2008

Chopping and soil incorporating mustard
Green Manure in the San Luis Valley,

Final Project Report to EPA:

"Reducing Pesticide Use in Potatoes by Using Biocontrol Crops and Compost Tea"

Submitted by: Merlin Dillon
Area Extension Agent - Agronomy
Colorado State University
San Luis Valley Research Center
0249 East Road 9 North
Center, CO 81125
Phone: 719-754-3494, ext. 12
E-mail: **merlin.dillon@colostate.edu**

EXECUTIVE SUMMARY

This trial has three primary sections: 1) Effect of green manure crops on reducing nematodes (CRKN) and improving potato yield and quality; 2) Effect of compost tea on reducing early blight in potatoes, and 3) Effect of compost and compost tea on reducing powdery scab in potatoes.

Part 1. Green Manure Crops

Green manure crops were grown on commercial farmers' fields in 2007 and 2008. This research continued field trials conducted in 2005 and 2006; some results are reported. Potatoes were grown on these same plots the following year to determine the effect of the green manure crops on nematodes and on the yield and quality of the following potato crop.

Certain green manure crops were effective in reducing nematodes prior to potato planting.

Part 1a. Green Manure Effects on Nematodes:

The 2007-08 trial was characterized by low populations of Columbia root-knot nematode (*Meloidogyne chitwoodi*, CRKN) and the 2008-09 trial was characterized by relatively high starting densities of CRKN. All wet fallow and green manure treatments in both trials completely suppressed the expression of tuber symptoms caused by tuber infection with CRKN. Not all the suppression may have been due to green manure crops, however, as the cold winters preceding both potato crops undoubtedly contributed to the population decline before potatoes were planted. Furthermore, an early date of vine kill and harvest in the 2009 potato crop may have prevented late season tuber infection. In milder winters, greater survival and higher populations at planting may be expected so population change after green manure crops is important to summarize. Since population densities increased substantially under forage peas in 2007 and under sunflower in 2008, these crops should probably be avoided as a green manure crops unless Vydate can be used on the following potato crop. Interestingly, these population increases were not repeated in the other year of the trials. Since densities were so low when green manure crops were planted in 2007 it was difficult to discern any difference in performance of the other treatments. Therefore, the best criteria to evaluate green manure crops are the population levels after incorporation in 2008. **Best suppression of CRKN occurred in plots that had been planted to radish and/or sudangrass with pure stands of each appearing to be slightly better that the mixture. Both crops had lower numbers of CRKN than wet fallow suggesting a response from incorporated biomass as well as a non host effect.**

Population densities of root-lesion nematodes increased considerably under annual ryegrass and barley in 2007 and under wheat in 2008. Although significant differences occurred between treatments, **levels were too low both years for differences between treatments to be biologically meaningful. However, since *P. neglectus* rarely damages potato it should not be used as a major determining factor when choosing a green manure crop.**

Since stubby-root nematodes vector tobacco rattle virus into potato plants to cause Corky ringspot (CRS), even low numbers can be a threat. Densities after barley remained low in 2007 but increased markedly in 2008 as did stubby-root nematodes in wheat. Small grains typically harbor stubby-root nematodes. Population levels of stubby-root nematodes increased from near zero to 5-20/250 g soil in sudangrass and canola during 2007 but did not increase in sudangrass during 2008. This latter result is unusual as prior studies have frequently reported that sudangrass increases stubby-root nematodes and should be avoided in fields with a history of CRS. Densities in most other treatments, except mustard and forage pea in 2008, remained low during both trials. **Numerically, the best green manure crop in either trial was**

radish in 2008 in which numbers of stubby-root nematodes declined to zero and remained zero until after potato was harvested. While low populations in some other treatments were statistically equal to zero they still represented levels capable of transmitting TRV.

Part 1b. Effect of Green Manure Crops on Potato Production

Data from four years (2006-09) of green manure crops indicate that green manure crops influence total tuber yield and tuber size distribution. Therefore, the choice of green manure crop for a potato cropping system must depend on tuber size requirement. In all four years, planting potatoes after "Sordan 79 Hay Removed" produced maximum total and marketable tuber yields. Incorporating all residue of Sordan 79 tops and roots increases the potential of nitrogen tie-up by soil microbes, which could impact subsequent potato growth and yield. Canola and mustard, when incorporated into the soil before potatoes are planted, reduced marketable tuber yield significantly in all four years. In three out of four years, green manure cover crops did not significantly influence tuber internal defects.

Data indicate that, in a green manure cover crop-potato cropping system, it is very economical to plant Sordan 79, remove the top growth for hay; then incorporate remaining residue prior to planting potatoes the following year. This treatment may, or may not, reduce nematodes best; this research indicates it produces better potato yield and quality.

Part 1c. Ag Research Service cooperation

A soon-to-be-released, new NLEAP-GIS 4.2 model was used to evaluate these cover crops and will be used to update the web tool prototype. The preliminary results show that cover crops are generally effective in reducing nitrate leaching.

Potato-Potato Rotation: a traditional potato–potato rotation with high nitrogen input will average long term nitrate leaching potential of 81 lb NO_3-N per acre. The average nitrate leaching across 94 center pivots could be potentially be in excess of 1,000,000 lbs of NO_3-N.

Barley-Barley Rotation: with a well-managed malting barley–malting barley rotation without potato, the nitrate leaching potential is reduced to 28 lb NO_3-N per acre, or about 350,000 lb NO_3-N across 94 pivots.

Potato-Barley Rotation: Most potato growers use a short rotation, a potato – barley rotation. A well-managed, traditional potato-barley rotation will reduce the average nitrate leaching potential to 33 lb NO_3-N per acre or about 400,000 lb NO_3-N across 94 center irrigated pivots. If the farmer moves to a potato-barley-barley rotation, the average nitrate leaching is reduced even further to an average 28 lb NO_3-N per acre.

Potato-Green Manure Crop Rotation: If the farmer changes his/her practices to include a summer green manure crop that also saves large amounts of water, the nitrate leaching potential goes down to 13 lb NO_3-N /acre, about 170,000 lb NO_3-N on 94 center pivots.

Potato-Green Manure (Hay Removed) Rotation: If the farmer removes a hay crop before incorporating the green manure to increase his/her potential profits, the average nitrate leaching potential is still low at 21 lb NO_3-N/acre.

Part II. Application of compost tea to potatoes reduced early blight lesions on potatoes.

The main purpose of this study was to evaluate the interactive effect of compost tea, fungicide program, and nitrogen rate on early blight incidence, and on tuber performance of Russet Norkotah and Russet Nugget, and to determine whether compost tea could be used as an alternative to fungicide application in potato production. Data from this study indicate that compost tea, when applied at an optimum N rate of 160 lb N/ac can be used as an alternative to fungicide application to reduce early blight incidence on potato leaves, and to produce maximum potato tuber yields.

Part III. Effect of Compost and Compost Tea on control of Powdery Scab.

Application of compost and compost tea to potatoes was generally not effective in reducing powdery scab infestations on potatoes. The field trials indicated that use of compost or compost tea and their combination did not control powdery scab on the tubers as compared with the untreated control. In 2008, while there were no significant differences between treatments, there was a trend to showing a higher incidence of powdery scab on the control or the compost treatment when compared with the Omega treatments. This also held true in terms of total yields and marketable yields. In 2009, when compost, compost tea and the combinations were compared with Omega and Omega plus compost, there were significant differences evident in terms of percent incidence and the percent unmarketable. Omega alone or in combination with compost showed a significant reduction in disease when looking at percent incidence and percent unmarketable/severity index as compared to the untreated control or compost plus compost tea. While there is an indication that compost coupled with Omega may bring even more benefits than Omega by itself, the reductions in disease were not significant.

It appears that through two years of trials, the use of compost and compost tea or combinations of the two as a management or control for powdery scab is not effective. Additional research will be completed in the greenhouse to continue to compare different combinations of Omega and compost type products to control powdery scab of potato.

Part IV. Comparing Potato Cropping Systems Effects on Soil and Water Resources + Economics.

San Luis Valley potato growers will be making their individual choices of potato rotations. Currently, most growers opt for the two year Potato/Grain rotation. Irrigation cost is changing (more expensive water charges) and some will have to choose rotations that use less water. Still their choice will be a combination of their aversion to wind erosion vs. irrigation cost vs. potential potato yield and their reading of future potato prices. Malt barley or wheat prices also factor into their willingness to grow a green manure crop which has no income for that year.

The potato/sordan rotation uses the least water and might be popular for that reason. However, it allows the most wind erosion unless a winter cover crop were used.

The Potato/Barley/Sordan rotation uses less water than the current favorite, Potatoes/Barley. This PBS rotation is being promoted as allowing little wind erosion, low water use, high potato yield and it also reduces the amount of potato acres in the region. Some growers will not adapt this because they want to have more acres in potatoes. Some growers might adapt it when they figure that it is less risky since they have fewer acres and in potatoes and less money at risk. In the end, each grower makes his individual decision depending on how they view the economic and environmental situation. They know that they can make a lot of money in potatoes when the market is good. And, they don't want to have less acres in the good potato year. They want to have more acres.

Will potato farmers adopt a new "Green Practice', such as going to a three year potato barley sordan rotation to reduce consumptive use, reduce pathogens in your potato crops, and reduce wind erosion while sequestering carbon into organic matter in their soil?

1. Conservation tillage or mulch tillage systems of residue management are now used by over 80 % of San Luis Valley farmers. Additional growers state they will adopt within the next few years.
2. Sordan and mustard or oilseed radish green manure crops are now used by over 20% of potato farmers; a very recent change due to interest in soil quality and microbial diversity.

3. Oilseed radish cover crops were originally moldboard plowed as part of green manuring. This practice has been reduced. Mulch tillage methods of green manure incorporation are proving to be better in hastening decomposition and microbial biomass buildup.

Part V. Grower Management Practices Survey

A survey of San Luis Valley potato growers was sent out in the summer of 2009. This survey determines growers' practices regarding compost tea vs. foliar fungicides, management of green manure crops, and attitudes and reasons they grow green manure crops. Survey is attached.

Part I. Effect of Green Manure Crops on Nematodes and Potatoes

Methods and Materials

The purpose of this trial was to find the effects of green manure crops on potato production. Therefore, green manure crops were planted in 2007 again in 2008. Potatoes were then planted into the same plot locations the following year.

Green manure crops were established on the Beiriger commercial potato farm in 2007 and again on the Brown/Shriver farm in 2008. Treatments were replicated 5 times because of the highly variable nature of nematode populations; and plots were randomized according to pre-green manure crops soil sample results. Some green manures were not included in both years. Below is a listing of the green manure treatments each year:

Green Manure	Year	Year	Planted
Wet Fallow	2007	2008	No Crop; weeds controlled.
Barley	2007	2008	April
Barley + Compost	2007	2008	April
S-sudan (Honey Sweet)	2007	------	June
Sordan 79	2007	2008	June
Sordan 79 Hay Removed	2007	2008	June
Sunflower	2007	2008	June
Mustard	2007	2008	June
Canola	2007	2008	June
Peas	2007	2008	April
Annual Ryegrass	2007	------	April
Radish	------	2008	June
Sordan 79/Radish Mix	------	2008	June
Winter Wheat	------	2008	Prior September

Green manure crops were planted into a field of Sordan 79 sorghum-sudan in 2007. The field was watered and managed as Sordan 79 green manure. The site in 2008 was already planted as winter wheat. Winter wheat plots were left growing whereas in all other plot areas, the winter wheat was roto-tilled in early April. Barley and Peas were planted in April but the remainder was managed as fallow until the green manures were planted in June.

NOTE: Wet Fallow is not planted; weeds are controlled. Usually, all non-planted plots have Roundup applied prior to planting to create a "Stale Seedbed" which helps to reduce later emerging weeds. The Wet Fallow is a control plot for nematode control as it is often better than a cereal crop. Barley or Wheat are hosts to nematode (especially Columbia Root knot Nematode (CRKN)) so that this nematode increases in these crops. On the other hand, nematodes will often hatch when the land is irrigated but if there is no crop and weeds are controlled, the newly hatched nematodes will die with nothing to live on.

Sordan 79 is a sorghum-sudan cultivar reported to reduce CRKN; Honey Sweet is a different sorghum-sudan cultivar not known to reduce CRKN. Other green manure crops were included to find out their effect on reducing CRKN and to determine their effect on yield of the following potato crop.

General Comments:

The green manure treatments were planting into a field of Sorghum-sudan in 2007 and Winter Wheat in 2008. Both fields were commercial fields of Russet Norkotah the following year. Planting into sorghum-sudan was ideal because the green manures were planted and watered about the time needed. An exception was the barley treatments in 2007; these were planted in April and severely underwatered until the sudan needed water in June. Contrarywise the following year, the green manure crops planted into the winter wheat were severely overwatered prior to the June planting of most green manures (winter wheat was using lots of water during May. Winter wheat plots performed fine because it was a winter wheat field. Also, the peas planted in April grew very well. The barley suffered some because even though it was planted in April, development was much slower than the already established winter wheat and the crop performed well below expectations. Much of the nitrogen available for winter wheat was leached before the barley was able to use it.

Since the June planted green manures were overwatered prior to planting, nitrogen was leached in those plots also. The winter wheat was being irrigated heavily during May and June; yet the June planted green manure crops did not use much water until the end of June. Finally, after it was really too late, 40 #/acre nitrogen was applied for all the June planted green manure crops.

There were two other severe problems in the 2008 trial. One, the emergence of small seeded green manures like canola, mustard and radish were problematic. The north side plots emerged very well but those plots on the south side had very poor emergence. Poor plots were replanted on June 29. The second problem was the herbicide application. Roundup (5%) was applied to the Wet Fallow and all June planted green manure plots prior to planting. This herbicide rate is so strong that it affects the borders of adjacent early-planted, emerged plots. The edges of many barley, winter wheat and pea plots were damaged. Because of this damage and the poor emergence of many June planted green manures, Dr. Delgado elected not to harvest dry matter of green manure nor to take soil samples to determine nutrient uptake by green manures in 2008 or potato nutrient uptake in 2009. Eleven (11) plots were designated as too poor for the 2009 potato harvest, Dr. Essah did not harvest those plots in 2009. Those 11 plots are also not sampled for nematodes.

General Management Information

2007

2007 planting dates: Barley, Peas and Ryegrass on April 19; Sorghum-sudan, mustard, canola, sunflower planted June 20.
Fertilizer: Barley and Barley + Compost = 100 # N/acre; Ryegrass = 50 # N/acre; Peas = O on May 23.
NOTE: No nitrogen was applied for most green manure crops; green manure incorporation could result in microbial nitrogen tie-up for the following potato crop.
Herbicides in 2007: Barley and Ryegrass = Bronate at 1.6 pt/acre on May 24. Wet Fallow and June planted Green Manure crops, (Roundup, 5%) on June 14. Herbicide on barley and ryegrass was Bronate at 1.6 pt/acre.
Wet Fallow treated again: 2,4-D + Clarity at ½ pt/ac + ½ pt/acre on July 5.

Roundup (5%) applied prior to June plantings burned edges of some barley and pea plots. One plot of sunflower had no stand (Plot 724); one Sordan plot no good because of grassy weeds (727); all sunflower plots had weeds (no preplant herbicide).
Barley harvested on Aug. 28. Barley was severely underwatered in both May and June. Barley growth was poor; Barley yield = 46.9 bu/acre; Barley + Compost = 48.1 bu/acre, a statistically nonsignificant difference.
Green manure roto-tilled on Aug. 29.

2008

2008 planting dates: Barley and Peas on April 23; Canola, radish, sunflower and sudan planted June 10.
Herbicides in 2008: For Barley, 1.33 pt/a 2,4-D amine on June 19; for Peas, Raptor at 4 oz/a + 2,4-DB at 6 oz/a. For Sudan plots, Aim at 2.5 oz/a + Ammonium sulfate at 2-4 #/a on June 30.
Green manures incorporated (roto-tilled) on Sept. 8.
Barley and winter wheat harvested on Sept. 4.
Barley grain yield = 40.1 bu/acre; Barley + Compost = 53.5* bu/acre; Winter Wheat = 82.4* bu/acre; $LSD_{10\%}$= 32.8 bu/acre. Top Statistical Yield group designated*.

Part 1A. Nematode Methods and Materials

Nematode Evaluations: Soil samples for nematode population assessment were collected before planting green manure crops (April 17, 2007; April 4, 2008), after green manure crops had been incorporated and allowed to breakdown (October 26, 2007; October 7, 2008), and at planting (May 13, 2008; May 11, 2009), and harvest (September 17, 2008; September 8, 2009) of potato. Samples were collected by taking 10 one in. diameter cores to a depth of 12 in. from the area of the plot where the middle 10 feet of the two center rows of potato would be (green manure crop) or had been (potato crop) planted. Soil samples were sieved, mixed and nematodes were extracted from a 250 g subsample by wet sieving-density centrifugation. All plant-pathogenic nematodes present in the samples were counted. Live/dead determinations were made for CRKN on the initial sample date and live CRKN was used as the blocking variable. Nematodes that were moving or moved when prodded were considered alive.

Tuber Evaluations: Potatoes were harvested on September 18, 2008 and September 9, 2009 by digging the center 10 feet of one of the middle rows of each plot with a level bed digger. A random sample of 25 4-12 oz tubers was collected from each plot for evaluations of nematode damage. Tubers were stored at room temperature for a minimum of 600 degree-days (base 5 °C) to permit symptom development by CRKN that infected tubers late in the season and then stored below 5 °C until evaluated Tubers were peeled by hand and the number of root-knot nematode infection sites was counted under a magnifying lamp. Data recorded included percent tuber infection (1 or more infection sites), percent culled tubers (6 or more infection sites) and infection index (0 = 0, 1 = 1-3, 2 = 4-5, 3 = 6-9, 4 = 10-49, 5 = 50-99, 6 = 100+ infection sites) as a measure of infection intensity.

