or labor if you want to successfully produce a green manure crop.

Short-term vs. long-term benefits

While many of the pest management benefits may come soon after producing a green manure crop, other benefits will not be evident for years. If you regularly use green manure crops, you may find that the benefits increase every year. If you only grow a green manure crop every four or five years, you may find that the short-term benefits are all you see.

Other cropping system factors

You can affect the success of your green manure cropping through other management decisions. In general, soil quality will improve or be maintained if you:

- Minimize tillage
- Avoid over watering
- Avoid soil compaction
- Prevent wind and water erosion

Changing system components

Remember that you are working within a system and changing the components of a system may change the outcomes.
For instance, one successful cropping system has a mustard green manure crop following wheat (*see the Dale Gies System Profile publication*). In this system

the mustard is planted without disturbing the wheat straw. In late October, both the mustard and wheat straw are incorporated together.

You may want to change this system by incorporating the wheat straw before planting the mustard. This may seem like an insignificant change, however, it may be that the incorporation of the wheat straw *with* the mustard is important in the success of this system. By incorporating the wheat straw you might increase the weed pressure, increase the nitrogen requirements of growing the mustard, or increase the risk of nitrate leaching and wind erosion in the following winter and spring.

This should not prevent you from developing your own system, but be aware of the possible complications when changing system components.

Getting started with green manures

On-farm testing is a good way to evaluate green manures when done correctly. However, a single side-by-side comparison, although easy to conduct, will not tell you if your observations were the result of the practices you were comparing or the result of other varying conditions. For best results:

- Start with a small part of a larger field
- Leave areas that are managed as normal
- Use replication and randomization
- Call your local extension office for help and resources on conducting on-farm tests.

Other resources

Cover Crop Fact Sheets
Sudangrass
White Mustard
Dale Gies System Profile
On-farm Research Results, 1999-2001, Dale Gies Farm
This publication and other cover crop information are available online at http://grant-adams.wsu.edu

Table 1

System Effects on Water Infiltration Rate

Date and System[1]	Infiltration time[2]		
	1	2	3
	-------minutes-----		
9/3/1999			
Gies system, after wheat harvest	0.7		
Conventional system, after wheat harvest	7.6		
2/11/2000			
Gies system, after potato harvest	4.9	5.2	6.1
Conventional system, after sugar beet harvest	2.4	20.1	
3/7/2001			
Gies system, after potato harvest	1.8	9.9	
Conventional system, after sugar beet harvest	15.9	25.0	

[1] both locations have the similar soil texture
[2] 1, 2, and 3 are the average infiltration times for consecutive applications of 1" of ponded water

Table 2

Potato Yields following a Mustard Green Manure Crop, with and without fumigant
Gies On-Farm Trials, 1999 - 2001

1999-2000

1999:	White mustard, *S. alba* Martigena planted 8/10/99 and incorporated on 10/25/99		
	Dry biomass yield:	5564	lb/ac
	Biomass N:	93	lb/ac
	Wheat residue:	6007	lb/ac
	Wheat residue N:	34	lb/ac
2000:	Fumigated with metham sodium (Vapam) at end of March at a rate of 37.5 gallons per acre		
	Russet Norkotah potatoes planted 4/15/00 and harvested on 9/7/00		

	Yield	
	Fumigant	No Fumigant
	-------------------tons/ac[1]-------------------	
Total (#1s + #2s + culls)	32.03	31.14
Total U.S. #1's (>4oz.)	26.5 (82.7%)	25.5 (81.8%)
<4 oz[2]	3.05	2.58
4-8 oz	9.40	9.40
8-16 oz	14.28	13.94
>16 oz	2.81	2.17
culls and #2s	2.06	2.68

[1] Yields are averages of six paired replications, no significant differences were found

[2] tubers less than 2" in diameter were not harvested

Table 3

2000-2001

2000: **White mustard**, *S. alba* Martigena planted 8/9/00 and incorporated on 10/24/00

