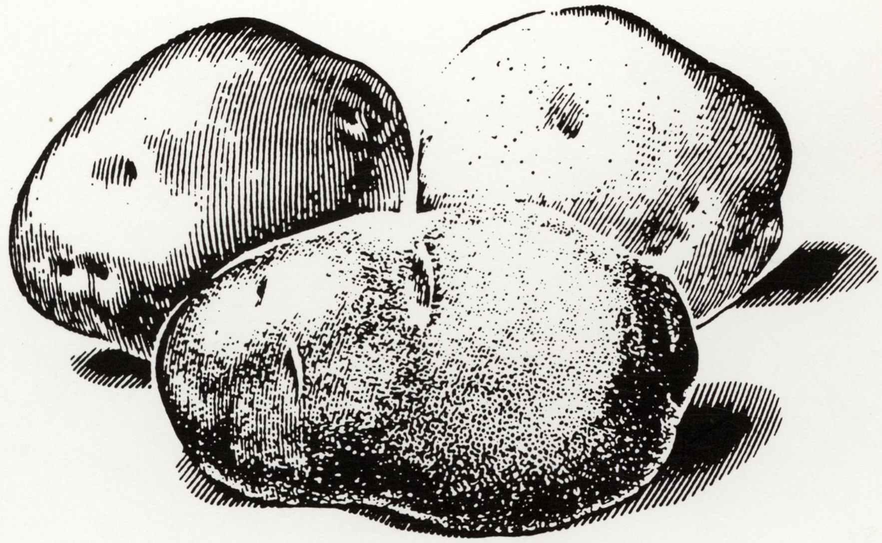
1994
MICHIGAN POTATO RESEARCH REPORT

VOLUME 26



Michigan State University
Agricultural Experiment Station

In Cooperation With

The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION

February 15, 1995

To All Michigan Potato Growers & Shippers:

The Michigan Potato Industry Commission, Michigan State University's Agricultural Experiment Station, and Cooperative Extension Service are pleased to provide you with a copy of the results from the 1994 potato research projects.

This report includes research projects funded by the Michigan Potato Industry Commission as well as projects funded through the USDA Special Grant and other sources.

Providing research funding and direction to principal investigators at MSU is a function of the Michigan Potato Industry Commission's Research Committee.

Best wishes for a prosperous 1995 season,

The Michigan Potato Industry Commission

THE MICHIGAN POTATO INDUSTRY COMMISSION • 13109 SCHAVEY RD., STE. 7 • DEWITT, MI 48820 • (517) 669-8377

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1994 MSU POTATO RESEARCH REPORT

R.W. Chase, Coordinator

Introduction and Acknowledgements

The 1994 Potato Research Report contains reports of potato research projects conducted by MSU potato researchers at several different locations. The 1994 report is the 26th report which has been prepared annually since 1969. This volume includes research projects funded by the Special Federal Grant 88-34141-3372, the Michigan Potato Industry Commission and numerous other sources. The principal source of funding for each project has been noted at the beginning of each report.

We wish to acknowledge the excellent cooperation of the Michigan potato industry and the MPIC for their continued support of the MSU potato research program. We also want to acknowledge the significant impact that the funds from the Special Federal Grant have had on the scope and magnitude of several research areas.

Many other contributions to MSU potato research have been made in the form of fertilizers, pesticides, seed, supplies and monetary grants. We also acknowledge the tremendous cooperation of individual producers who cooperate with the numerous on-farm projects. It is this dedicated support and cooperation that makes for a productive research program for the betterment of the Michigan potato industry.

We further acknowledge the professionalism of the MPIC Research Committee. The Michigan potato industry should be proud of the dedication of this Committee and the keen interest they take in determining the needs and direction of Michigan's potato research.

Thanks go to Dick Crawford, for the day-to-day operations at the Research Farm; Jeff Smeenk, CSS Potato Technician and Dr. Kazimierz Jastrzebski, visiting scientist from Poland. Also, a special thanks to Jodie Schonfelder for the typing and preparation of this report and to MSUE Don Smucker, Montcalm CED for maintaining the weather records.

Weather

Maximum temperatures averaged slightly cooler in May, July and August when compared with the 15 year average and slightly higher in April, June and September (Table 1). There were four days in June and one in July when the temperature exceeded 90°. August was generally a cool and very wet month with only eight days above 80°.

1994 rainfall was 5.95 inches higher than the 15 year average (Table 2). August rainfall at 8.05 inches was nearly 4 inches more than the 15 year average. Conditions were generally dry until rains of 4.87 inches fell during June 23-25 followed by several rainy spells in July and August. Rainfall in June, July and August all exceeded significantly the 15 year average. September was exceptionally dry and provided excellent conditions for harvest, however, the dryer soil increased bruise susceptibility to blackspot.

Table 1. The 15 year summary of average maximum and minimum temperatures during the growing season at the Montcalm Research Farm.