Data Analysis: Nematode population densities were adjusted for soil moisture to number/250 g dry soil and transformed to $\log_{10}(x+1)$ before analysis (analysis of variance, ANOVA). Back-transformed means are reported. Duncan's Multiple Range Test was used to separate means only when ANOVA was significant at $P \leq 0.05$ unless otherwise stated.

Results 1A. Green Manure Effects on Nematodes

Results are discussed in regard to the Beiriger Farm where green manure crops were planted in 2007 and then determine their effects on the following 2008 potato crop. Similarly, the Brown-Shriver Farm had green manure crops planted in 2008 and this was followed by a 2009 potato crop.

Results of Beiriger Green Manure Trial, 2007-8.

Effect of Green Manure Crop on Nematodes, 2007-2008, Beiriger Farm

Root-knot nematode: This site was characterized by very low populations of Columbia root-knot nematodes (*Meloidogyne chitwoodi*) which averaged 12/250g dry soil across the site at the start of the trial, 62% of which were alive at the time of evaluation (Table 1). After growth and initial decomposition of the green manure crops, populations remained the same or declined in all treatments except peas, which had increased to 600/250 g soil in some plots. However, even populations in the pea treatment declined to very low levels by spring due to further decomposition of the incorporated vegetation and/or winter mortality. Densities over all treatments averaged less than 1/250 g soil at potato planting and by potato harvest had increased slightly only in the annual ryegrass treatment. These low populations were reflected in a nearly complete absence of root-knot infection in the tubers. Only 6 of the 1,500 tubers that were peeled had any root-knot infection and most had only one nematode infection site.

Root-lesion nematode: Densities of root-lesion nematode (*Pratylenchus neglectus*) were low at this site and averaged 14/250 g dry soil at the start of the trial (Table 2). Populations increased on all green manure crops, particularly under annual ryegrass and barley. Densities declined by an average of 80% over the winter and were far below any potential damage level when potatoes were planted. Highest populations were in annual ryegrass plots and lowest populations were after canola and wet fallow. Populations declined further during the potato crop but remained highest in the plots that had been planted to annual ryegrass.

Stubby-root nematodes: Only a few stubby-root nematodes (*Paratrichodorus allius*) were detected in isolated plots before green manure crops were planted (Table 3). After incorporation, population levels had increased to an average of 2/250 g soil across the trial area but there were no differences between treatments. Interestingly, significant differences did exist in samples taken when potatoes were planted with higher densities in sudangrass and canola plots and none recovered from wet fallow, barley and annual ryegrass. Densities were nearly equal in all treatments at potato harvest and averaged 4/250 g soil across all plots.

Table 1. Populations (No./250 g dry soil) of Columbia root-knot nematodes (*Meloidogyne chitwoodi*) from 0-12 in deep in green manure plots. San Luis Valley, CO – 2007-08.

Treatment[1]	Before Planting GM[2]	After Incorporation[3]	R Value[4]	Potato Planting[5]	Potato Harvest[6]
Wet Fallow	11[7]	1 b	0.09 b	0	0 b
Wet Fallow+micronutrients	12	14 b	1.32 b	0	0 b
Barley cv Baronesse	6	9 b	0.30 b	0	0 b
Barley + Compost	6	2 b	0.26 b	0	0 b
Sunflower cv Nusun 4651	11	1 b	0.40 b	0	0 b
Sudangrass cv Sordan 79	15	9 b	1.86 b	0	0 b
Sordan 79, Hay removed	4	3 b	2.89 b	0	0 b
Mustard cv Pacific Gold	8	2 b	3.00 b	0	0 b
Forage Peas cv Arbika	16	184 a	17.80 a	1	1 b
Canola cv 357 Magnum	15	2 b	0.54 b	0	0 b
Annual Ryegrass Big Daddy	32	16 b	1.19 b	1	14 a
Sudangrass cv Honeysweet	12	2 b	0.27 b	0	0 b
Pr > F	ns	0.001	0.02	ns	0.0005

[1]See text for full treatment descriptions.
[2]April 17, 2007
[3]October 26, 2007
[4]R (reproductive index) = population density in October/population density in April.
[5]May 13, 2008
[6]September 17, 2008
[7]Means within the same column that are followed by the same letter are not significantly different ($P \leq 0.05$). Columns with no letters had no significant differences between means. Data were log transformed before analysis and back-transformed means are presented.

Table 2. Populations (No./250 g dry soil) of root-lesion nematodes (*Pratylenchus neglectus*) from 0-12 in deep in green manure plots. San Luis Valley, CO – 2007-08.

Treatment[1]	Before Planting GM[2]	After Incorporation[3]	Potato Planting[4]	Potato Harvest[5]
Wet Fallow	19[6]	39 de	4 c	5 bcd
Wet Fallow+micronutrients	19	51 cd	8 c	5 bcd
Barley cv Baronesse	17	123 bc	24 ab	16 ab
Barley + Compost	13	221 ab	29 ab	11 bc
Sunflower cv Nusun 4651	15	31 de	11 bc	6 bcd
Sudangrass cv Sordan 79	14	53 cd	12 ab	5 bcd
Sordan 79, Hay removed	8	51 cd	38 ab	8 bcd
Mustard cv Pacific Gold	13	63 cd	12 bc	1 d
Forage Peas cv Arbika	14	15 e	10 bc	5 bcd
Canola cv 357 Magnum	13	50 cd	3 c	3 cd
Annual Ryegrass Big Daddy	14	435 a	74 a	59 a
Sudangrass cv Honeysweet	16	53 cd	17 abc	19 c
Pr > F	ns	0.0001	0.005	0.001

[1]See text for full treatment descriptions.
[2]April 17, 2007
[3]October 26, 2007
[4]May 13, 2008
[5]September 17, 2008
[6]Means within the same column that are followed by the same letter are not significantly different ($P \leq 0.05$). Columns with no letters had no significant differences between means.
Data were log transformed before analysis and back-transformed means are presented.

Table 3. Populations (No./250 g dry soil) of stubby-root nematodes (*Paratricodorus allius*) from 0-12 in deep in green manure plots. San Luis Valley, CO – 2007-08.

Treatment[1]	Before Planting GM[2]	After Incorporation[3]	Potato Planting[4]	Potato Harvest[5]
Wet Fallow	< 1[6]	2	0 c	4
Wet Fallow+micronutrients	0	4	0 c	1
Barley cv Baronesse	0	1	0 c	2
Barley + Compost	< 1	4	1 bc	3
Sunflower cv Nusun 4651	0	1	1 bc	4
Sudangrass cv Sordan 79	0	2	5 ab	2
Sordan 79 Hay	0	1	20 a	5
Mustard cv Pacific Gold	<1	5	2 bc	9
Forage Peas cv Arbika	< 1	2	2 bc	2
Canola cv 357 Magnum	0	1	6 ab	12
Annual Ryegrass Big Daddy	1	0	0 c	3
Sudangrass cv Honeysweet	< 1	3	5 ab	2
Pr > F	ns	ns	0.005	ns

[1]See text for full treatment descriptions.
[2]April 17, 2007
[3]October 26, 2007
[4]May 13, 2008
[5]September 17, 2008
[6]Means within the same column that are followed by the same letter are not significantly different ($P \leq 0.05$). Columns with no letters had no significant differences between means.
Data were log transformed before analysis and back-transformed means are presented.

Effect of Green Manure Crop on Nematodes, 2008-2009, Brown/Shriver Farm

Root-knot nematodes: The site used in 2008-09 was characterized by high populations of Columbia root-knot nematode (*Meloidogyne chitwoodi*) which averaged 314/250 g dry soil across the site at the start of the trial, 61% of which were alive at the time of evaluation (Table 4). After growth and initial decomposition of the green manure crops, population densities were highest in plots with sunflower (483/250 g soil) and statistically similar in plots with wheat, barley, mustard and peas. Lowest densities were in plots that had been planted to sudangrass (2/250 g soil) and/or radish (3/250 g soil). Addition of compost to barley plots reduced population levels 67% but this was not significant. With regard to reproductive index, only sunflower had an Rf value greater than 1.0 which was significantly greater than all other green manure crops. There appeared to be high mortality of CRKN over the winter as even numbers in sunflower plots declined to 14/250 g soil by the time potato was planted in the spring. Few CRKN were detected in any plots. Population densities increased during the potato growing season and reached levels similar to those observed the previous fall. Highest numbers were in plots following sunflower (417/250 g soil), mustard, or barley while lowest average densities (2-4/250 g soil) were in plots that had been planted to peas, radish, or sudangrass + radish. Other plots were intermediate and populations in the barley plots with compost were still 66% less than barley plots without compost. Due to the low population densities of CRKN at planting and the early harvest date of this field by the grower, there was essentially no tuber infection by CRKN in any of the treatments.

Root-lesion nematodes: Densities of root-lesion nematode (*Pratylenchus neglectus*) were low at this site and averaged 4/250 g dry soil at the start of the trial (Table 5). Population levels increased to 122/250 g soil under winter wheat which was significantly higher than all other green manure crops. Lowest densities were after radish (1/250 g soil) and were significantly less than all crops (and wet fallow plots) except forage peas and sudangrass + radish. Similar trends were present at the potato planting and harvest sample dates but population densities in all treatments were too low for these differences to be biologically meaningful.

Stubby-root nematodes: Population densities of stubby-root nematodes (*Paratrichodorus allius*) averaged 5/250 g dry soil across the site before green manure crops were planted (Table 6). After green manure crops, levels were highest (20/250 g soil) in wheat and barley plots and lowest in radish plots (0/250 g soil). Wet fallow, sunflower, sudangrass, and sudangrass + radish had low numbers (1-3/250 g soil) as well but because of variability, not all were significantly less than wheat and barley. Densities remained the same or declined in all treatments during the potato year and continued to be 0/250 g soil in radish plots for the remainder of the study.

Table 4. Populations (No./250 g dry soil) of Columbia root-knot nematodes (*Meloidogyne chitwoodi*) from 0-12 in deep in green manure plots. San Luis Valley, CO – 2008-09.

Treatment[1]	Before Planting GM[2]	After Incorporation[3]	R Value[4]	Potato Planting[5]	Potato Harvest[6]
Wet Fallow	351[7]	27 bc	0.21 b	1 abc	26 bcd
Wet Fallow+micronutrients	259	17 bcd	0.12 b	1 abc	38 bc
Barley cv Baronesse	377	99 ab	0.60 b	2 abc	88 ab
Barley + Compost	341	33 bc	0.19 b	5 abc	30 bcd
Sunflower cv Nusun 4651	311	483 a	1.80 a	14 a	417 a
Sudangrass cv Sordan 79	275	2 d	0.02 b	1 bc	16 bcd
Sordan 79, Hay removed	330	9 bcd	0.22 b	0 c	22 bcd
Mustard cv Caliente 61	327	57 ab	0.21 b	0 c	103 ab
Forage Peas cv Arbika	273	58 ab	0.49 b	0 c	2 d
Radish	333	3 cd	0.02 b	0 c	4 cd
Sudangrass+ Radish	360	12 bcd	0.08 b	1 bc	4 cd
Winter wheat cv Platte	329	121 ab	0.74 b	11 ab	24 bcd
Pr > F	ns	0.0001	0.0001	0.0052	0.0004

[1]See text for full treatment descriptions.
[2]April 4, 2008
[3]October 7, 2008
[4]R (reproductive index) = population density in October/population density in April.
[5]May 11, 2009
[6]September 8, 2009
[7]Means within the same column that are followed by the same letter are not significantly different ($P \leq 0.05$). Columns with no letters had no significant differences between means.
Data were log transformed before analysis and back-transformed means are presented.

Table 5. Populations (No./250 g dry soil) of Columbia root-knot nematodes (*Pratylenchus neglectus*) from 0-12 in deep in green manure plots. San Luis Valley, CO – 2008-09.

Treatment[1]	Before Planting GM[2]	After Incorporation[3]	Potato Planting[4]	Potato Harvest[5]
Wet Fallow	2[7]	10 b	3 b-f	6 bcd
Wet Fallow+micronutrients	2	12 b	4 b-f	2 cd
Barley cv Baronesse	5	19 b	6 bcd	11 bc
Barley + Compost	3	12 b	11 b	24 ab
Sunflower cv Nusun 4651	2	8 b	1 c-f	6 bcd
Sudangrass cv Sordan 79	1	16 b	4 bcd	5 bcd
Sordan 79, Hay removed	2	9 b	8 bc	7 bcd
Mustard cv Caliente 61	3	13 b	0 f	4 bcd
Forage Peas cv Arbika	8	3 bc	1 def	2 cd
Radish	1	1 c	0 ef	1 d
Sudangrass+ Radish	3	6 bc	3 b-f	3 cd
Winter wheat cv Platte	3	122 a	92 a	84 a
Pr > F	ns	0.0001	0.0001	0.0001

[1]See text for full treatment descriptions.
[2]April 4, 2008
[3]October 7, 2008
[4]May 11, 2009
[5]September 8, 2009
[6]Means within the same column that are followed by the same letter are not significantly different ($P \leq 0.05$). Columns with no letters had no significant differences between means.
Data were log transformed before analysis and back-transformed means are presented.

Table 6. Populations (No./250 g dry soil) of Columbia root-knot nematodes (*Paratrichodorus allius*) from 0-12 in deep in green manure plots. San Luis Valley, CO – 2008-09.

Treatment[1]	Before Planting GM[2]	After Incorporation[3]	Potato Planting[4]	Potato Harvest[6]
Wet Fallow	5[7]	2 bc	0 d	9 ab
Wet Fallow + micronutrients	1	1 bc	1 bcd	3 abc
Barley cv Baronesse	3	21 a	10 a	11 a
Barley + Compost	5	16 ab	9 a	5 abc
Sunflower cv Nusun 4651	4	3 abc	0 cd	2 abc
Sudangrass cv Sordan 79	2	3 abc	3 abcd	2 abc
Sordan 79, Hay removed	3	2 bc	5 abc	2 abc
Mustard cv Caliente 61	2	11 ab	0 d	1 c
Forage Peas cv Arbika	3	9 abc	2 abcd	4 abc
Radish	4	0 c	0 c	0 c
Sudangrass + Radish	3	2 abc	1 abcd	1 bc
Winter wheat cv Platte	9	20 a	7 abc	5 abc
Pr > F	ns	0.0051	0.0011	0.0480

[1]See text for full treatment descriptions.
[2]April 4, 2008
[3]October 7, 2008
[4]May 11, 2009
[5]September 8, 2009
[6]Means within the same column that are followed by the same letter are not significantly different ($P \leq 0.05$). Columns with no letters had no significant differences between means.
Data were log transformed before analysis and back-transformed means are presented.

Ratio of PRE/POST GM Nematode Populations, Brown/Shriver Farm, 2008.

The same data from Table 4 above is used to calculate an R Value. This is the ratio of the Columbia Root Knot Nematode density prior to green manure crop (PRE) compared to that after green manure crop (POST) sampled just prior to potato planting. An effective green manure crop produces a very small R value ratio. Those green manures which allow nematode reproduction have a high R Value

In the table below (Table 7), treatments are sorted from lowest to highest R Value based on live pre-GM CRKN densites. R values were calculated from live and from total pre-GM but R Values based on live counts appeared to be the most informative. . In this case, Barley, Peas, Winter Wheat and Sunflowers allowed CRKN reproduction shown by the highest R Values. Conversely, Radish (Terranova), Sordan 79, Radish (Adios), Radish (Doublet), Radish/Sordan79 mix, Mustard and Wet Fallow allowed the least nematode growth and reproduction shown by the very low R Values.

Table 7. 2008 CRKN populations by treatment sorted by R Value.

CRKN	SORTED BY R VALUE POST TOTAL/PRE LIVE					
NEMATODES/250G DRY SOIL		PRE LIVE	PRE TOTAL	POST TOTAL	R VAL TOT/TOT	R VAL TOT/LIVE
GREEN MANURE CROP	TRT	RK	RK	RK	RK	RK
Radish cv Terranova	**12**	**238**	**346**	**3**	**0.01**	**0.01**
Sordan 79	**5**	**231**	**345**	**8**	**0.02**	**0.02**
Radish cv Adios	**10**	**221**	**332**	**5**	**0.02**	**0.03**
Radish cv Doublet	**11**	**256**	**406**	**8**	**0.03**	**0.05**
Sordan/Doublet Mix	**13**	**363**	**595**	**31**	**0.07**	**0.11**
Mustard cv Caliente 61	**8**	**230**	**375**	**31**	**0.09**	**0.14**
Wet Fallow - Jorge	**9**	**241**	**386**	**25**	**0.12**	**0.17**
Barley + Compost	**3**	**318**	**485**	**58**	**0.19**	**0.30**
Sordan 79 - Hay	**6**	**443**	**604**	**375**	**0.22**	**0.30**
Wet Fallow	**1**	**297**	**478**	**79**	**0.21**	**0.38**
Barley cv Baroness	**2**	**266**	**417**	**195**	**0.60**	**0.87**
Peas cv Arbika	**7**	**297**	**450**	**70**	**0.49**	**0.90**
Winter Wheat	**14**	**352**	**496**	**148**	**0.74**	**1.10**
Sunflower	**4**	**239**	**391**	**748**	**1.80**	**3.39**

Summary, Green Manure Effects on Nematodes:

The 2007-08 trial was characterized by low populations of CRKN and the 2008-09 trial was characterized by relatively high starting densities of CRKN. All wet fallow and green manure treatments in both trials completely suppressed the expression of tuber symptoms caused by tuber infection with CRKN. Not all the suppression may have been due to green manure crops, however, as the cold winters preceding both potato crops undoubtedly contributed to the population decline before potatoes were planted.