Dry biomass yield: 4773 lb/ac

2001: Fumigated with metham sodium at end of March at a rate of 37.5 gallons per acre
Russet Norkotah (Colorado 8 selection) potatoes planted 4/20/01 and harvested on 9/17/01
Total N applied during growing season: 160 lbs per acre

	Yield	
	Fumigant	No Fumigant
	-------------------tons/ac[1]-------------------	
Total (#1s + #2s + culls)	34.59	34.06
Total U.S. #1's (>4oz.)	31.00 (89.6%)	29.34 (86.1%)
<4 oz[2]	3.04	2.85
4-8 oz	7.77	7.30
8-16 oz	18.48	16.89
>16 oz	4.75	5.15
culls and #2s	0.55	1.87

Table 4

2000: **Oriental mustard**, *B. juncea* Pacific Gold planted 8/9/00 and incorporated on 10/24/00

Dry biomass yield: 5023 lb/ac

2001: Fumigated with metham sodium at the end of March at a rate of 37.5 gallons/acre
Russet Norkotah (Colorado 8 selection) potatoes planted 4/20/01 and harvested on 9/17/01
Total N applied during growing season: 160 lbs per acre

	Yield	
	Fumigant	No Fumigant
	-------------------tons/ac[1]-------------------	
Total (#1s + #2s + culls)	31.38	31.90
Total U.S. #1's (>4oz.)	27.59 (88%)	27.71 (87%)
<4 oz[2]	2.25	1.72
4-8 oz	7.82	7.10
8-16 oz	16.15	14.70
>16 oz	3.62	5.91
culls and #2s	1.53	2.47

[1] Yields are averages of five paired replications, no significant differences were found

[2] tubers less than 2" in diameter were not harvested

Table 5

2001 Mustard Planting Date Study

Effect of planting date and growing degree days (GDD, base 40) on mustard dry matter (DM) yields (10/24/01)

Planting date	DM Yield		% Yield loss[1]	GDD
	------lb/ac------			
14-Aug	4302		na[2]	
17-Aug	4758	a	0%	1433
24-Aug	3858	b	19%	1234
31-Aug	3209	c	33%	1026
7-Sep	1142	d	76%	838
14-Sep	0	e	100%	660
21-Sep	0	e	100%	468

[1] Yield loss compared to first planting date
[2] Loss due to allelopathic effects of fresh millet residue incorporated the same day as mustard planting

Growing Degree Days (base 40), Long-term average and 2001

Month	GDD	
	1943-79	2001
August	895	1016
Sept.	631	733
October	286	286

Table 6

2001 Mustard N Fertilizer Response Trial

Planted 8/14/01, harvested 10/24/01		
Applied N	Ave. Dry Matter	
---lb/ac---	------lb/ac[1]------	
S. alba Martigena		
50	3906	c
88	4263	c
125	7731	ab
163	8280	a
200	6499	b
B. juncea B.j.1		
50	3808	c
88	5516	bc
125	6013	b
163	10479	a
200	9911	a

[1] Yields followed by the same letter are not significantly different according to LSD (0.05)

Table 7

Mustard Green Manure Crop Estimated Variable Costs-2001

Item	Unit	Cost/unit	Quantity	Mustard cost/ac	Normal cost/ac
Seed	lb.	$2.00	10	$20.00	$0.00
Planting	acre	$6.10	1	$7.50	$0.00
Fertilizer	lb.	$0.38	100	$38.00	$0.00
Herbicide	acre	$15.00	1	$15.00	$0.00
Irrigation power	acre-in	$1.78	9	$16.02	$5.34
Chopping	acre	$6.00	1	$6.00	$6.00
Disking/packing	acre	$5.00	2	$10.00	$10.00
			Total:	**$112.52**	**$21.34**
				Mustard cost over normal practice:	**$91.18**
				Mustard cost over normal practice, without fertilizer costs:	**$53.18**

Other costs to consider:

1) Cost of extra labor, equipment, and management time at a time of the year when the mustard may not be your priority task

2) Cost of fitting the mustard into your rotation

3) Cost of extra irrigation water if you exceed your base amount