	April		May		June		July		August		September		6-Month Average	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1980	49	31	69	42	73	50	81	58	81	58	70	49	71	48
1981	56	35	64	39	73	50	77	51	78	53	67	47	69	46
1982	53	28	72	46	70	44	80	53	76	48	66	44	70	44
1983	47	28	60	38	76	49	85	57	82	57	70	46	70	46
1984	54	34	60	39	77	54	78	53	83	55	69	45	70	47
1985	58	38	70	44	71	46	81	55	75	54	70	50	71	48
1986	60	36	70	46	77	50	82	59	77	51	72	50	73	49
1987	61	36	77	46	80	56	86	63	77	58	72	52	76	52
1988	52	31	74	46	82	53	88	60	84	61	71	49	75	50
1989	56	32	72	34	81	53	83	59	79	55	71	44	74	46
1990	NA	NA	64	43	77	55	79	58	78	57	72	47	NA	NA
1991	60	40	71	47	82	59	81	60	80	57	69	47	74	52
1992	51	34	70	42	76	50	76	54	75	51	69	46	69	46
1993	54	33	68	45	74	55	81	61	79	60	64	46	70	50
1994	57	34	66	43	78	55	79	60	75	55	73	51	71	49
15-YR. AVG.	55	33	68	43	76	52	81	57	79	55	70	47	72	48

Table 2. The 15 year summary of precipitation (inches per month) recorded during the growing season at the Montcalm Research Farm.

Year	April	May	June	July	August	September	Total
1980	3.53	1.65	4.37	2.64	3.21	6.59	21.99
1981	4.19	3.52	3.44	1.23	3.48	3.82	19.68
1982	1.43	3.53	5.69	5.53	1.96	3.24	21.38
1983	3.47	4.46	1.19	2.44	2.21	5.34	19.11
1984	2.78	5.14	2.93	3.76	1.97	3.90	20.48
1985	3.63	1.94	2.78	2.58	4.72	3.30	18.95
1986	2.24	4.22	3.20	2.36	2.10	18.60	32.72
1987	1.82	1.94	0.84	1.85	9.78	3.32	19.55
1988	1.82	0.52	0.56	2.44	3.44	5.36	14.14
1989	2.43	2.68	4.85	0.82	5.52	1.33	17.62
1990	1.87	4.65	3.53	3.76	4.06	3.64	21.51
1991	4.76	3.68	4.03	5.73	1.75	1.50	21.45
1992	3.07	0.47	1.18	3.51	3.20	3.90	15.33
1993	3.47	3.27	4.32	2.58	6.40	3.56	23.60
1994	3.84	2.63	6.04	5.16	8.05	1.18	26.90
15-YR. AVG.	2.96	2.95	3.26	3.09	4.12	4.57	20.95

Growing Degree Days

For potatoes, we are using a base temperature of 50°F. Its greatest value is following emergence. To compute the growing degree days for a particular day, one must determine the daily mean temperature by averaging the maximum and minimum temperature for the day and to be most meaningful, the most local weather data is of greatest value. From this calculated daily mean, 50 is subtracted and the remaining value is labelled the degree days for that date. If the value is equal to 50 or below, the value for that day is zero. These values are accumulated day by day and for the purpose of this report, the starting date is May 1 and ends September 30.

Table 3 summarizes the cumulative base 50° growing degree days for May through September. Total base 50° Growing Degree Days (GDD) were very similar to 1993, but much higher than 1992 and much lower than 1991. By the end of August, GDD were 160 days behind 1993 reflecting a cooler season than 1993 and conditions very favorable for late blight.

Table 3. Growing Degree Days* - Base 50°.

	Cumulative Monthly Totals				
	May	June	July	August	September
1991	452	1014	1632	2185	2491
1992	282	718	1210	1633	1956
1993	261	698	1348	1950	2153
1994	231	730	1318	1780	2148

*1991 and 1992 data calculated from Vestaburg weather station in Montcalm County (Dr. Jeff Andresen, Geography). 1993 and 1994 data from the weather station at MSU Montcalm Research Farm (Don Smucker, Montcalm County Extension Director).

Previous Crops and Fertilizers

The general plot area was planted to drilled soybeans in 1993 which were disked in late summer and seeded to winter rye at 1½ bushels/A. Except in fertilizer trials, where the amounts of fertilizers applied are specified in the individual project reports, the following fertilizers were used in the potato trials:

	Analysis	Rate	Nutrients
plowdown	0-0-60	200 lbs/A	0-0-120
planter	20-10-10	210 lbs/A	42-21-21
sidedress at hilling	46-0-0	150 lbs/A	69-0-0
irrigation	28-0-0	15 gal/A	42-0-0
irrigation	28-0-0	15 gal/A	42-0-0

Soil Tests

Soil tests for the general plot area were:

	lbs/A				Cation Exchange Capacity
pH	P_2O_5	K_2O	Ca	Mg	
6.0	452	222	838	151	2.7 me/100 g

Herbicides

Hilling was done in late May, just prior to potato emergence, followed by a tank mix of metolachlor (Dual) at 2 lbs/A plus metribuzin (Lexone) at ½ lb/A.