Furthermore, an early date of vine kill and harvest in the 2009 potato crop may have prevented late season tuber infection. In milder winters, greater survival and higher populations at planting may be expected so population change after green manure crops is important to summarize. Since population densities increased substantially under forage peas in 2007 and under sunflower in 2008, these crops should probably be avoided as a green manure crops unless Vydate can be used on the following potato crop. Interestingly, these population increases were not repeated in the other year of the trials. Since densities were so low when green manure crops were planted in 2007 it was difficult to discern any difference in performance of the other treatments. Therefore, the best criteria to evaluate green manure crops are the population levels after incorporation in 2008. **Best suppression of CRKN occurred in plots that had been planted to radish and/or sudangrass with pure stands of each appearing to be slightly better that the mixture. Both crops had lower numbers of CRKN than wet fallow suggesting a response from incorporated biomass as well as a non host effect.**

Population densities of root-lesion nematodes increased considerably under annual ryegrass and barley in 2007 and under wheat in 2008. Although significant differences occurred between treatments, **levels were too low both years for differences between treatments to be biologically meaningful. However, since *P. neglectus* rarely damages potato it should not be used as a major determining factor when choosing a green manure crop.**

Since stubby-root nematodes vector tobacco rattle virus into potato plants to cause CRS, even low numbers can be a threat. Densities after barley remained low in 2007 but increased markedly in 2008 as did stubby-root nematodes in wheat. Small grains typically harbor stubby-root nematodes. Population levels of stubby-root nematodes increased from near zero to 5-20/250 g soil in sudangrass and canola during 2007 but did not increase in sudangrass during 2008. This latter result is unusual as prior studies have frequently reported that sudangrass increases stubby-root nematodes and should be avoided in fields with a history of CRS. Densities in most other treatments, except mustard and forage pea in 2008, remained low during both trials. **Numerically, the best green manure crop in either trial was radish in 2008 in which numbers of stubby-root nematodes declined to zero and remained zero until after potato was harvested.** While low populations in some other treatments were statistically equal to zero they still represented levels capable of transmitting TRV.

Part Ib. Response of Irrigated Potato to Green Manure Cover Crops

Dr. Samuel Essah, CSU Potato Scientist and Extension Specialist, SLV Research Center, Center, CO.

Growing green manure cover crops as part of a crop rotation has been reported as an important part of many cropping systems (Sincik et al. 2008). The green manures help build soil fertility, and are very beneficial when grown before crops that need a lot of nitrogen (N). The green manure crop affects both the amount of N available for the main crops and the depth distribution of available N in the soil.

Potato is a crop that is highly responsive to cover crop treatments and N fertilizer. Studies by Griffin and Hesterman (1991) showed that growing potatoes after sweet clover, yielded higher plant dry matter that in the non-legume cover crop treatments, but produced no higher tuber yield. On the other hand, Gasser (2000), observed that growing potatoes after plowing and burying grassland resulted in optimum potato production with minimum nitrogen fertilizer. They observed that tuber quality was lowered when excess N fertilizer was used.

Information on the effect of green manure cover crops on subsequent potato yield and quality has not been well documented in the San Luis Valley. The objective of this study was to evaluate the effect of green manure cover crops on tuber yield and quality of subsequent potatoes planted.

Experimental Procedure

Field experiments were conducted at the San Luis Valley, Colorado (latitude 37° 40' N, longitude 106° 9' W, and 7,700 ft. altitude), in potato grower fields, from 2006 to 2009. The soils are generally gravely sandy loam, and classified as loamy-skeletal, mixed (calcareous), frigid *Aquic ustorthents*.

The experiments were laid out as a randomized complete block design with five replications. Each experiment followed a two-year green manure cover crop-potato rotation. Plot size was 35 ft. long by 12 ft. wide. Green manure cover crops were planted in 2005 and 2006 for the 2006 and 2007 potato crops, respectively. Green manure cover crops planted prior to the 2006 and 2007 potato crops included Sordan 79, mustard, sorghum-sudan Super Sweet, Sordan 79 Hay Removed, canola, and a wet fallow (control), where no green manure cover crop was planted.

Additional green manure cover crops were added to the study and planted prior to the 2008 and 2009 potato crops. Green manure cover crops were planted in 2007 and 2008 for the 2008 and 2009 potato crops, respectively. Green manure cover crops planted before the 2008 potato crop included, barley, barley + compost, sunflower, Sordan 79, Sordan 79 Hay Removed, sorghum-sudan var. Super Sweet, canola, mustard, peas, annual rye grass, and a wet fallow as control. In 2008, sorghum-sudan var. Super Sweet, canola, and annual rye grass were dropped from the green manure cover crop treatments and replaced with radish, Sordan 79 mix (Sordan 79 + radish), and winter wheat.

In the potato year, each plot was 35 ft. long by 11.3 ft. wide (4 rows). Row spacing was 34 inches. Potatoes were planted at in-row seed spacing of between 11 to 12 inches, depending on the cultivar used. Potato cultivar Rio Grande Russet was used in 2006 and 2007, and the cultivar Russet Norkotah was used in 2008 and 2009. Potatoes were planted between May 10 and 15 each year. The potato growers followed the Colorado State University recommended practices for the cultivars grown. Between September 15 and 20 of each potato year, a 10 ft section from the middle row of each plot was harvested using an experimental plot potato digger. Tubers harvested were weighed to obtain total tuber yield for each plot. Harvested tubers were mechanically sized into various size distribution groups based on weight (> 4 oz, 4-10 oz, 4-16 oz, > 6 oz, 6-16 oz, > 10 oz, 6-12 oz, tubers). The effect of green manure cover crop treatments on tuber external and internal defects were evaluated. In addition, the effect of green manure cover crop on tuber rot and tuber specific gravity were evaluated in 2009. Tuber specific gravity was evaluated using the weight-in-air/weight-in-water method.

Analysis of variance (ANOVA) was performed using the General Linear Model of SAS (SAS Institute Inc. Cary, NC, Version 9.1). In each case, year was tested using rep (year) as the error term. ANOVA was performed for total tuber yield, tuber size distribution groups, and tuber quality parameters. Differences among treatment means were compared using the least significant difference test (LSD) at the 0.05 level of probability.

Results and Discussion

Tuber Yield and Tuber Size Distribution (2006 and 2007)

There was no significant difference between 2006 and 2007 in tuber yield and quality. Therefore, the average of the two years data are presented and discussed. Potatoes following sorghum sudan Super Sweet Super Sweet, Sordan 79, Sordan 79 with the tops removed as hay, and fallow ground (control), produced the highest total tuber yield (fig 1a). However, maximum marketable tuber (> 4 oz, 4-16 oz, 6-12 oz) yield was produced when potatoes followed sorghum sudan Super Sweet Super Sweet, Sordan 79, and Sordan 79 Hay Removed (fig 1 a and b). Potatoes planted after mustard and canola had been incorporated into the soil produced minimum total and marketable tuber yield (fig 1a and b). It was observed that even though potatoes planted after fallow ground produced total tuber yield comparable to sorghum-sudan Super Sweet, Sordan 79, and Sordan 79 hay removed, it did produce less marketable tuber yield. The yield performance observed for Sordan 79 with hay removed indicates that the remaining short stalks and roots of the Sordan 79 when incorporated into the soil improved the soil for maximum potato tuber yield. Also, it is possible that when the tops of Sordan 79 were not removed, but incorporated into the soil, it did tie up nitrogen through microbial decomposition.

Tuber Internal and External Defects

With the exception of potatoes following sorghum sudan Super Sweet Super Sweet and Wet Fallow plots, which produced 1.3 and 1.6% external defects, respectively, potatoes following all other green manure cover crops produced less than 1.0% tuber external defects (fig 2). Green manure cover crops did not significantly influence tuber internal defects. Potatoes planted after canola produced 0.5% of tubers with hollow heart, but this was not significantly different from the other treatments (fig 2).

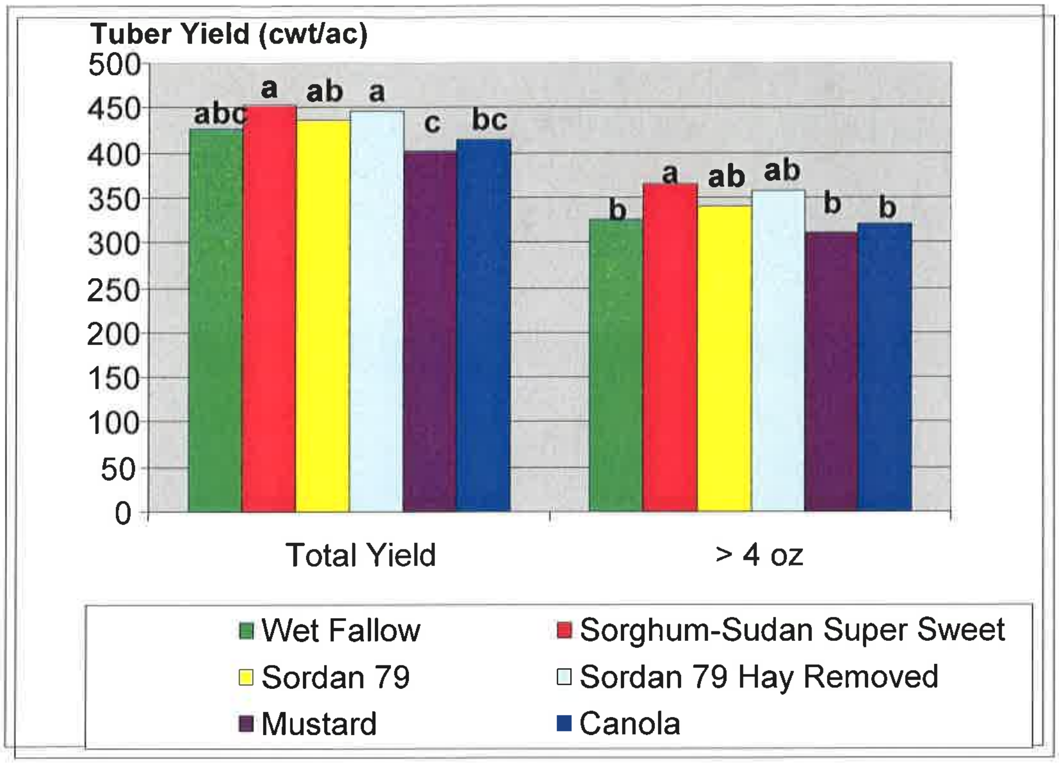

Fig. 1a Effect of green manure cover crops on total and marketable (> 4 oz) tuber yield (average of 2006 and 2007).

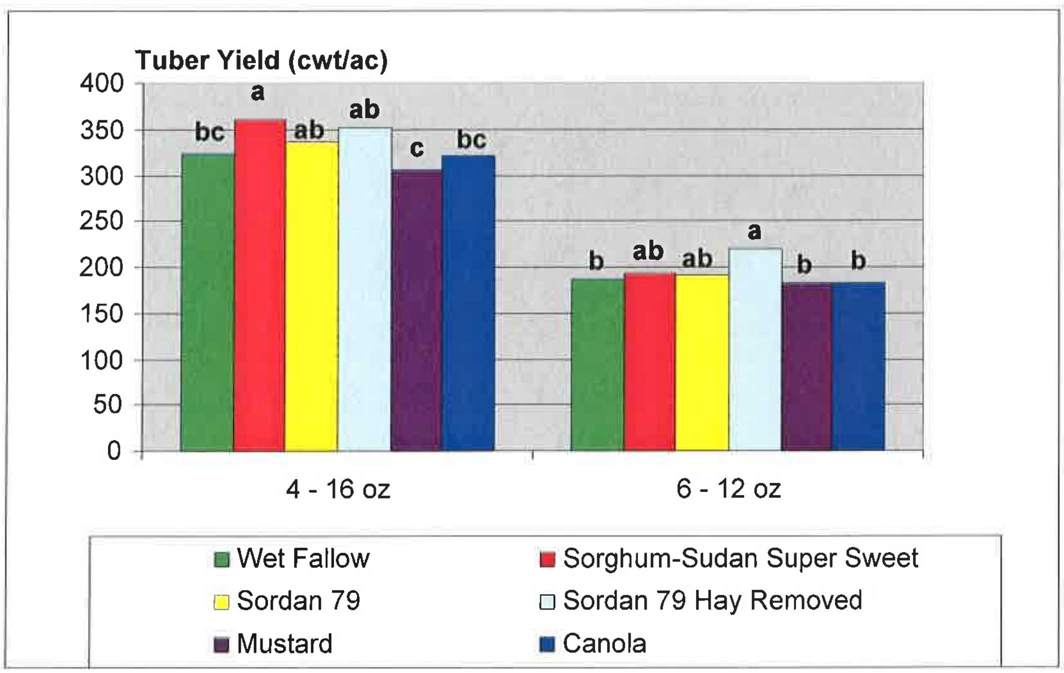

Fig. 1b Effect of green manure cover crops on marketable (4-16 oz, 6-12 oz) tuber yield (average of 2006 and 2007).

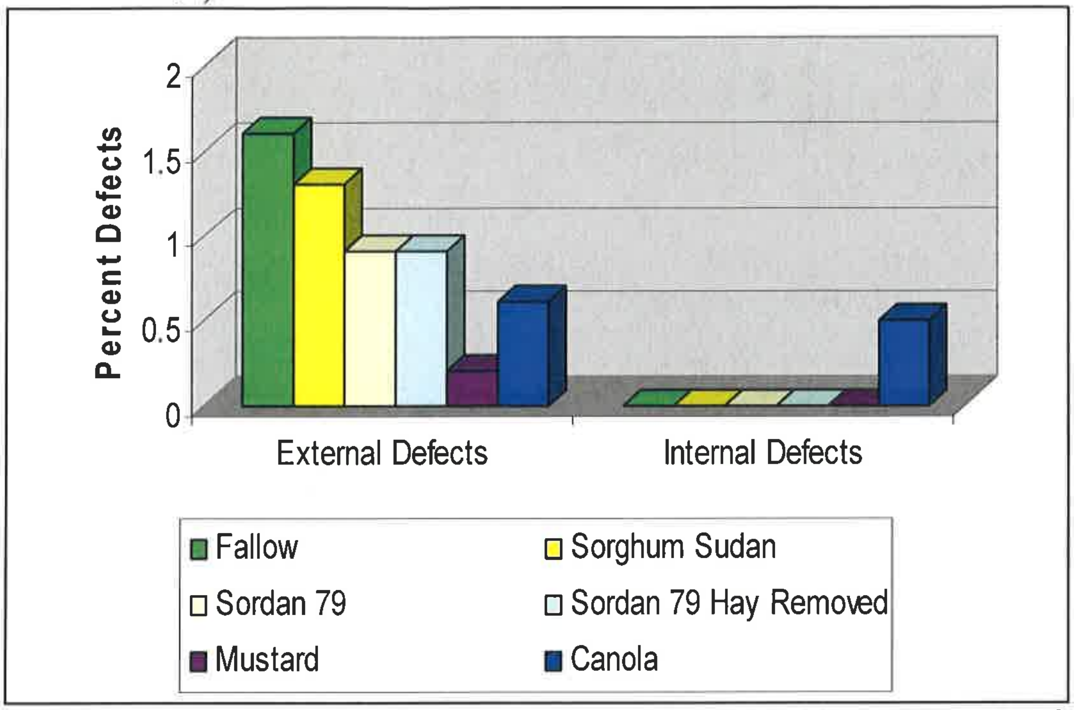

Fig. 2. Effect of green manure cover crops on tuber external and internal defects of Rio Grande Russet (average of 2006 and 2007).

Tuber Yield and Tuber Size Distribution (2008 and 2009)

Some green manure cover crops used in 2008 were replaced in 2009; therefore, the results are presented and discussed separately for the two years.

2008 Results

In 2008, potatoes planted after Sordan 79 Hay Removed produced the highest total tuber yield (563 cwt/ac), compared to all other treatments (fig 3a). Potatoes following Wet Fallow, barley + compost, sorghum sudan Super Sweet Super Sweet, canola, sunflower, and mustard produced the lowest total tuber yield. Maximum marketable tuber (> 4 oz, 4-10 oz, 4-16 oz) yield was obtained when potatoes were planted after Sordan 79 Hay Removed, barley, and rye grass (fig 3b,3d). Large marketable size (6–16 oz) tubers were produced when potato was planted after barley, barley + compost, sunflower, Sordan 79 Hay Removed, peas, and rye grass (fig 3c). The 2008 data indicate that different green manure cover crops can be used to influence tuber size distribution in potatoes.

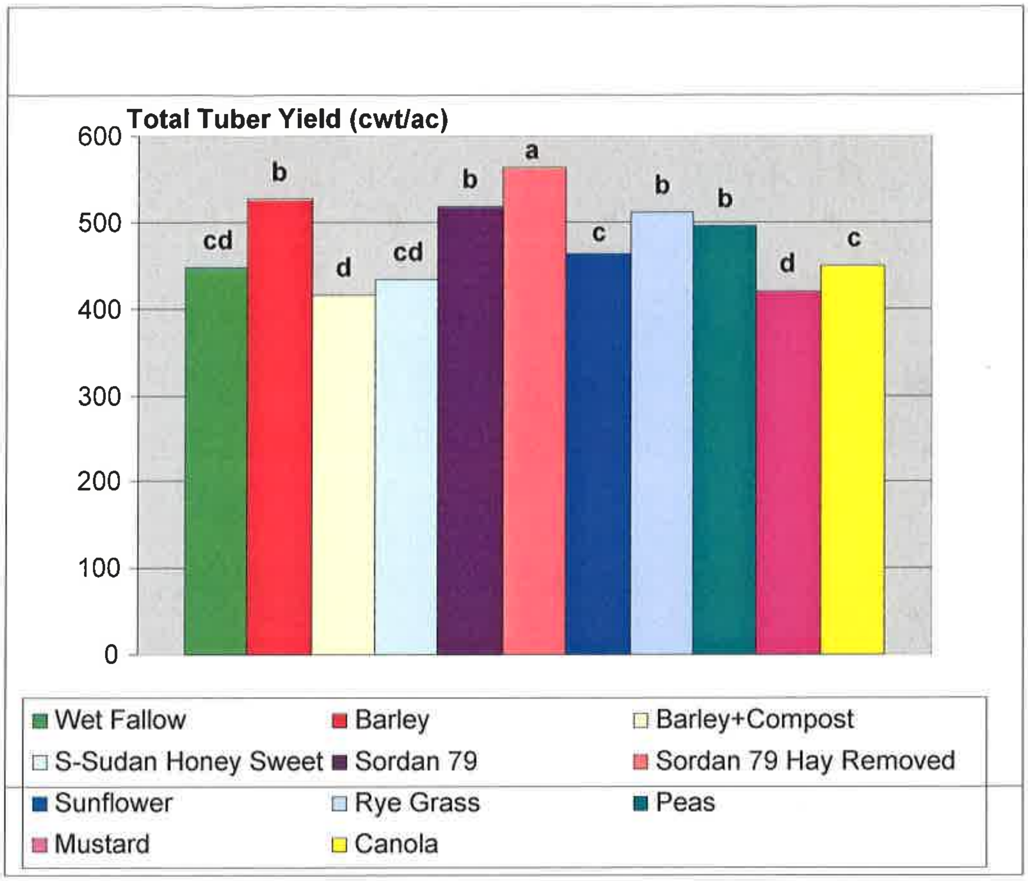

Fig. 3a Effect of green manure cover crops on > 4 oz tuber yield of Russet Norkotah (2008).

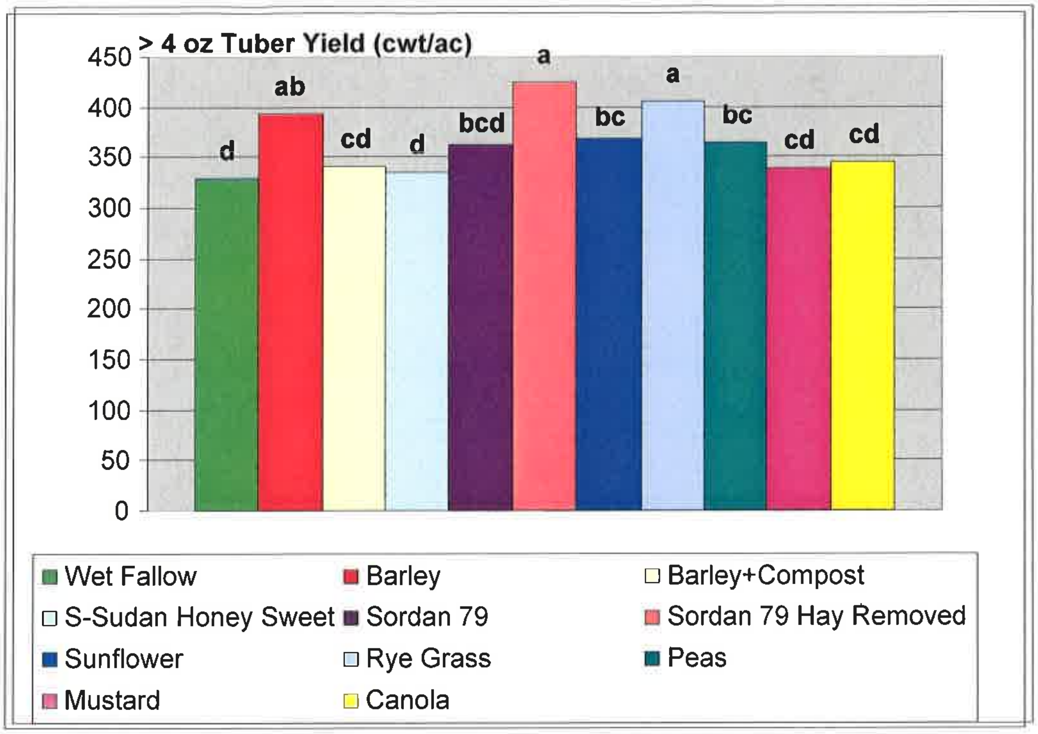

Fig. 3b Effect of green manure cover crops on on total yield of Russet Norkotah (2008).

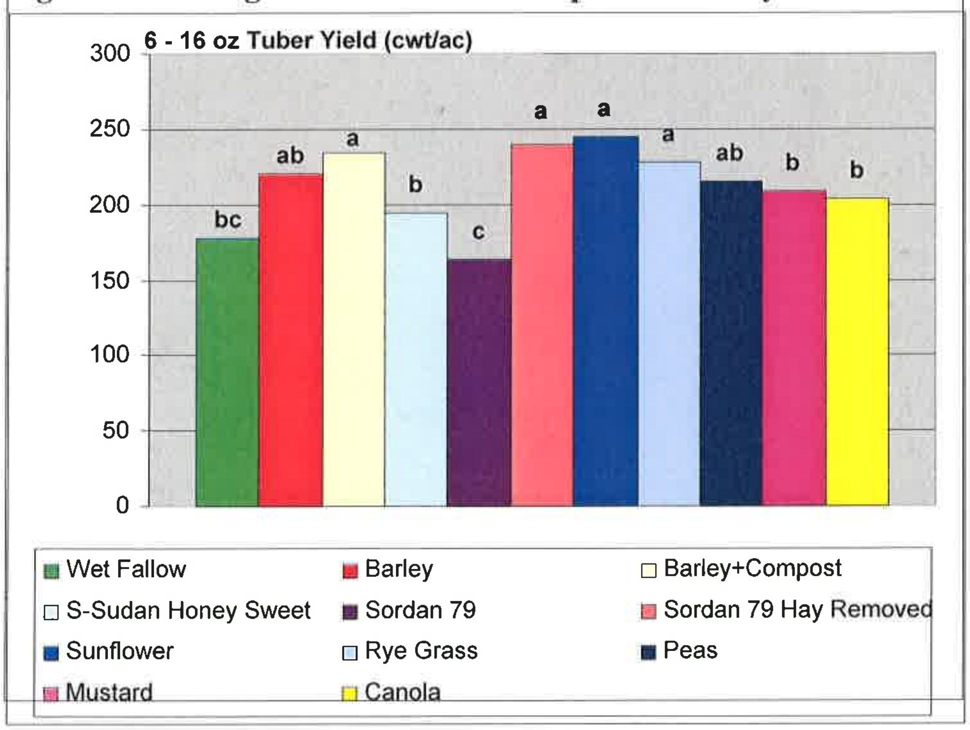

Fig. 3c Effect of green manure cover crops on 6-16 oz tuber yield of Russet Norkotah (2008).

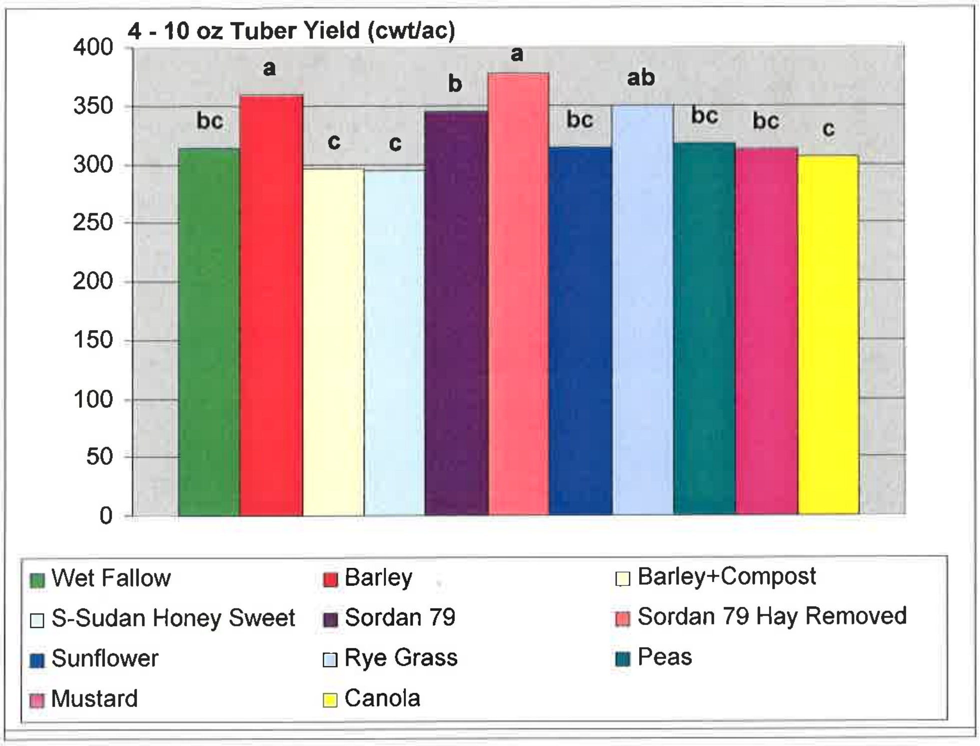

Fig 3d Effect of green manure cover crops on >4 oz tuber yield of Russet Norkotah (2008)

Tuber Quality

Potatoes following peas and fallow ground produced the highest external defects (1.0 and 1.8%, respectively). All other treatments produced less than 1.0% tuber external defects (fig 4). Even though planting potatoes after canola and mustard resulted in low tuber yields, it did produce tubers with the highest specific gravity (1.081 and 1.080, respectively), compared to the other treatments (fig 5). In 2008, green manure cover crops did not influence tuber internal defects.

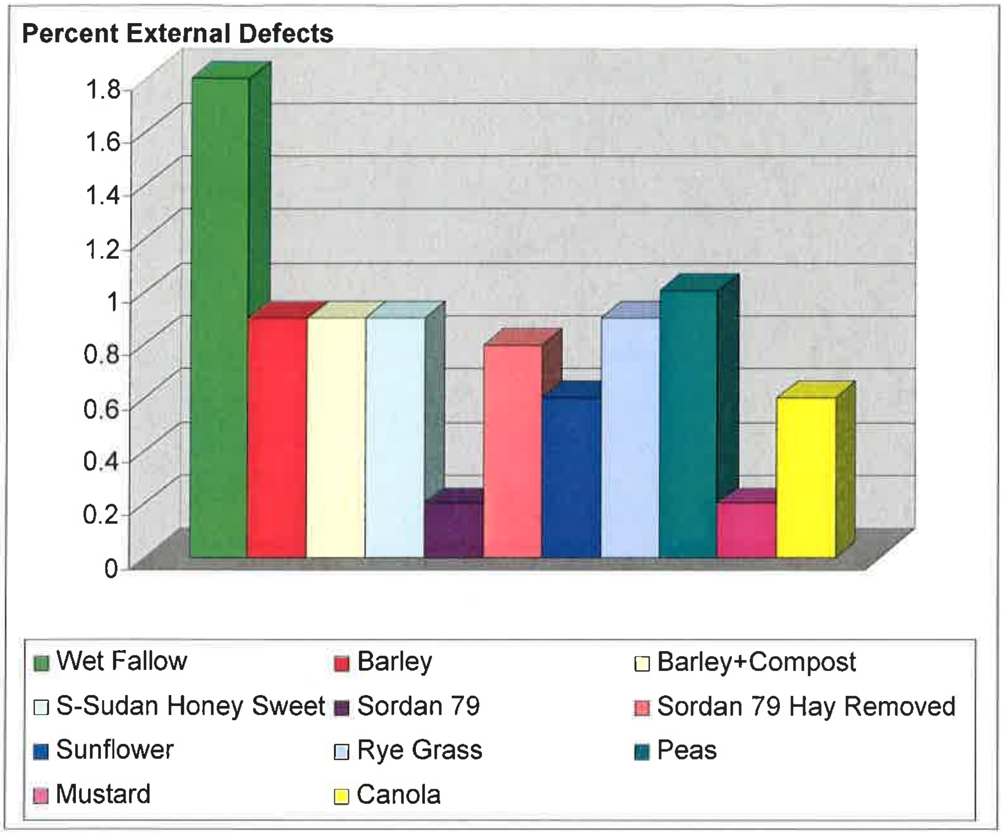

Fig. 4 Effect of green manure cover crops on tuber specific gravity of Russet Norkotah (2008).

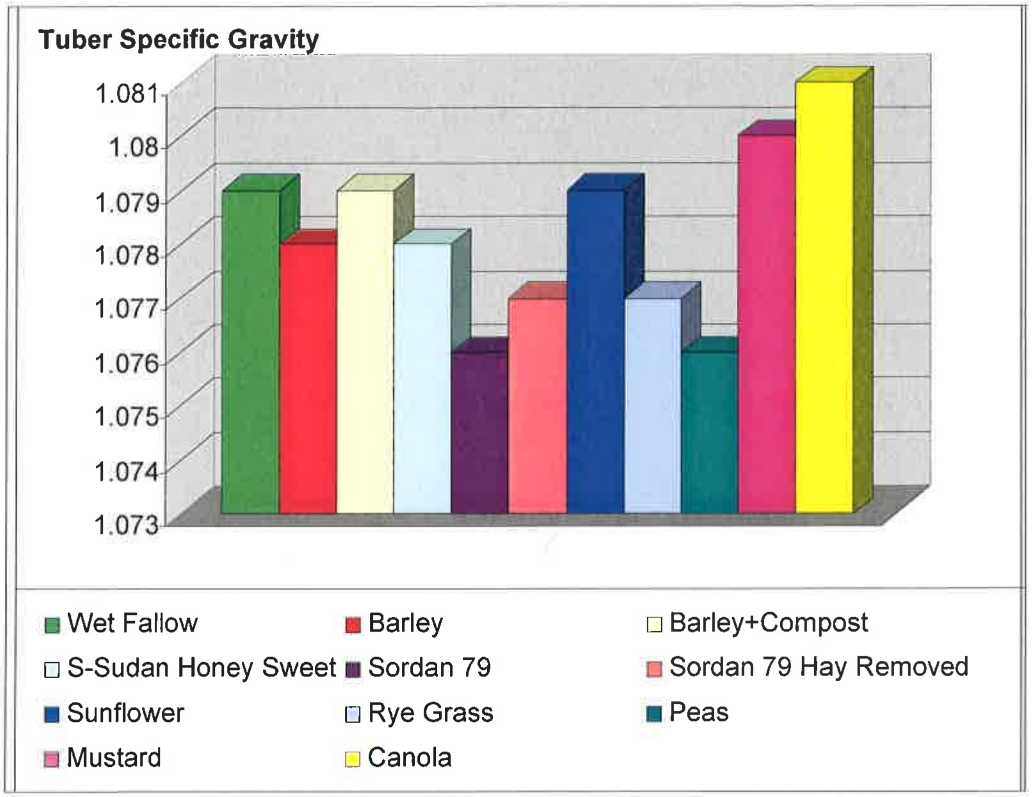

Fig. 5 Effect of green manure cover crops on tuber external defects of Russet Norkotah (2008).

2009 Results

Tuber Yield and Tuber Size Distribution

In 2009, maximum total and marketable (> 4 oz, 4-16 oz, > 6 oz) tuber yields were produced when potatoes were planted after barley, sunflower, Sordan 79 79 with hay removed, Sordan 79 mix, winter wheat, and fallow ground (Table 1). For > 10 oz tubers, barley, Sordan 79 Hay Removed, peas, and radish, influenced the production of maximum tuber yields. These results clearly indicate that the type of green manure crop used can strongly influence tuber size distribution.

Table 1. Response of Russet Norkotah to different green manure cover crops, 2009.

Treatment	Total	> 4 oz	> 6 oz	4-16 oz	4-10 oz	> 10 oz
	Yield (cwt/ac)					
Fallow	493a[1]	428ab	346a	407a	288a	140b
Barley	498a	443a	359a	415a	269b	173a
Barley+Compost	411c	348d	290b	307c	207d	141b
Sunflower	512a	445a	346a	431a	301a	144b
Sordan79 Hay Removed	484ab	430ab	333a	382a	255bc	175a
Sordan 79	456b	384c	298b	369b	274b	111c
Peas	467b	420ab	353a	378a	237c	184a
Mustard	466b	403b	323ab	369b	275b	128b
Radish	462b	401b	306b	367b	252bc	149ab
Sordan79/Radish	496a	435a	329a	397a	319a	116bc
Winter Wheat	506a	448a	351a	402a	308a	140b

[1] Letters in the same column and bearing the same letter are not significantly different at the 0.05 level of probability

Tuber Defects

For the four years study, 2009 was recorded the highest percentage of tuber external and internal defects. Barley, barley + compost, peas, and radish, produced tubers with the highest percentage of tuber external defects (5.7 to 9.1%) – Table 2. Fallow, barley, barley + compost, peas, and winter wheat produced the highest tuber internal defects (9.4 to 15.1%) and tuber rots (7.2 to 19.9%) – Table 2.

Table 2. Effect of green manure cover crops on tuber quality of Russet Norkotah, 2009.