Irrigation

Irrigation was initiated on June 10 and seven applications were made at 0.75 inches per application. The last application was on August 3 which was followed by rains of 2.72 inches on August 3 and 4. There were frequent periods of surplus soil moisture.

Insect and Disease Control

Thimet was applied at planting at 11.3 ounces/1000 ft. of row. Foliar applications of M-Trak were initiated on June 15. Other insecticides used during the season were M-one, Asana, Cygon, Monitor and Agri-Mek. Fungicide applications were initiated on June 30 with Pencozeb. Bravo, Kocide LF or Champ were also used in the 10 fungicide applications. Late blight severity values were high and required a five day spray interval during August.

Funding Fed. Grant/MPIC

1994 POTATO VARIETY EVALUATIONS

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The objectives of the evaluation and the management studies are to identify superior varieties for fresh market or for processing and to develop recommendations for the growers of those varieties. The varieties were compared in groups according to the tuber type and skin color and to the advancement in selection. Total and marketable yields, specific gravity, tuber appearance, incidence of external and internal defects, chip color (from 45 and 50 F storage), consistency and after cooking darkening as well as susceptibilities to common scab, Fusarium dry rot, Erwinia soft rot and blackspot bruising were determined.

The field experiments were conducted at the Montcalm Research Farm in Entrican. They were planted in randomized complete block design, in four replications. The plots were 23 feet long and spacing between plants was 12 inches. Inter-row spacing was 34 inches. A total of 160 different varieties and advanced selections were tested from MSU and other North American and European breeding programs.

Both round and long variety groups were harvested at two dates. The yield was graded into four size classes, incidence of external and internal defects was recorded, and samples for specific gravity, chipping, bruising and cooking tests were taken. Chip quality was assessed on 25-tuber samples, taking two slices from each tuber. Chips were fried at 365°F. The color was measured with an M-35 Agtron colorimeter and visually with the SFA 1-5 color chart. Prior to chipping, the tubers were stored at 45 or 50°F.

Results

A. Round White Varieties

Ten varieties and 15 breeding lines were compared at two harvest dates. Atlantic, Snowden, Onaway, and Superior were used as checks. The average yield was high and specific gravity was slightly above the normal level. Hollow heart was prevalent in the late harvest and blackspot bruise was severe. The results are presented in Tables 1 and 2.

Variety Characteristics

Onaway - medium-early fresh market variety with excellent yield potential and a low specific gravity. Tubers are round to oblong, large, deep eyes, susceptible to growth cracks and early blight. It has very good internal quality, but the storability is poor because of susceptibility to tuber early blight. 1994 was not good year for tuber appearance.

Atlantic - medium-late, chipping variety of high specific gravity and good yield potential. Susceptible to scab, soft rot, white knot, and to internal defects (hollow heart, vascular discoloration, internal brown spot). The variety exhibited considerable hollow heart in the oversize tubers, otherwise the variety performed well in 1994.

Snowden - late maturing variety of excellent chipping quality. Specific gravity high. Tubers are round, small to medium size, well shaped with excellent internal quality. It is not resistant to scab, but has some resistance to *Fusarium* dry rot. Variety maturity in 1994 was earlier than other years.

Superior - medium-early, fresh market variety. Tubers are well-shaped, medium size with a medium specific gravity. Resistant to scab but very susceptible to *Verticillium* wilt. In 1994, 33% hollow heart was observed in the oversize tubers.

Chaleur - medium early fresh market variety from Canada. Yield and specific gravity were low during 3 years of testing in Michigan. Tubers were large, few per hill, and of good appearance with a very good flesh color. Internal defects are low. It has moderate resistance to scab.

Portage - early to medium early fresh market variety. Showed good yield potential and tuber appearance was good, specific gravity low, and very susceptible to scab. In 1993, the incidence of hollow heart was high, while in 1994 hollow heart and vascular discoloration incidence were above average.

Prestile - very late, fresh market variety from Maine. It has shown excellent yield potential and good tuber shape. Specific gravity is medium. Internal defects have been low in Michigan and it is resistant to scab.

AF1060-2 - late, fresh market variety of high yield potential and excellent internal quality, but low specific gravity. It is susceptible to scab. Maine may name this one soon.

St. Johns - tested in 1993 as AF828-5, medium late fresh-market variety of high yield potential (but consistently lower than AF1060-2), but low specific gravity. There was some variation in shape, but general appearance was good with large tubers and excellent internal quality. It is susceptible to scab infection.

AF875-15 - tested two years in this trial. Medium early, chip variety of high yield potential. Maturity was probably enhanced by heavy early blight infection. Medium-sized tubers, somewhat irregular in shape and deep apical eyes. Susceptible to scab infection. A tendency towards hollow heart and vascular discoloration was observed in 1994.