Treatment	% External Defects[1]	% Internal Defects[2]	% Rots
Fallow	4.2	11.1	9.6
Barley	6.6	15.1	9.3
Barley + Compost	6.0	12.4	19.9
Sunflower	4.6	0	0.5
Sordan 79 Hay Removed	3.8	2.9	4.7
Sordan 79	2.9	2.3	4.3
Peas	5.7	9.4	11.3
Mustard	2.9	1.6	3.7
Radish	9.1	2.7	4.9
Sordan 79/Radish Mix	3.9	3.0	3.4
Winter Wheat	2.6	10.0	7.2

[1] Includes growth cracks, knobs, and misshapes

[2] Includes hollow heart and brown center

Summary and Conclusions

The purpose of this study was to evaluate the effect of green manure cover crops on subsequent potato tuber yield and quality. Data from the four years study indicate that green manure crops influence total tuber yield and tuber size distribution. Therefore, the choice of green manure crop for a potato cropping system must depend on tuber size requirement. In all four years, planting potatoes after Sordan 79 Hay Removed produced maximum total and marketable tuber yields. Incorporating Sordan 79 tops and roots increases the potential of nitrogen being tied up by soil microbes, which could impact subsequent potato growth and yield. Canola and mustard, when plowed into the soil before potatoes are planted, decreased marketable tuber yield significantly in all four years. In three out of four years, green manure cover crops did not significantly influence tuber internal defects.

Data from this study indicate that, in a green manure cover crop-potato cropping system, it will be very economical to plant Sordan 79, remove the tops for hay, and then incorporate it prior to planting potatoes the following year.

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Part Id. Agricultural Research Service-SLV Green Manure & Cover Crops Cooperation (*Dr. Jorge Delgado, SPRN Unit, Ft. Collins, CO.*)

Introduction: The ARS has been cooperating in cover crop research with CSU, NRCS, local farmers, and consultants since the early 1990s (Delgado et al. 2007). Results from the most recent cooperation are presented here. One of the major goals across this cooperation has been to develop viable, sustainable cropping systems that reduce the impact of agriculture on the environment. Our most recent results show that summer cover crops significantly reduce the potential for soil erosion and nitrate leaching. These summer cover crops can also increase the potential for higher yields at farmers' fields and save water, increasing water use efficiency across the region. These are great benefits not only for the farmers, but also for the people of Colorado.

Goals: One of our goals was to use data from this cooperation to develop quick, easy-to-use tools that can be used to assess the effects of cover crops across the environment. This recent cooperation has enabled the incorporation of the results and data into user-friendly tools that could allow farmers to assess the effects of management on nitrogen use efficiencies. See an already developed prototype at http://199.133.175.80/nttwebars/ (Figure 1). Users will be able to use this prototype of the Nitrogen Trading Tool to quickly assess the effects of management practices such as the use of cover corps, on the environment. As an example we can evaluate a rotation of potato-potato versus a potato cover crop for hay (Figure 2). The comparison shows that the reduction in N losses was about 2000 lb N across 135 acres (Figure 3). If desired, users could see a detailed report showing the nitrate leaching potential at the click of a button (Figure 4). A quick report can also be generated and downloaded from the web-based tool (Figure 5). This prototype has not yet been released and is in the testing stage. Data from these studies and from our cooperation will also be used to develop the scenarios to be evaluated.

Preliminary Results. A soon-to-be-released, new NLEAP-GIS 4.2 model was used to evaluate these cover crops and will be used to update the web tool prototype. The preliminary results show that cover crops are generally effective in reducing nitrate leaching.

Potato-Potato Rotation: For example, a traditional potato–potato rotation with high nitrogen input will average over the long term a nitrate leaching potential of 81 lb NO_3-N per acre (Figure 6). The average nitrate leaching across 94 center pivots could be potentially be in excess of 1,000,000 lbs of NO_3-N.

Barley-Barley Rotation: If we change the rotation of potato–potato to a small, well-managed, malting barley–malting barley rotation without potato, the nitrate leaching potential is reduced to 28 lb NO_3-N per acre, or about 350,000 lb NO_3-N across the same area (Figure 7).

Potato-Barley Rotation: However, farmers may want to plant a better cash crop such as potato. The inclusion of a well-managed, traditional potato-barley rotation will reduce the average nitrate leaching potential to 33 lb NO_3-N per acre or about 400,000 lb NO_3-N across 94 center irrigated pivots (Figure 8). If the farmer moves to a potato-barley-barley rotation, the average nitrate leaching is reduced even further to an average 28 lb NO_3-N per acre (Figure 9).

Potato-Summer Cover Crop Rotation: Now if the farmer changes his/her practices to include a summer cover crop that also saves large amounts of water, the nitrate leaching potential goes down to 13 lb NO_3-N /acre, about 170,000 lb NO_3-N in these 94 center irrigated pivots (Figure 10).

Potato-Summer Cover Crop Hay Rotation: If the farmer removes the hay of the cover crops to increase his/her potential profits, the average nitrate leaching potential is still low at 21 lb NO_3-N/acre (Figure 11).

Mass Balance: Delgado et al. (1998, 2000) reported that this kind of analysis is included, and in order to have a better mass balance these evaluations need to consider the amount of nitrate that is being added with irrigation water. In this analysis the amount of NO_3-N background from the underground water that is being added for these fields is 36 lb NO_3-N per acre, about 450,000 lb NO_3-N for these 94 center irrigated pivots.

These studies are in agreement with Delgado (1998) and Delgado et al. (2001) showing that the incorporation of malting barley into potato rotations helps to mine NO_3-N from ground waters. The deep rooted crop serves as a vertical filter, sieving, mining and cleaning underground water (Delgado 1998, Delgado et al. 2006, 2008, 2007). The barley – potato rotation will mine about 100,000 lb NO_3-N per 94 center irrigated pivots. The summer cover crops recover NO_3-N in the underground water from the deeper rooted crops because they have much higher mining ability (in this example, 60% higher). The use of a summer cover crop–potato rotation can help to mine or remove NO_3-N from groundwater as much as 160,000 lb NO_3-N per 94 center irrigated pivots.

New Tools: A new web tool is in development and a prototype can be tested at the following link: http://199.133.175.80/nttwebars/ (Figure 1). This is a prototype and data from all these studies will be used to continue to fine tune and improve the web- based prototype. ARS has approved a new web link to all of these tools, such as the Nitrogen Index, NLEAP-GIS, and Nitrogen Trading Tool to help users assess nitrogen use efficiencies. At this new link expected to be available this spring, users will be able to download the tools and/or to use a web-based version of them. The new link approved to be available in the future is http://www.ars.usda.gov/npa/spnr/nuewebtools .

As we complete analysis of cover crops studies and other related studies, these important nitrogen use efficiency tools will continue to be improved in their ability to assess the effects of management on nitrogen use efficiencies and impact on the environment.

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Part II. Interactive Effect of Compost Tea, Fungicide Application, and Nitrogen Rate on Late Blight Incidence and Potato Tuber Performance

Dr. Samuel Essah, Assistant Professor and Extension Specialist *and Andrew J. Houser, Research Associate,* SLVRC, Center, CO.

Introduction

Early blight of potato is a disease influenced by soil fertility and plant nutrition. High nitrogen (N) application rates have been shown to suppress early blight (Davis 1985). However, N rates are typically higher for early blight control compared to the optimum requirements for maximum yield (Barclay et al. 1973). Excessive N application can suppress potato yield, and also reduce tuber specific gravity. More economical control of early blight has been achieved by managing fertility for optimal yield and using protectant fungicides to manage the disease (Mackenzie 1981).

Compost tea is the water extract of composted manure and/or plant materials. The resulting tea is rich in a diverse population of bacteria, fungi, protozoa, and soluble plant nutrients. When compost tea is sprayed on a plant, the leaf surface is occupied by beneficial organisms, forming a physical barrier against the pathogenic species and providing a competitive environment in which the pathogenic species lose out ($ACRES_{USA}$ 2001). Additionally, as a foliar nutritional source, compost tea stimulates healthy plant growth, helping the plant to further resist attack. For sustainable potato production, and for environmental conservation, there is the need for alternative methods of suppressing potato foliar disease and still improve potato tuber yield and quality. The objective of this study was to evaluate the interactive effect of compost tea, fungicide program and nitrogen management on early blight incidence, potato tuber yield, tuber size distribution and quality.

Experimental Procedure

Experimental Setup: Plots were established in 2007, 2008, and 2009, at the San Luis Valley Research Center at Center, CO. The previous crop before the 2007 and 2009 potato crop was barley, and the previous crop before the 2008 potato crop was sudan grass. The experiment was established as a factorial arrangement of the treatments in a randomized complete block design. Each treatment was replicated four times. Treatments included compost tea applied at a rate of 8 gal/ac. The fungicide program used was the application of Bravo at 1.5 pt/ac, Quadris at 6.1 fl oz/ac, and Dithane at the rate of 2.0 lb/ac. The two N fertilizer rates used were, 120 and 160 lb N/ac. The six treatments in this study were, 120 lb N/ac (control, low N rate); 160 lb N/ac (control, optimum N rate); 120 lb N/ac + compost tea (120 N-CT); 160 lb N/ac + compost tea (160 N-CT); 120 lb N/ac + Fungicide (120N-F); and 160 lb N/ac + Fungicide (160N-F). Two potato cultivars Russet Norkotah and Russet Nugget were used as test crops.

Cultural Management: Seed pieces were machine planted on May 11 2007, May 6 2008, and May 14 2009. Within row spacing was 12 inches, with row spacing of 34 inches. Individual plots were four rows wide and 25 ft. long. Throughout the growing season, plot care and cultural management practices followed the recommendation by CSU, San Luis Valley Research Center. On September 4, 2007, August 29, 2008, and September 8, 2009, potato vines were killed using a mechanical vine beater. Tubers from plots were machine harvested from the middle two rows on September 25, 2007, September 25, 2008, and September 23, 2009.

Data Collection: Early blight lesions on leaflets were scored by visual observation. Three plants were scored per plot, and the scores were averaged to obtain a score for the plot.

Tubers harvested from each plot were weighed to record total field yield. Tubers from each plot were graded for external and internal defects (Growth cracks, knobs, misshapes, hollow heart and brown center). Tubers were sorted into various size distribution groups based on weight (4-16 oz, 4-10 oz, 4-12 oz, 6-12oz, and 6-16 oz). Ten large (10-16 oz) tubers were taken for hollow heart and brown center evaluation. Tuber specific gravity was measured using the weight-in-air/weight-in-water method.

Results and Discussion

Russet Norkotah

Early Blight Incidence

The use of fungicide at both N rates and compost tea at the optimum N rate of 160 lb N/ac, significantly reduced early blight incidence in 2007 (Table 1). At the lower N rate of 120 lb N/ac, it was observed that compost tea application did not control early blight as good as the other treatments. In 2008, however, the application of compost tea at both N rates, and the use of fungicide at the lower N rate, significantly reduced early blight incidence, compared to the other treatments. In 2009, the application of compost tea at the optimum N rate and the use of fungicide at both N rates reduced early blight lesions compared to the other treatments. Within the compost tea and fungicide treatments, it was observed that in 2009, early blight incidence was significantly lower when optimum N rates were used in combination with compost tea or fungicide. It should be noted that early blight incidence was higher in 2008 compared to the other two years of the study.

Table 1. Interactive effect of compost tea, fungicide application, and nitrogen rate on early blight incidence in Russet Norkotah.

Treatment	Percent Early Blight Lesions Observed		
	2007	2008	2009
120 N[1]	11.2 b[2]	56.5 bc	32.1 a
160 N	10.3 b	64.6 a	35.0 a
120 N-CT	17.2 a	53 c	34.6 a
160 N-CT	8.8 bc	51.3 c	21.3 b
120 N-F	4.7 c	58.7 bc	24.2 b
160 N-F	4.8 c	65.4 a	13.3 c

[1] N = Nitrogen Rate (lb N/ac); N-CT = Nitrogen Rate and compost tea applied; N-F = Nitrogen Rate and fungicide applied.

[2] Figures in the same column and bearing the same letter are not significantly different at the 0.05 level of probability

Total Yield and Tuber Size Distribution

In 2007, none of the treatments influenced tuber yield significantly at the lower N rate of 120 lb/ac. However, at the optimum N rate of 160 lb N/ac, it was observed that fungicide application resulted in increased total yield compared to compost tea application and the control (fig. 1a). Marketable tuber (4-16 oz) yield was increased when fungicide was applied, compared to the control, but the yield increase did not significantly differ from yields obtained from compost tea applied plots (fig. 1 b). No significant difference was observed among the treatments for the 4-10, 4-12, and 6-12 oz tuber yields in 2007 (fig 1 c-e).

In 2008, the response of tuber yield to the treatments was different from that observed in 2007. With the exception of the 4-10 oz tuber yield, the yield of all other tuber sizes, as well as total tuber yield was reduced when compost tea was applied at the lower N rate of 120 lb N/ac (Fig 2 a-e). Yields obtained from fungicide applied plots were similar to the control at the lower N rate. At the optimum N rate of 160 lb N/ac, however, total and marketable tuber yields did not differ among the treatments.

In 2009, the application of compost tea at the lower N rate increased total tuber yield and large marketable tuber (> 6 oz, and 6-16 oz) yields, compared to the control (fig 3 a, d and e). However, yields from the fungicide applied treatment at the lower N rate did not differ from yields obtained from compost tea applied plots (fig 3 a-e). Yields were similar for all treatments at the optimum N rate of 160 lb N/ac., with the exception of the medium size (4-10 oz) tuber yield, where compost tea applied plots produced significantly higher yields than the fungicide applied and the control treatments (fig 3 c).

Data from the three years study indicate that compost tea can be applied as an alternate to fungicides in Russet Norkotah production, at an optimum N rate of 160 lb N/ac to produce similar or higher tuber yields.

Tuber Quality

Tuber external defects were generally low in all three years of this study. Tuber percent external defects ranged from 1.2 to 2.7, 0.8 to 5.0, and 0.2 to 1.2, in 2007, 2008, and 2009, respectively (Table 2, 3, and 4). Compost tea applied at the optimum N rate of 160 lb N/ac was among the treatments with the lowest percent external defects in 2007 and 2008 (1.9 and 2.3%, respectively). No significant difference was observed in tuber external defect in 2009. The treatments did not significantly influence tuber internal defects in all three years. In general, only slight differences were observed in tuber specific gravity among the treatments.

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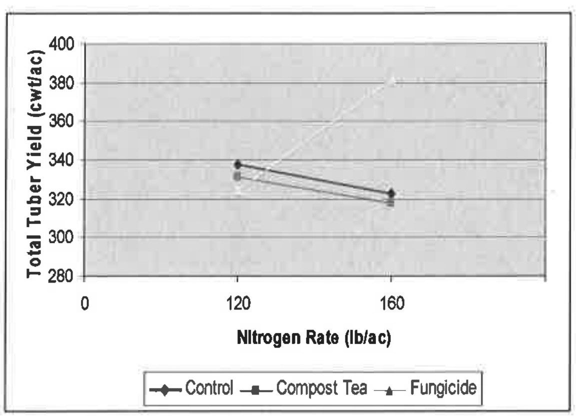

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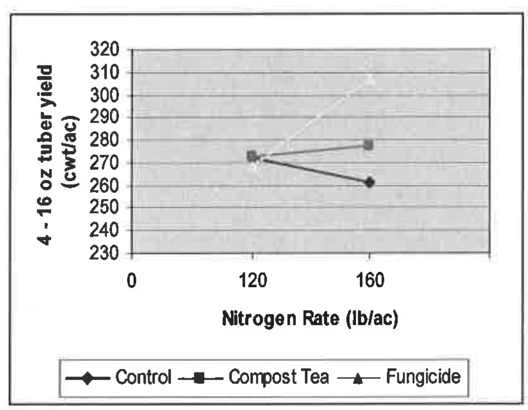

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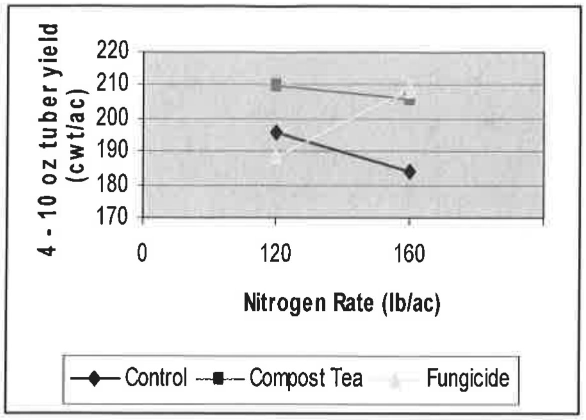

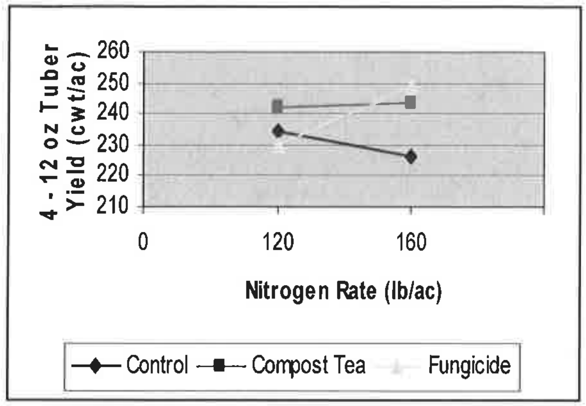

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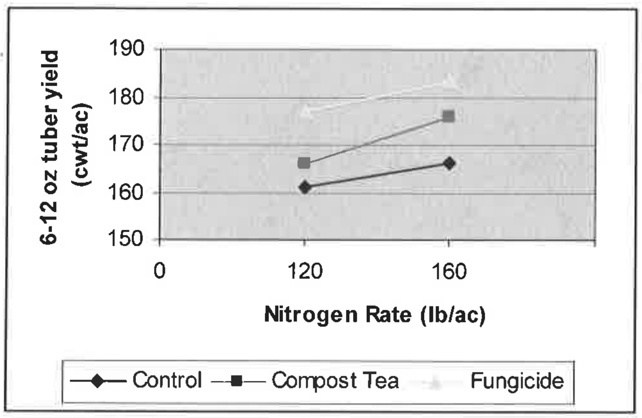

Figure 1 (2007). Interactive effect of compost tea, fungicide program and nitrogen management on total yield and tuber size distribution of Russet Norkotah.

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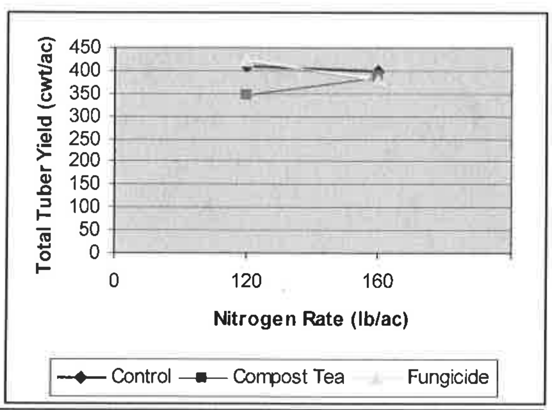

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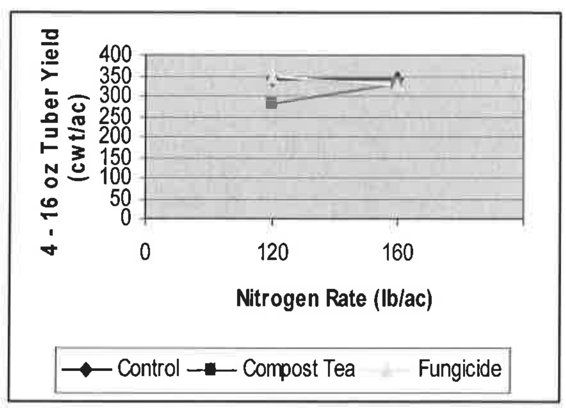

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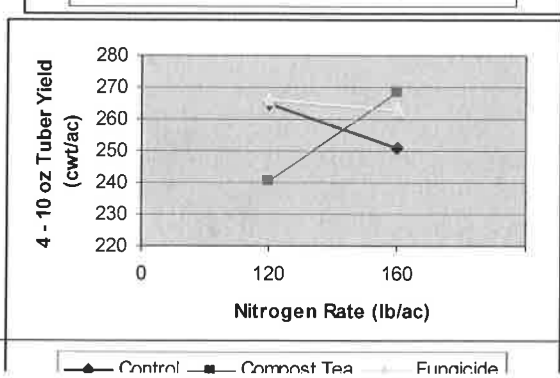

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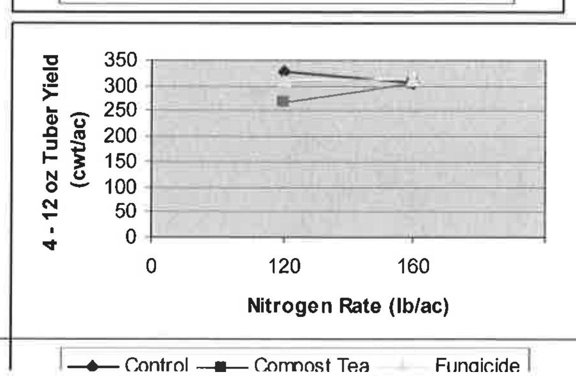

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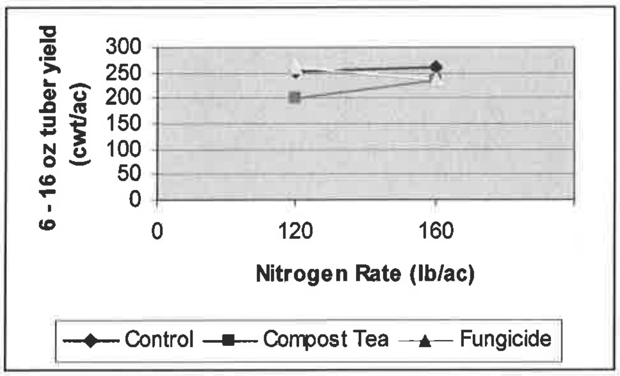

Figure 2 (2008). Interactive effect of compost tea, fungicide program and nitrogen management on total yield and tuber size distribution of Russet Norkotah.

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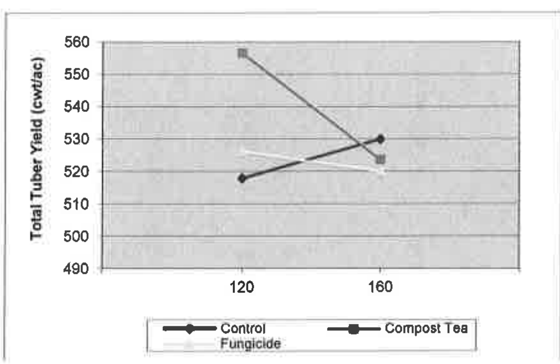

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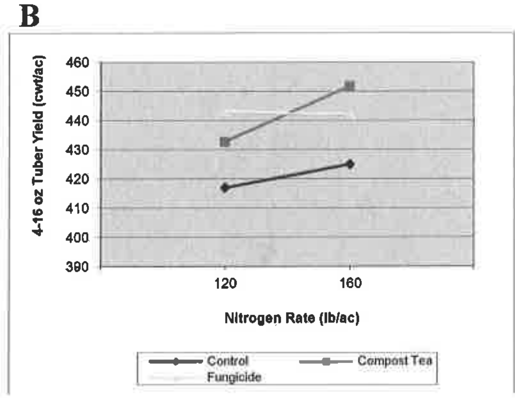

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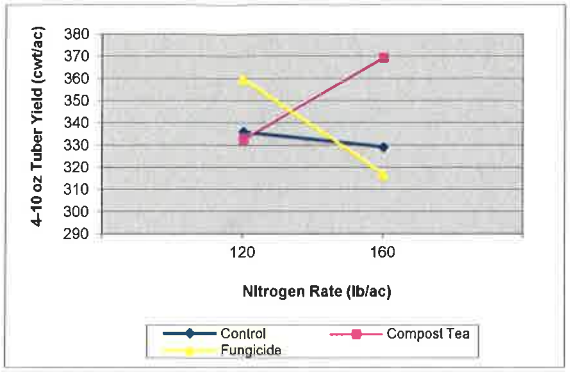

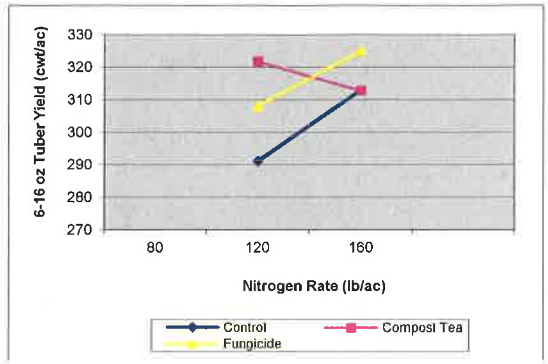

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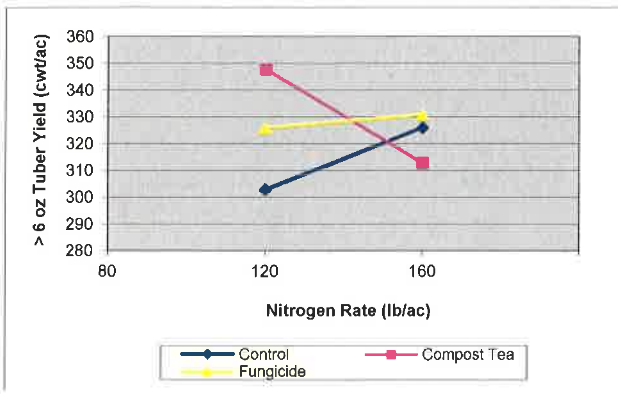


Figure 3 (2009). Interactive effect of compost tea, fungicide program and nitrogen management on total yield and tuber size distribution of Russet Norkotah.

Table 2. Interactive effect of compost tea, fungicide program and nitrogen management on tuber external and internal defects, and specific gravity of Russet Norkotah (sel. 8), 2007.

Treatment	% External Defects[2]	% Internal Defects[3]	Specific Gravity
120N[1]	2.4	0	1.080
160N	1.2	1.9	1.080
120N-CT	2.7	2.8	1.083
160N-CT	1.9	0	1.080
120N-F	1.8	0.6	1.085
160N-F	2.5	1.8	1.083

[1] N = nitrogen rate; CT = compost tea applied; F = fungicide applied
[2] Includes growth cracks, knobs and misshapes
[3] Includes hollow heart and brown center

Table 3. Interactive effect of compost tea, fungicide program and nitrogen management on tuber external and internal defects, and specific gravity of Russet Norkotah (sel. 8), 2008.

Treatment	% External Defects[2]	% Internal Defects[3]	Specific Gravity
120N[1]	5.0	0	1.076
160N	2.6	0	1.074
120N-CT	3.6	1.6	1.074
160N-CT	2.3	0.8	1.074
120N-F	0.8	0	1.077
160N-F	2.2	0.6	1.075

[1] N = nitrogen rate; CT = compost tea applied; F = fungicide applied
[2] Includes growth cracks, knobs and misshapes
[3] Includes hollow heart and brown center

Table 4. Interactive effect of compost tea, fungicide program and nitrogen management on tuber external and internal defects, and specific gravity of Russet Norkotah (sel. 8), 2009.

Treatment	% External Defects[2]	% Internal Defects[3]	Specific Gravity
120N[1]	0.3	0.4	1.086
160N	0.4	0.6	1.080
120N-CT	0.8	0	1.086
160N-CT	1.4	0	1.080
120N-F	1.6	0	1.087
160N-F	3.9	0	1.082

[1] N = nitrogen rate; CT = compost tea applied; F = fungicide applied
[2] Includes growth cracks, knobs and misshapes
[3] Includes hollow heart and brown center

RUSSET NUGGET

Early Blight Incidence

The application of fungicide significantly reduced early blight incidence at both N rates in 2007 (Table 5). More early blight lesions were observed in plots where compost tea was applied with low N rate (Table 5). The percentage of early blight lesions observed on potato leaves in 2008 and 2009 was significantly reduced when compost tea or fungicide was applied at the optimum N rate of 160 lb N/ac. (Table 5).

Table 5. Interactive effect of compost tea, fungicide application, and nitrogen rate on early blight incidence in Russet Nugget.

	Percent Early Blight Lesions Observed		
Treatment	2007	2008	2009

120 N[1]	8.9 bc	3.9 ab	32.1 a
160 N	14.4 b	3.4 b	35.0 a
120 N-CT	21.3 a	4.5 a	34.6 a
160 N-CT	10.5 b	3.3 b	21.3 b
120 N-F	4.8 c	4.7 a	24.2 b
160 N-F	4 c	3.5 b	13.3 c

[1] N = Nitrogen Rate (lb N/ac); N-CT = Nitrogen Rate and compost tea applied; N-F = Nitrogen Rate and fungicide applied.

[2] Figures in the same column and bearing the same letters are not significantly different at the 0.05 level of probability

Total Yield and Tuber Size Distribution

No significant difference was observed in tuber yield among the treatments when N was applied at the low rate of 120 lb N/ac in 2007 (fig 4 a-e). However, at the optimum N rate of 160 lb N/ac, fungicide application increased marketable tuber (4-16, 4-10, 4-12, and 6-12 oz) yield, compared to the control. The yields from fungicide applied plots at the optimum N rate did not differ significantly from yields produced for the compost tea applied plots.

In 2008, compost tea application increased total tuber yield by 12% at the low N application rate. Total yields were however similar at the optimum N rate (fig 5 a). Production of marketable (4-16, 4-10, 4-12 oz) tuber yields were increased when compost tea was applied at the low N application rate (fig 5 b-d). However, at the optimum N rate, marketable tuber yields were similar for the compost tea and fungicide applied treatments.

In 2009, no significant difference was observed in tuber yields among the treatments at the low N rate (fig 6 a – e). However, at the optimum N rate of 160 lb N/ac, fungicide application increased total, > 6 oz, 4-16 oz, and 4-10 oz tuber yields, compared to when compost tea was applied.

Tuber Quality

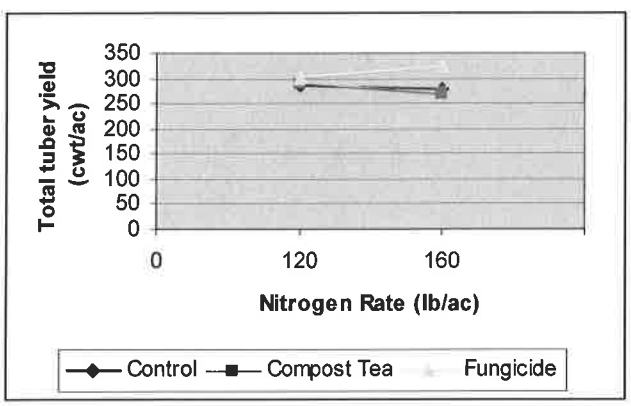
In general, a low percentage of external defects were observed in all three years. Percent external defects ranged from 0.3 to 2.7, 0.7 to 2.0, and 0.6 to 1.2, in 2007, 2008, and 2009, respectively, (Table 6, 7, and 8). No internal defects were observed in any of the tubers in all three years of this study, with the exception of 0.5% observed for 120 lb N/ac in 2009. Tuber specific gravity was high in all treatments, and ranged from 1.087 to 1.092, 1.096 to 1.103, and 1.102 to 1.107, in 2007, 2008, and 2009, respectively. Nitrogen rate influenced tuber specific gravity in the compost tea and fungicide applied treatments. Treatments at the 120 lb N/ac rate produced higher tuber specific gravities than the 160 lb N/ac rate treatments (Table 6, 7, and 8).

Table 6. Interactive effect of compost tea, fungicide program and nitrogen management on tuber external and internal defects, and specific gravity of Russet Nugget, 2007.

Treatment	% External Defects[2]	% Internal Defects[3]	Specific Gravity
120N[1]	2.4	0	1.089

160N	0.6	0	1.089
120N-CT	0.3	0	1.089
160N-CT	2.7	0	1.087
120N-F	1.2	0	1.092
160N-F	0.8	0	1.090

[1] N = nitrogen rate; CT = compost tea applied; F = fungicide applied
[2] Includes growth cracks, knobs and misshapes
[3] Includes hollow heart and brown center



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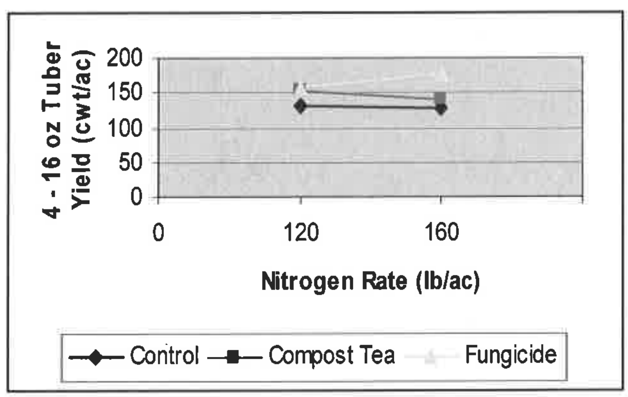

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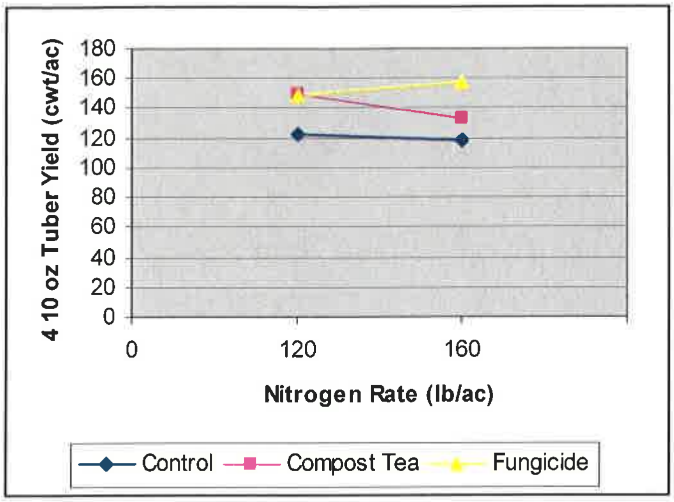

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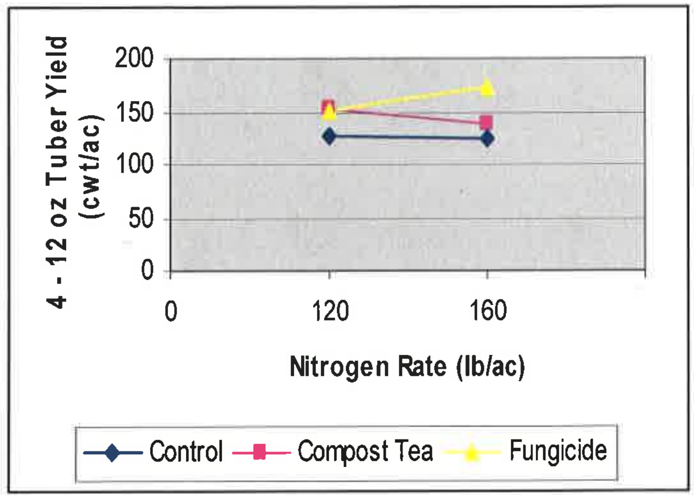

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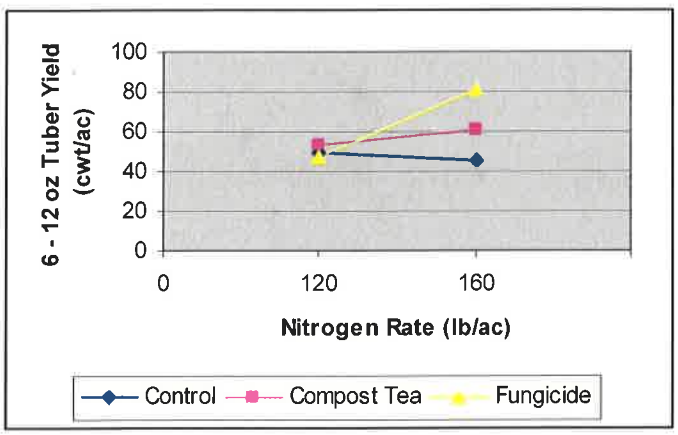

Figure 4 (2007). Interactive effect of compost tea, fungicide program and nitrogen management on total yield and tuber size distribution of Russet Nugget.