NY84 - tested two years in this trial. Medium late variety of high yield potential, but very low specific gravity. Good internal quality. It shows moderate resistance to scab infection.

NY95 - tested two years in this trial. Medium late, high yielding variety of excellent chipping quality, high specific gravity and very good internal quality. It also has moderate scab resistance. This line may be dropped by New York.

FL1533 - was tested in the adaptation trial in 1993. It is a high yielding chipping selection with very good internal quality but a specific gravity that is below 1.080. It is susceptible to scab and late blight.

FL1833 - was tested for the first time in 1994. This variety had high yield potential, high specific gravity, very good internal quality but susceptible to scab.

MSB076-2 - this MSU selection was tested in the adaptation trial in 1993. It is high yielding, has very high specific gravity, acceptable chip quality and resistant to scab. In 1994 we observed a tendency for hollow heart in oversize tubers.

AC Ptarmigin - this protected variety from Ag Canada is a high yielding clone with excellent internal quality, low specific gravity with oval-shaped tubers. It has moderate resistance to scab.

MS700-70 - a high yielding chipping selection from MSU that was previously tested in the 1980's. This selection has high yield potential, high specific gravity and good internal quality.

ND2417-6 - a cold-chipping slection with above average yield potential, but moderate specific gravity. It is also susceptible to scab.

ND2471-8 - a cold-chipping selection with below average yield potential, high specific gravity and small tuber size. Hollow heart was noted in the A-size tubers in the North Central trial. It is susceptible to scab.

AC Novachip - a protected variety from Ag Canada with above average yield potential, high specific gravity but a tendency towards hollow heart. It is scab susceptible.

MN15111 - a chipping selection with average yield, moderately high specific gravity and a small percentage of oversize tubers. It is moderately susceptible to scab.

NY102 - this selection has been in the SFA trials but tested for the first time at MRF. It had average yield, few oversize tubers and a moderately high specific gravity. It is moderately susceptible to scab.

MSB007-1 - a MSU selection which is oblong in shape with a bright skin. This selection would fit a tablestock market because of its good cooking quality and resistance to hollow heart. Its weakness is susceptibility to scab.

B. Long Varieties

Seven varieties and eight breeding lines were tested in two dates of harvest. The trial was noted for its greater than average percentage of tubers under 4 ounce size. Other than Goldrush and Russet Norkotah, the lines were late or very late. Both Russet Burbank and Russet Norkotah performed poorly. Many western breeding program selections were tested. The lines with the best overall potential included Century Russet, AO82611-7 and A7961-1. The results are summarized in Tables 3 and 4.

Variety Characteristics

Russet Burbank - used as a standard in the trial. Late maturity, average yields. Specific gravity good for processing and baking. Has a tendency to form off-shape and undersize tubers and is resistant to scab. In 1994 its yield was below average.

Russet Norkotah - early to mid-season variety. Yield potential and specific gravity are rather low. Tubers are oblong to long and well shaped with some resistant to scab. After cooking darkening was recorded in some years as well as susceptibility to *Verticilium* wilt. It performed poorly in 1994.

Ranger Russet (A7411-2) - late, processing variety. Yield potential average but specific gravity is high and internal quality is good. Susceptible to blackspot and scab.

Goldrush - medium early, fresh market variety. Yield potential is medium to high, specific gravity low, and internal quality good. Tubers are russet, oblong to long, and well shaped. After-cooking quality is better than Russet Norkotah. It is moderately resistant to scab and performed well in 1994.

A84180-8 - medium late, russet variety, tested two years in Michigan. It showed high yield potential. Tubers were long, well shaped, and uniform in size. Specific gravity was medium-low and a strong tendency to hollow heart was noted.

A81473-2 - tested for the first time, this late-maturing selection had the highest yield, moderate specific gravity but a tendency to form hollow heart. It is scab resistant.

Century Russet - a light russeted selection with high yield potential, moderately high specific gravity and excellent internal quality. It is moderately susceptible to scab.

A82119-3 - a russet selection with high yield potential, moderately high specific gravity but susceptibility to hollow heart and scab.

AO82611-7 - a russet selection with high yield potential but a lower percent US #1 yield, high specific gravity and good internal quality. It is moderately susceptible to scab.

Itasca - is a oval, white-skinned variety with above average yield, low specific gravity and excellent internal quality. It is moderately susceptible to scab.

A7961-1 - this Idaho russet has high yield potential but a lower percent US #1 tubers, high specific gravity and a tendency towards hollow heart in the oversize tubers. It performed well in the Mid-America fry tests. It is scab resistant.

COO83008-1 - this russet selection has average yield, moderately high specific gravity and a susceptibility to hollow heart. It also showed resistance to scab.

Crestone Russet - this russet selection had poor emergence, below average yields, low specific gravity and some resistance to scab.