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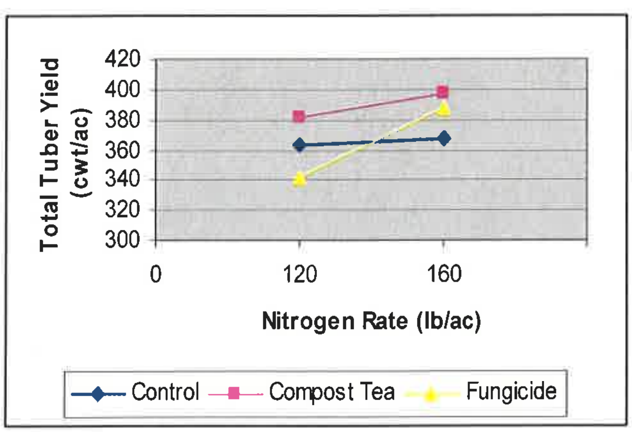

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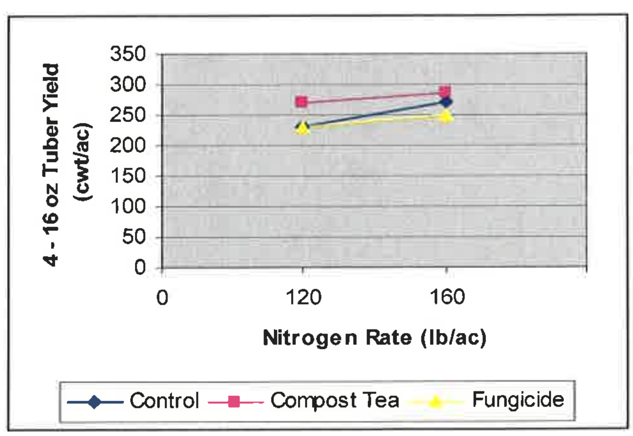

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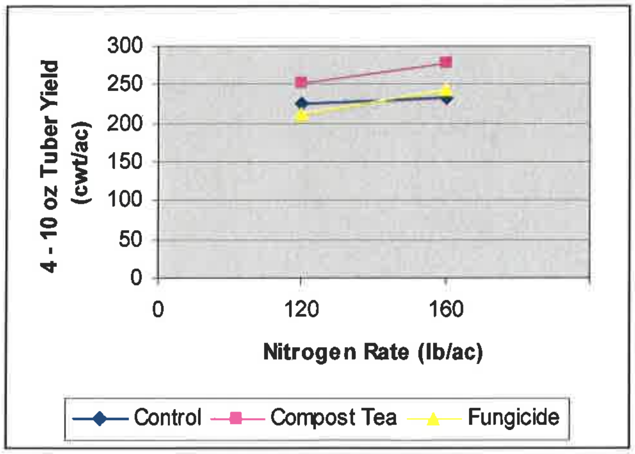

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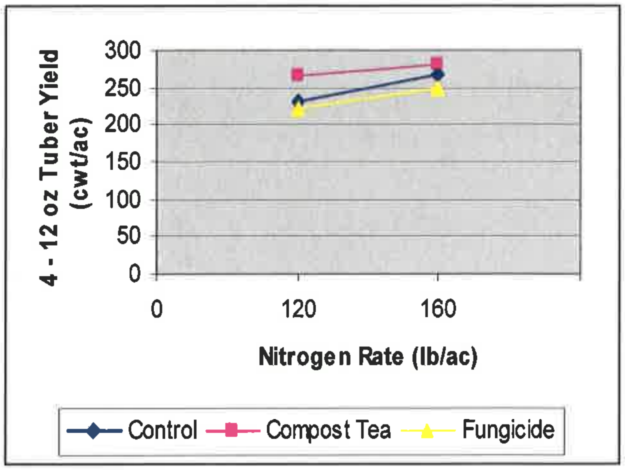

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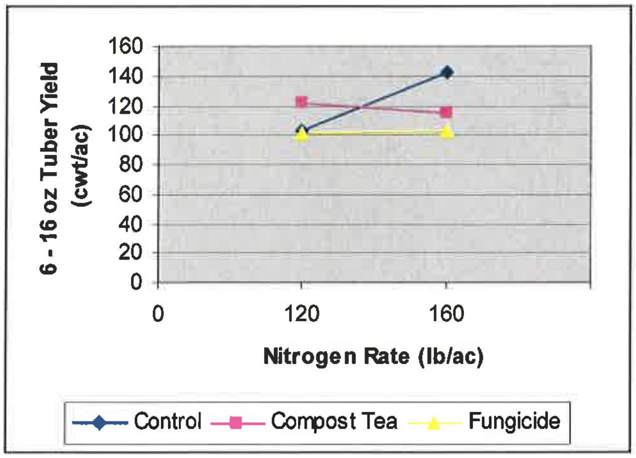

Figure 5 (2008). Interactive effect of compost tea, fungicide program and nitrogen management on total yield and tuber size distribution of Russet Nugget.

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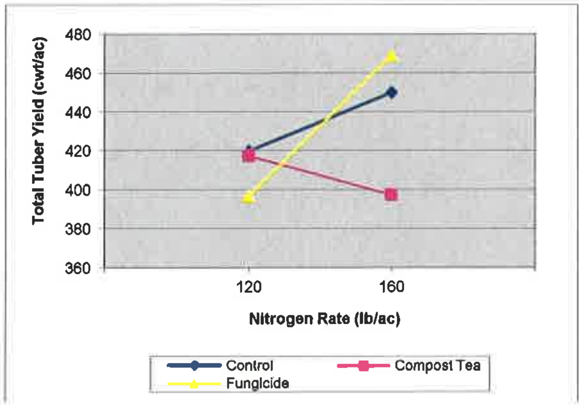

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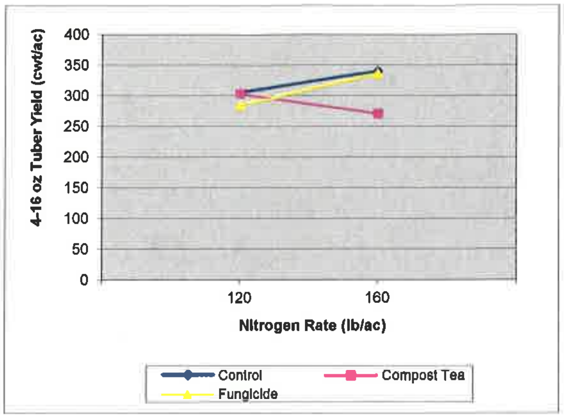

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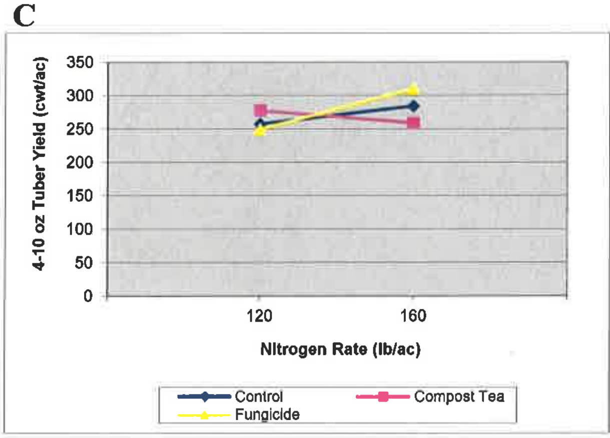

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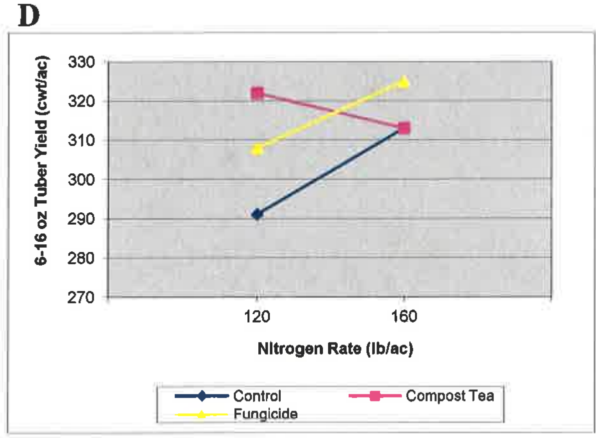

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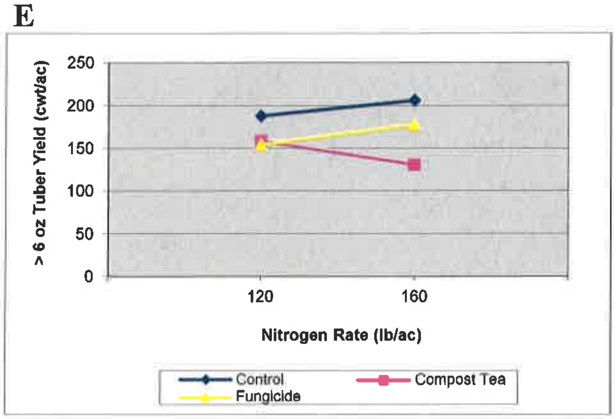

Figure 6 (2009). Interactive effect of compost tea, fungicide program and nitrogen management on total yield and tuber size distribution of Russet Nugget.

Table 7. Interactive effect of compost tea, fungicide program and nitrogen management on tuber external and internal defects, and specific gravity of Russet Nugget, 2008.

Treatment	% External Defects[2]	% Internal Defects[3]	Specific Gravity
120N[1]	0.7	0	1.097
160N	1.0	0	1.096
120N-CT	1.5	0	1.102
160N-CT	1.0	0	1.098
120N-F	2.0	0	1.103
160N-F	1.0	0	1.097

[1] N = nitrogen rate; CT = compost tea applied; F = fungicide applied
[2] Includes growth cracks, knobs and misshapes
[3] Includes hollow heart and brown center

Table 8. Interactive effect of compost tea, fungicide program and nitrogen management on tuber external and internal defects, and specific gravity of Russet Nugget, 2009.

Treatment	% External Defects[2]	% Internal Defects[3]	Specific Gravity
120N[1]	0.6	0.5	1.106
160N	1.1	0	1.103
120N-CT	0.9	0	1.106
160N-CT	1.0	0	1.102
120N-F	1.2	0	1.107
160N-F	0.2	0	1.103

[1] N = nitrogen rate; CT = compost tea applied; F = fungicide applied
[2] Includes growth cracks, knobs and misshapes
[3] Includes hollow heart and brown center

SUMMARY AND CONCLUSION

The main purpose of this study was to evaluate the interactive effect of compost tea, fungicide program, and nitrogen rate on early blight incidence, and on tuber performance of Russet Norkotah and Russet Nugget, and to determine whether compost tea could be used as an alternative to fungicide application in potato production. Data from this study indicate that compost tea, when applied at an optimum N rate of 160 lb N/ac can be used as an alternative to fungicide application to reduce early blight incidence on potato leaves, and to produce maximum potato tuber yields.

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MacKenzie, D.R. 1981. Association of potato early blight, nitrogen fertilizer rate, and potato yield. Plant Dis 65:575-577.

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Part III. Evaluation of Compost and Compost Tea on the management and control of powdery scab of potato under San Luis Valley conditions.

Dr. Robert D. Davidson (Professor) and Andrew J. Houser (Research Associate), Colorado State University

Methods and Materials

Cultivar utilized in trials: DT6063-1R (Cherry Red), highly susceptible to powdery scab damage

Trials utilizing compost in the soil and compost tea during the season were conducted in 2008 and 2009 in the San Luis Valley (SLV) on a cooperating grower's farm; site selected for high powdery scab infestation. These trials compared the use of compost type materials against an untreated control and the chemistry (Omega™) known to have efficacy against powdery scab under typical SLV environmental conditions.

Results (as shown in Tables 1 & 2 in 2008 and Table 3 in 2009) indicated that use of compost or compost tea and their combination did not control powdery scab on the tubers as compared with the untreated control. In 2008, while there were no significant differences between treatments, there was a trend to showing a higher incidence of powdery scab on the control or the compost treatment when compared with the Omega treatments. This also held true in terms of total yields and marketable yields. In 2009, when compost, compost tea and the combinations were compared with Omega and Omega plus compost, there were significant differences evident in terms of percent incidence and the percent unmarketable. Omega alone or in combination with compost showed a significant reduction in disease when looking at percent incidence and percent unmarketable/severity index as compared to the untreated control or compost plus compost tea. While there is an indication that compost coupled with Omega may bring even more benefits than Omega by itself, the reductions in disease were not significant.

It appears that through two years of trials, the use of compost and compost tea or combinations of the two as a management or control for powdery scab is not effective. Additional research will be completed in the greenhouse to continue to compare different combinations of Omega and compost type products to control powdery scab of potato

Table 1. Evaluation of compost on the incidence of powdery scab on tubers of susceptible cultivar, San Luis Valley, Colorado, 2008.

	Tuber symptoms			
Treatment	Percent Incidence[a]	Percent Healthy[b]	Severity Index[c]	Unn
1. Untreated Control	81.7	18.4	209.4	
2. Omega @ 1.5 pt./A (one nozzle dir. over seed), At Planting	70.2	29.8	140.2	
3. Omega @ 3.0 pt./A (one nozzle dir. over seed), At Planting	69.4	30.6	134.9	
4.Compost @ 4.0 tons/A (Applied in-furrow prior to planting)	72.7	27.3	168.2	
CV	10.83	30.0	30.63	
F value	0.18	0.18	0.24	
LSD(P=0.05)	NS	NS	NS	

[a] Percent incidence = mean percent of the total number of tubers with one or more powdery scab lesion at harvest. Mean of four replications.

[b] Percent healthy = mean percent of the total number of tubers with zero powdery scab lesions at harvest. Mean of four replications.

[c] Severity Index = mean percent of the number of infected tubers/treatment/replication multiplied by the avg. severity of the lesions, where 1 = very little or no disease and 5 = heavily infested.

[d] Percent Unmarketable = mean percent of the total number of tubers with a lesion severity rating of three or higher at harvest. Mean of four replications.

[e] Severity Index (Unmarketable) = mean percent of the number of unmarketable tubers due to powdery scab lesion severity/treatment/replication multiplied by the average severity of the lesions, where 1 = very little or no disease and 5 = heavily infested.

Means followed by the same letter are not significantly different at P=0.05.

Table 2. Evaluation of fungicide programs vs. compost on tuber yield and quality of susceptible cultivar, San Luis Valley, Colorado, 2008.

	Percent[a]				
Treatment	< 4 oz.	4-10 oz.	> 10 oz.	culls	C

1. Untreated Control	26.5	42.6	25.7	5.3	4
2. Omega @ 1.5 pt./A (one nozzle dir. over seed), At Planting	19.0	40.1	34.1	6.7	4
3. Omega @ 3.0 pt./A (one nozzle dir. over seed), At Planting	19.2	48.4	24.2	8.2	4
4.Compost @ 4.0 tons/A (Applied in-furrow prior to planting)	26.0	47.5	18.7	7.8	4
CV	21.05	16.17	26.45	51.96	[illegible]
F value	0.09	0.36	0.06	0.69	[illegible]
LSD(P=0.05)	NS	NS	NS	NS	

[a] Based on tuber weight in kilograms, mean of four replications.
[b] Total yield expressed as hundred weight per acre, 2-20 foot rows per treatment per replication, mean of four replications.
[c] Total yield expressed as hundred weight per acre (All unmarketable tubers due to high powdery scab severity have been removed from the total yield), 2-20 foot rows per treatment per replication, mean of four replications.

Means followed by the same letter are not significantly different at P=0.05.

Robert D. Davidson (Professor) and Andrew J. Houser (Research Associate), Colorado State University

Table 3. Evaluation of compost on the incidence of powdery scab on tubers of susceptible cultivar, San Luis Valley, Colorado, 2009.