A8495-1 - a russet selection with below average yield, high specific gravity and a tendency to hollow heart. It showed moderate resistance to scab and performed well in the Mid-America fry tests.

C. Adaptation

The Michigan adaptation trial serves as a screen for advanced breeding lines from various states. The best lines from this trial will enter the dates of harvest experiment the following year. Forty-four lines were tested in 1994. Atlantic, Snowden, and Superior were used as checks. The results are presented in Table 5.

The yields of many selections in the adapation trial were very high. Some selections with good performance are as follows. NY101, a light-yellow-fleshed selection, has high yield as also seen in 1993. Internal quality was excellent as was shape. It is also scab resistant. NDO1496-1, a cold-chipping selection, was high yielding, has high specific gravity and large, round, bright tubers but is highly susceptible to scab. B0257-12, from Beltsville, is a high yielding selection with a high specific gravity and excellent internal quality, but highly susceptible to scab. COO80011-5, is a russet selection with high yield potential, low specific gravity, very good internal quality and scab resistance. B9922-11, a Beltville russet selection, shows promise with above average yield, high specific gravity and resistance to scab. NDA2031-2, a cold-chipping selection, had high yield with a large set, but a small in size. It is susceptible to scab. MSU selections that merit further testing are summarized in tables 6 and 7.

D. North Central Regional Trial

The North Central Trial is conducted in a wide range of environments, in 14 states and provinces, to provide adaptability data for the release of new varieties. In 1994, 10 breeding lines and seven named varieties were tested of various tuber types. The results are presented in Table 8. The range of yields were wide. The best yielding selection was W1149 with a high specific gravity, but a high susceptibility to hollow heart and scab. P83-6-18, a long white selection, had high yield potential. The Purdue line P84-13-12, had excellent chip quality and scab resistance but a low yield and small tubers. The red variety Fontenot yielded well, while Red Ruby had a nice appearance, some scab resistance, but small tubers. As in the Long Trial, Russet Burbank and Russet Norkotah performed poorly.

E. European Trial

In 1994, with the support of the Newe Brunswick Potato Agency, 11 Euorpean varieties from the Netherlands and Scotland were evaluated in Michigan. Spunta, Desiree, Saginaw Gold, Michigold and Yukon Gold were added to the trial (Table 9).

Variety Characteristics

Morning Gold - High yields of U.S. No. 1 potatoes and vigorous early growth. Tuber shape blocky to oval and medium deep eyes. Medium yellow flesh color, tendency for stolons to remain attached and skin spotting noted.

Brodick - High yields of U.S. No. 1 potatoes with very good scab rating. Second year of severe susceptibility to hollow heart and internal brown spot. Vigorous early growth with strong vine. Stem has dark color. Tubers have red splashes, rounded in shape with some pointed shape. Lenticel spotting evident at harvest. Good chip color.

Sante - High yields of U.S. No. 1 potatoes and minimal internal defects. Vigorous and upright early growth. Tubers round with light yellow flesh.

Agria - Good yields but with pick outs of growth crack and long-pointed tubers. Medium yellow flesh color. Vine growth open and spreading.

Fianna - Good yields with high specific gravity and chip color. Minimal internal defects. Average early growth. Tubers oblong and flattened, slight lenticel spotting and some knobby tubers.

Penta - Good yields with medium specific gravity. Average early growth and smaller plants. Tubers round with some pointed shape. Red eye color, slight netting and medium yellow flesh color.

Morene - Medium yields of tubers generally pointed in shape. Scab tolerance good and late maturity.

Spunta - Average vigor of early growth. High incidence of pick outs with severe lenticel spotting. General appearance was rated low.

Estima - Average yields with medium specific gravity, poor chip color and susceptible to scab. Tubers oblong in shape with several pointed shapes and lenticels evident. Medium yellow flesh color.

Desiree - Plants have a dark stem color and average early growth. Tuber shape oblong, deep eyes, light yellow flesh and tendency for stolons to remain attached.

Dundrod - Below average yields and low specific gravity. Tubers oblong, white flesh and lenticels evident.

Avanti - Yields were below average with a high percentage of potatoes under 2 inches. Tubers were oblong-long with a smooth netted skin and a medium yellow flesh.

Saginaw Gold - Early growth was very vigorous. Tubers were irregular in shape with some black scurf, bright appearance and a light yellow flesh.

Michigold - Vigorous early growth. Tubers are round to blocky with a netted skin. Medium yellow flesh and air checks noted post harvest.

Yukon Gold - Plants erect and upright. Tubers bright, medium yellow flesh and severe hollow heart in large tubers.

Hertha - Lowest yielding variety with very high percentage of tubers under 2 inches. Good chip color and good scab resistance. Tubers small, smooth skin and round in shape with some pointed.

F. Upper Peninsula Variety Trial

A potato variety trial was conducted by Dr. Rich Leep and Jim Lempke on the Mike VanDamme Farm in Cornell. The plots were planted on May 14 and were harvested on October 3. In-row plant spacing was 12 inches and row width was 36 inches. No irrigation was applied during the season. The yield, size distribution and specific gravity data are shown in Table 10.