	Tuber symptoms			
Treatment	Percent Incidence[a]	Percent Healthy[b]	Severity Index[c]	Unn
1. Untreated Control	98.7 a	1.3 c	342.22	[illegible]
2. Omega @ 1.5 pt./A (one nozzle dir. over seed), At Planting	92.02 bc	7.97 ab	307.64	[illegible]
3. Omega @ 1.5 pt./A (one nozzle dir. over seed), At Planting Compost @ 4.0 tons/A (Applied in-furrow prior to planting)	89.17 c	10.82 a	274.57	[illegible]
4.Compost @ 4.0 tons/A (Applied in-furrow prior to planting)	93.92 abc	6.07 abc	335.57	[illegible]
5[f].Compost Tea @ 8.0 gal./A (Applied in-season)	97.38 ab	2.63 bc	324.92	[illegible]

6[f].Compost @ 4.0 tons/A (Applied in-furrow prior to planting) Compost Tea @ 8.0 gal./A (Applied in-season)	93.35abc	6.63 abc	363.78
CV	4.85	77.16	-
F value	0.10	0.10	-
LSD(P=0.10)	5.71	5.71	NS

[a] Percent incidence = mean percent of 40 tubers (gathered uniformly throughout each plot) with one or more powdery scab lesion at harvest. Mean of four replications.
[b] Percent healthy = mean percent of the 40 tubers (gathered uniformly throughout each plot) with zero powdery scab lesions at harvest. Mean of four replications.
[c] Severity Index = mean percent of the percent incidence/treatment/replication multiplied by the avg. severity of the lesions, where 1 = very little or no disease and 5 = heavily infested.
[d] Percent Unmarketable = mean percent of the total number of evaluated tubers with a lesion severity rating of three or higher at harvest. Mean of four replications.
[e] Severity Index (Unmarketable) = mean percent of the number of unmarketable tubers due to powdery scab lesion severity/treatment/replication multiplied by the average severity of the lesions, where 1 = very little or no disease and 5 = heavily infested.
[f] Compost tea was applied using an R&D CO_2 charged backpack sprayer at 35psi, with two XR 8002 VS nozzles, at 20 gallons of water/acre. It was applied five times throughout the season, starting 49 DAP (July 1, July 14, July 29, August 4, and August 21).

Means followed by the same letter are not significantly different at P=0.05.

Robert D. Davidson (Professor) and Andrew J. Houser (Research Associate), Colorado State University

Part IV. **Comparing Potato Cropping Systems Effects on Soil and Water Resources + Economics.**

Dr. Richard Sparks, NRCS, Irrigation Specialist/Agronomist, Monte Vista Field Office.

Western US research[1] on 108 paired fields revealed these conclusions: "while short rotations (potatoes grown at least 6 times in 12 years) may seem profitable, they result in significant increases in pesticide applications and reductions in potato yields"!

1. **Higher pesticide, fertilizer, and tillage costs (short rotations)**
   - 1.5 more fungicide applications
   - Over 70% fields required fumigation

2. **Reduced tuber quality and yield (short rotations)**
   - 19 days earlier onset of plant senescence
   - 5 days earlier complete senescence

3. **With longer rotations, (potatoes grown no more than 3 times in 12 years)**
   - Tuber yield increased by 10.0% and average tuber weight by 11.1%.
   - Potato yields increased 11.9% and 20.0% for U.S. No. 1 and total yield.
   - Only 25% of fields required fumigation.

[1] ***Brigham Young Univ., Provo, UT, Univ. of Idaho, Aberdeen, ID, Oregon State Univ., Hermiston, OR***

Comparison of SLV Potential Rotations

PB = Potato / Barley THE STANDARD 2 Year Rotation

Soil Quality:
Pathogens continue to increase; fungicide costs are high.
Wind erosion remains high: **19.3 T/ac/yr.**
Organic matter is low but stable; microbial diversity is relatively low.
Nitrogen inputs remain high: **high nitrate leaching risk.**
Irrigation Water Requirements (IWR):
Consumptive water use is relatively high at **16.6 in/yr avg.**

Economics:
Marketable potato yields slowly decline: **380 cwt/ac.**
Return above variable cost is good during average price years but worse than three year rotation in low price years. The risk for reduced yield increases from any water stress, pink rot, nematodes, and other pathogens.

PS = Potato / Sordan (or Mustard) 2 year Rotation

Soil Quality:
Root knot nematode reduced with Sordan 79.
Stubby root nematode and TRV reduced with mustard or radish.
Erosion excessively high: **23.4 T/ac/yr. Compliance with USDA programs in jeopardy on I = 134 loamy sand soils when planting sordan or mustards without winter rye cover.**
Organic matter lower: microbial diversity is improved.
Nitrogen inputs reduced: **moderate nitrate leaching risk.**

Irrigation Water Requirements (IWR):
Consumptive water use is much lower at **11.9 in/yr avg.**

Economics:
Marketable potato yields improve to **410 cwt/ac.**
Return above variable cost is good during average price years and lower in low price potato years.

PrS = Potato (rye cover) / Sordan (or Mustard) 2 year Rotation

Soil Quality:
Root knot nematode reduced with winter rye and sordan 79.
Stubby root nematode and TRV is reduced w/ mustard or radish.
Erosion is significantly decreased with rye cover & sordan to **7.7 T/Ac/Yr**; erosion is a little higher with a mustard green manure.
Organic matter improves with less erosion; microbial diversity is further improved with winter rye, sordan or mustard incorporation.
Nitrogen inputs are reduced; **low nitrate leaching risk.**

Irrigation Water Requirements (IWR):
Consumptive water use is still lower at **13.7 inches/yr** if rye and sordan are deficit irrigated; slightly higher when mustards or sordan is fully irrigated.

Economics:
Marketable yields improve to **410 cwt/ac.**
Return above variable cost is high during high price potato years and lower than all rotations during low price potato years due to lack of barley and rye seeding costs.

PBS = Potato / Barley / Sordan (or Mustard) 3 year Rotation

Soil Quality:
Root knot nematode reduced with Sordan 79.
Stubby root nematode and TRV decreased w/ mustard green manure.
Pink rot risk is significantly reduced due to less inoculum with less frequent potato crops.
Erosion is decreased to **10.7 T/Ac/Yr**; a little higher for mustard green manure.

Organic matter improves with no chopping, less tillage, and less erosion; microbial diversity is further improved by leaving barley residue left un-chopped, untilled or chiseled on the surface overwinter, and with sordan or mustard green manure incorporation.

Nitrogen inputs are slightly reduced; **moderate nitrate leaching risk.**

Irrigation Requirement:
Irrigation requirement decreased to **13.4 inches/ac/yr** for deficit irrigated sordan.

Economics:
Marketable yields further improve to **420 cwt/ac.**
No seeding or pumping costs incurred for winter rye cover. Fungicide costs significantly reduced.
Return above variable cost is good during average price years and losses are avoided in low price potato years.

PBSPBA(2) = Potato Barley Sordan Potato Barley Alf (2) 7 year Rotation

Soil Quality:
Nematodes decreased significantly.
Powdery scab and Pink rot risk is significantly reduced due to less inoculum with less frequent potato crops.

Erosion reduced to **11.1 T/Ac/Yr**.
Organic matter increased significantly.
Nitrogen inputs significantly reduced; nitrate leaching is at a minimum.

Irrigation Requirement:
Irrigation requirements increased to **17.1 inches/ac/yr.** due to high water requirement for short term alfalfa. Irrigation requirement is significantly less; however, than longer alfalfa stands.

Economics:
Marketable yields can be increased to **450 cwt/ac.**
Lower costs for nitrogen; fungicide costs are reduced.
Return above variable cost is good during average price years and losses are avoided in low price years.

Average irrigation requirements for crop rotations calculated with Blainey Criddle method. Erosion estimates calculated for mulch tillage residue management systems and loamy sand soils with a tolerable level of 5 T/ac/yr. Gravelly sandy loams will average 54 percent of these estimates, but generally have a lower tolerable level of 3 T/ac/yr.

Summary Data Comparing Crop Rotations

The table below summarizes the soil erosion, water use, and potato yield estimates shown above. Soil erosion is most for the Potato/Sordan rotation at 23.4 tons/acre; soil erosion is lowest for the Potato/Sordan rotation with rye cover crop after potatoes.

Water use is highest for the PBSPA (2) rotation because it has two years of alfalfa. The lowest water use is for the Potato/Sordan rotation, but this rotation has the highest soil erosion.

The lowest potato yield among these rotations is for the STANDARD Potato/Barley rotation (380 cwt/acre). The Potato/Barley/Sordan 3 year rotation increases yield to 420 cwt/acre. The PBSPA(2) rotation has only 2 potato crops in 7 years but has the highest yield estimate at 450 cwt/acre.

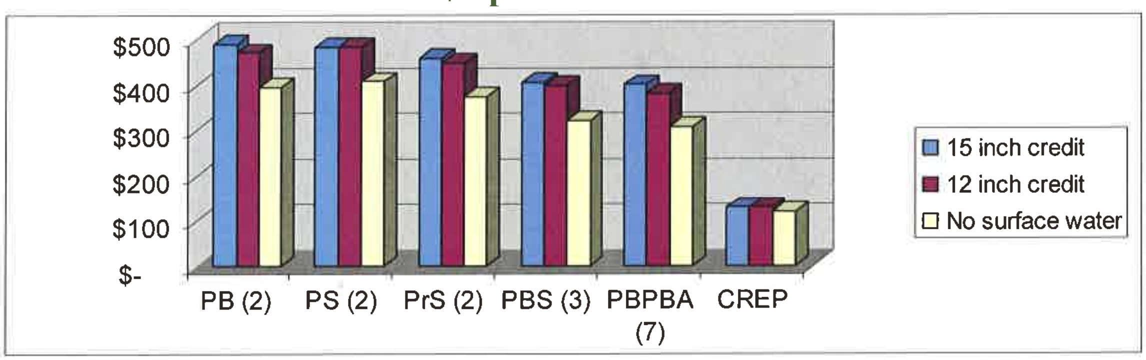
Summary Table

Rotations	Soil Erosion Tons/Ac Avg.	Avg. Irr. Req Inches / Ac	Potato Yield Avg CWT/Ac	Av. Net at $5 per cwt
Potato/Barley	19.3	16.6	380	118
Potato Sordan	23.4	11.9	410	70
Potato rye/Sordan	7.7	13.7	410	47
PBS	10.7	13.4	420	118
PBSPA(2)	11.1	13.4	450	155
CREP	2	1.2	0	129

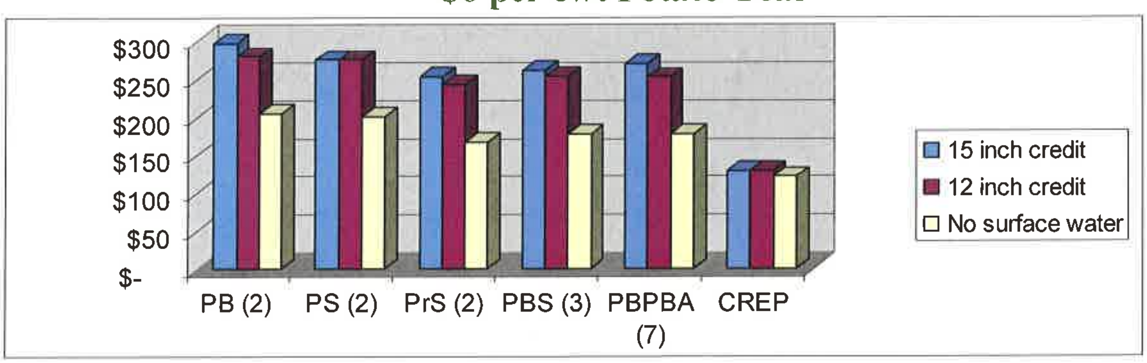
A potato barley sordan rotation would have the same net income when potatoes are at $5/ Cwt. CREP or equivalent retirement would be more economical. There would be additional fixed costs that could be as high as $265 for land payments, taxes, etc.

Comparison of Potato Rotations (Net Income per Ac) Including $75 per AC FT Cost Above Credited Water

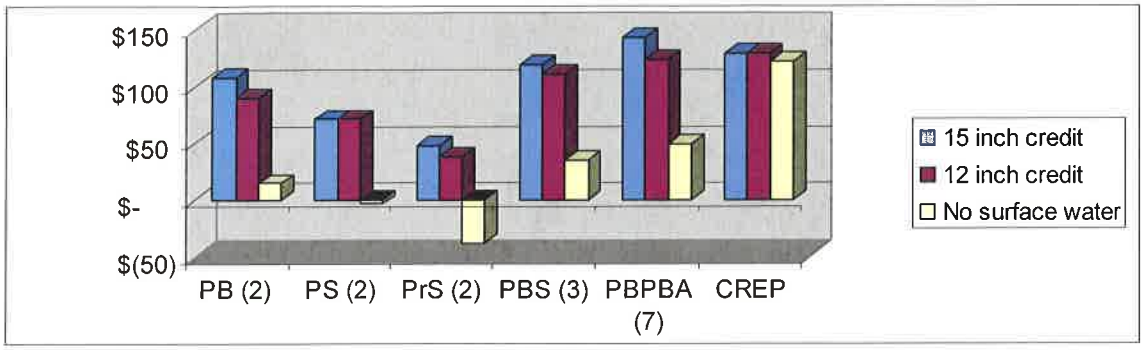
$7 per cwt Potato Year



$6 per cwt Potato Year

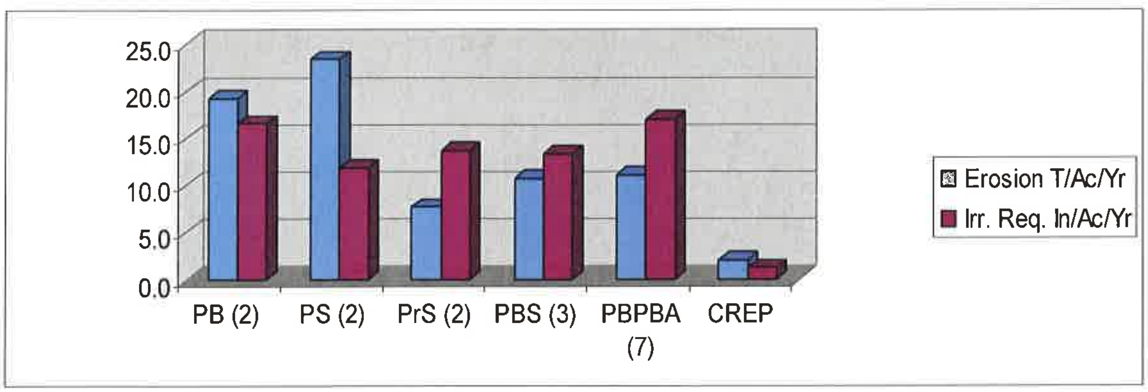


$5 per cwt Potato Year



Based on projected yields, fungicide costs, water requirements, 150 Bu / ac barley at $4.00 per bushel, $130 / ton alfalfa; Fixed costs for land and taxes (estimated $265) not accounted.

Wind Erosion and Irrigation Requirement Comparison of Rotations



Residue Management to Improve Organic Matter and Reduce Erosion

1 Chopped Barley Stubble prior to fall tillage.
Decomposition of chopped straw is significantly faster.
Chopping straw would be unnecessary if going to sordan.

Increasing the length and diversity of a rotation provides more opportunities to reduce tillage and increase residues or cover on the soil surface, that shorter rotations may not feasibly permit.

All crop residues can be left on the field to improve organic matter. Waste grain can be left on the surface over winter for waterfowl use.

Barley residue will not need to be chopped in the fall or fully incorporated to hasten decomposition, because of additional time in the spring before planting sordan.

2 Unchopped residue disced this past fall.
Three year rotation eliminates need to chop.

Leaving residue un-chopped significantly decreases wind erosion the following spring.

Additional time and soil temperature in the spring prior to planting sordan is adequate for decomposition.

3 Barley Residue Mulch Tilled. This offers good erosion protection the following spring prior to potatoes. Decomposition of fall incorporated residue is hastened by timely chopping and tilling.

4 Green manured sordan offers erosion protection
Chopping may not be essential, but if practiced does not result in fragile residue. Excessive incorporation should be avoided to minimize erosion.

Will potato farmers adopt a new "Green Practice', such as going to a three year potato barley sordan rotation to reduce consumptive use, reduce pathogens in your potato crops, and reduce wind erosion while sequestering carbon into organic matter in their soil?

4. Conservation tillage or mulch tillage systems of residue management are now used by over 80 % of San Luis Valley farmers. Additional growers state they will adopt within the next few years.
5. Sordan and mustard or oilseed radish green manure crops are now used by over 20% of potato farmers; a very recent change due to interest in soil quality and microbial diversity.

6. Oilseed radish cover crops were originally moldboard plowed as part of green manuring. This practice has been reduced. Mulch tillage methods of green manure incorporation are proving to be better in hastening decomposition and microbial biomass buildup.

Part V. Grower Management Practices Survey

A survey of San Luis Valley potato growers was sent out in the summer of 2009. This survey determines growers' practices regarding compost tea vs. foliar fungicides, management of green manure crops, and attitudes and reasons they grow green manure crops. The survey questions and results are attached. It is included in its entirety.

COLLEGE OF AGRICULTURAL SCIENCES
2012 TEAM RESEARCH AWARD

The College of Agricultural Sciences Team Research Award is presented to a team composed of two or more investigators, one of whom must be employed by Colorado State University as a faculty member. The Team Research Award is granted to a group who has conducted research that:

- Demonstrates a record of collaborative, interdisciplinary research and scholarly activities that has contributed to the advancement of science and achieved a positive impact on end users
- Is recognized nationally and/or internationally

ELIGIBILITY:
All College of Agricultural Sciences faculty and Administrative Professionals involved in team research are eligible for nomination.

RECOGNITION:
The College of Agricultural Sciences Team Research Award will be presented at the College of Agriculture Sciences recognition reception held in the spring semester. The recipient team will receive a plaque.

NOMINATION PROCEDURES:
Nominations must include:

- A letter of support from the appropriate Department Head or supervisor
- Two letters of support that address the contribution of the research team
- A self-evaluation from the team of the significant contributions and impact of the research
- Vitae/resume from each member not to exceed 2 total pages each

A research team may not receive the award more than once in 5 years.
All nomination materials should be submitted as a single pdf to Ryan.Abbott@colostate.edu **in the Office of the Dean, by 4 p.m. Monday, April 2, 2012**