G. Post-harvest Disease Evaluation: Fusarium Dry Rot and Erwinia Soft Rot

As part of the postharvest evaluation, resistance to *Fusarium sambucinum* (fusarium dry rot) was assessed by inoculating whole tubers post harvest. The tubers were held at 20°C for three weeks and then scored for disease by measuring the diameter of the decayed tissue. The rating was based upon a 0 - 9 scale with 0 referring to no infection and 9 equal to complete tissue decay. In 1994 over 150 advanced selections and breeding lines were tested. The results of the 1994 test are summarized in Table 11. As in the previous two years of testing, no absolute resistance was detected in the selections tested. However, there are number of lines that exhibited reduced decay due to the pathogen. Snowden, Russet Norkotah and Superior rated in the top tier of the rankings as in previous years. If you look at these varieties you will note that they are duplicated in the evaluation because they came from different trials. The different ratings for the same varieties reflect the variability associated with this type of evaluation. Therefore, multiple year data, as in most disease evaluations, helps sort out the more resistant and high susceptible lines. In 1994, many new lines were tested, and many of these lines and genetic stocks that were developed at MSU were in the same or better ranking as Snowden. We will follow these lines with guarded optimism.

Resistance to *Erwinia* soft rot was also evaluated in the same advanced selections and breeding lines. No absolute resistance was found among the cultivated material (data not shown). Genetic material obtained from Dr. J. Helgeson (University of Wisconsin, USDA/ARS) exhibited the most resistance to soft rot. We will be conducting follow-up evaluations.

H. Potato Scab Evaluation

Each year a replicated field trial is conducted to assess resistance to common and pitted scab. In 1994, 150 varieties and advanced breeding lines were planted in a scab inoculated field at the MSU Soils Farm. The varieties are ranked on a 1-5 scale based upon a combined score for scab coverage and lesion severity. Usually examining one year's data does not indicate which varieties are resistant but should begin to identify ones that can be classified as susceptible to scab. In 1994 the level of infection was quite high and the levels of infection in the check cultivars were in accordance with previous observations. Our goal is to evaluate important advanced selections and varieties in the study at least three years to obtain a valid estimate of the level of resistance in each line. Table 12 summarizes the 1994 scab trial results. Russet lines that shown the most resistance to scab infection in 1994 were A7961-1, A81473-2, B9922-11, B0339-1, COO8011-5, COO83008-1 and Lemhi Russet. Round white tablestock clones with resistance included Superior, Onaway, AF1433-4, MSB040-3, MSB106-7 (oblong), AC Ptarmigin (oval to oblong), Chaleur, NY84, MSC128-1, and MSC125-8. Yellow-fleshed selections with resistance were NY101, MSC120-1Y, MSA097-1Y, and MSB116-1Y. Scab resistance was also identified in the chip-processing clones Brodick, MSB076-2, P84-13-12, NY95 and MSB110-3.

I. Blackspot Susceptibility

Increased evaluations of advanced seedlings and new varieties for their susceptibility to blackspot bruising has been implemented in the variety evaluation program. Check samples of 25 tubers were collected (a composite of 4 reps) from each cultivar at the time of grading. A second 25 tuber sample was similarly collected and was placed in a hexagon plywood drum and tumbled 10 times to provide a simulated bruise. Both samples were peeled in an abrasive peeler in October and individual tubers were assessed for the number of blackspot bruises on each potato. These data are shown in Table 13.

Section A summarizes the data for the samples receiving the simulated bruise and Section B, the check samples. When available, the 1993 data are also shown. The bruise data is represented with two types of data: percentage of bruise free potatoes and average number of bruises per tuber. A high percentage of bruise-free potatoes is the desired goal; however, the numbers of blackspot bruises per potato is also important. Cultivars which show blackspot incidence of 3 or more spots per tuber from the simulated bruise are approaching the bruise-susceptible rating. These data become more meaningful when evaluated over 3 years which reflects different growing seasons and harvest conditions.

Bruising was more severe in 1994 than in 1993. Selections that showed the greatest blackspot incidence among the check samples were Ranger Russet, Lemhi Russet, MSC029-1R, B9922-11, AO82611-7, CO80011-5, Brodick, Atlantic, MSB076-2, NY102, ND2417-6, MSB1254-1, ND860-2, B0405-4, AF875-15, AF1060-2, and P88-9-8.

Table 1. **EARLY HARVEST ROUND WHITES**

(92 days)

Line	CTW/ACRE US#1	CTW/ACRE TOTAL	% DISTRIBUTION[1] US#1	Bs	As	OV	PO	SPEC GRAV	SFA	INTR. QUALITY[2] HH	VD	IBS	BC	TOT	3 YR AVE[3]
AC PTARMAGIN	311	384	81	11	78	3	8	1.076	2.5	0	0	0	0	6	
PORTAGE	277	346	80	10	69	11	10	1.077	2.5	11	0	0	0	29	314
AF875-15	276	355	78	12	74	4	10	1.090	1.5	1	0	0	0	6	351*
AF1060-2	262	322	81	15	75	6	4	1.078	3.0	2	0	0	0	15	273
PRESTILE	251	298	84	10	83	1	6	1.080	2.5	0	0	0	0	2	270
ST. JOHNS	241	287	84	13	81	3	3	1.075	2.5	0	0	0	0	6	
ND2471-8	235	290	81	17	78	3	2	1.089	1.5	0	0	0	0	7	
NY102	234	305	77	22	76	0	2	1.087	1.0	0	0	0	0	1	
SNOWDEN	228	308	74	25	71	2	1	1.094	1.0	5	0	0	1	6	225
FL1833	225	275	82	16	80	1	2	1.090	1.0	0	0	0	0	3	
SUPERIOR	223	279	80	15	77	3	5	1.079	2.5	1	0	0	1	8	254
NY95	222	311	71	26	71	1	3	1.091	1.5	0	0	0	0	2	286*
ONAWAY	216	309	70	16	65	5	15	1.077	3.5	0	0	0	0	11	267
ATLANTIC	210	266	79	14	78	1	7	1.090	1.5	0	0	0	0	2	297
ND2417-6	207	281	73	22	69	4	5	1.082	2.5	1	0	0	0	10	
MSB106-7	206	250	82	15	77	6	3	1.078	3.0	0	0	0	0	10	
FL1533	194	273	71	23	70	2	6	1.087	1.5	1	0	0	1	3	
NY84	188	245	77	15	74	3	8	1.073	3.0	0	0	0	0	2	247*
FL1839	169	227	75	16	74	0	9	1.086	1.0	0	0	0	0	1	
MS700-70	169	218	78	19	77	0	3	1.090	2.0	0	0	0	1	1	
AC NOVACHIP	162	201	80	16	80	1	3	1.085	3.0	0	0	0	0	1	
CHALEUR	151	176	85	12	85	1	3	1.075	3.0	0	0	0	0	1	211
MSB007-1	149	196	76	24	76	0	1	1.083	3.0	0	0	0	0	0	
MN15111	135	241	56	43	56	0	1	1.081	2.0	0	0	0	0	0	
LSD	48	44						0.004							

[1]Size

US#1 - A's + OV's
B's - < 2"
A's - 2-3.25"
OV - > 3.25"
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center
TOT - Total Tubers Cut

[3]3 Yr Ave - * 2 yr data

SFA - Chip SFA Rating
MAT - Maturity Rating

Planted May 10, 1994
Harvested Aug. 10, 1994

Table 2. **LATE HARVEST ROUND WHITES**

(132 days)

Line	CTW/ACRE US#1	CTW/ACRE TOTAL	% DISTRIBUTION[1] US#1	Bs	As	OV	PO	SPEC GRAV	SFA	INTR. QUALITY[2] HH	VD	IBS	BC	TOT	MAT	3 YR AVE[3]
ATLANTIC	466	511	91	7	76	16	2	1.095	1.5	19	0	1	0	40	3.5	429
AF1060-2	450	500	90	6	69	21	4	1.074	-	1	6	0	0	38	3.0	431
SNOWDEN	441	498	88	8	82	6	4	1.087	1.0	7	4	1	0	23	3.0	419
FL1533	425	486	87	8	74	13	5	1.079	1.5	5	0	0	6	34	4.0	
PORTAGE	410	490	84	8	66	17	8	1.071	-	7	10	0	0	40	2.5	400
PRESTILE	407	437	93	4	68	25	3	1.081	-	4	0	3	2	37	4.0	462
FL1833	396	440	90	6	80	10	4	1.088	1.5	3	0	0	0	28	3.0	
MSB076-2	394	455	87	8	84	3	5	1.097	1.5	9	0	0	0	10	4.0	
AC PTARMAGIN	379	470	81	7	72	9	12	1.067	1.5	0	3	1	1	27	2.5	
ST. JOHNS	364	414	88	7	71	17	5	1.076	-	1	2	0	0	38	3.5	
NY95	357	429	83	14	76	7	3	1.091	1.0	2	0	0	0	24	3.5	395*
AF875-15	357	418	85	8	68	17	7	1.081	1.5	8	7	1	4	39	2.0	405*
NY84	345	392	88	7	66	22	5	1.066	1.5	2	5	2	0	37	3.0	387*
MS700-70	335	382	88	7	73	14	5	1.086	1.0	5	1	0	3	35	4.0	
ND2417-6	330	423	78	15	71	7	7	1.078	1.5	1	0	0	0	17	2.0	
AC NOVACHIP	325	377	86	5	68	19	9	1.084	1.5	17	0	1	0	38	3.5	
ONAWAY	324	394	82	8	71	11	10	1.069		3	5	0	1	31	1.0	317
MN15111	316	409	77	19	75	2	4	1.083	1.5	1	0	0	0	5	4.0	
NY102	304	392	78	20	76	1	2	1.084	1.5	1	0	0	0	4	2.5	
MSB007-1	294	349	84	9	74	10	6	1.076		0	5	0	0	32	3.0	
SUPERIOR	268	312	86	9	73	13	5	1.072		9	1	0	3	30	1.0	248
CHALEUR	261	298	88	8	76	11	5	1.068		0	1	1	2	26	1.0	270
ND2471-8	260	330	79	14	77	1	7	1.084	1.5	0	1	0	0	4	1.0	
FL1839	254	298	85	10	81	4	5	1.080	1.0	4	0	0	0	10	2.0	
LSD	59	59						0.003								

[1]Size

US#1 - A's + OV's
B's - < 2"
A's - 2-3.25"
OV - > 3.25"
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center
TOT - Total Tubers Cut

[3]3 Yr Ave - * 2 yr data

SFA - Chip SFA Rating
MAT - Maturity Rating

Planted May 10, 1994
Harvested Sept 19, 1994

Table 3. **EARLY HARVEST LONG RUSSETS**

(92 days)

Line	CTW/ACRE US#1	CTW/ACRE TOTAL	% DISTRIBUTION[1] US#1	Bs	As	OV	PO	SPEC GRAV	INTR. QUALITY[2] HH	VD	IBS	BC	TOT	3 YR AVE[3]
ITASCA	200	309	65	34	65	0	1	1.066	0	0	0	0	0	
GOLDRUSH	171	244	70	26	64	6	4	1.065	0	0	0	0	12	182
A082611-7	171	329	52	40	51	1	8	1.079	0	0	0	0	2	
A84180-8	163	230	71	26	70	1	3	1.075	0	0	0	0	1	212*
CENTURY R.	129	251	51	49	51	0	0	1.074	0	0	0	0	0	
C0083008-1	126	177	71	26	71	0	3	1.073	0	0	0	0	0	
A81473-2	125	184	68	31	65	3	1	1.066	1	0	0	0	4	
CRESTONE R.	120	165	73	24	69	4	3	1.059	0	0	0	0	6	
A82119-3	110	204	54	46	54	0	0	1.072	0	0	0	0	0	
R. NORKOTAH	110	186	59	39	50	9	2	1.068	4	0	0	0	14	154
A7961-1	102	231	44	55	44	0	1	1.079	0	0	0	0	0	
R. BURBANK	89	252	35	64	35	0	1	1.076	0	0	0	0	0	128
A8495-1	83	164	50	48	50	0	1	1.078	0	0	0	0	0	
RANGER R.	75	154	49	51	49	0	1	1.078	0	0	0	0	0	121
LSD	37	46						0.0025						

Harvested Aug. 10, 1994

Table 4. **LATE HARVEST LONG RUSSETS**

(134 days)

Line	CTW/ACRE US#1	CTW/ACRE TOTAL	% DISTRIBUTION[1] US#1	Bs	As	OV	PO	SPEC GRAV	INTR. QUALITY[2] HH	VD	IBS	BC	TOT	MAT	3 YR AVE[3]
A81473-2	346	411	84	10	45	39	6	1.079	24	0	0	0	40	5.0	
CENTURY R.	340	442	77	20	66	11	3	1.081	1	0	0	0	31	4.0	
A82119-3	298	384	78	17	59	19	5	1.082	24	0	0	0	33	4.5	
AO82611-7	297	421	71	23	62	9	7	1.086	5	0	0	0	30	4.0	
ITASCA	281	389	72	25	67	5	3	1.069	0	0	0	0	20	2.5	
GOLDRUSH	276	335	83	14	57	25	4	1.072	13	2	0	0	37	2.5	284
A7961-1	264	393	67	29	63	4	4	1.085	9	0	0	0	14	3.5	
A84180-8	256	310	83	11	60	23	7	1.075	21	0	0	0	30	3.0	347*
C0083008-1	250	310	81	14	69	12	6	1.083	16	0	0	0	22	4.5	
CRESTONE R.	223	282	79	11	49	30	10	1.069	5	2	0	0	39	3.0	
RANGER R.	218	305	72	24	61	11	4	1.093	5	0	0	0	25	4.0	300
A8495-1	208	293	71	26	61	10	4	1.086	12	0	0	0	21	4.0	
R. BURBANK	205	348	59	35	55	4	6	1.081	6	0	0	0	12	3.0	295
R. NORKOTAH	172	262	66	29	54	12	5	1.07	16	0	0	0	21	2.5	197
LSD	61	58						0.003							

[1]Size

US#1 - A's + OV's
B's - < 4 oz
A's - 4 - 10 oz
OV - > 10 oz
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center
TOT - Total Tubers Cut

[3]3 Yr Ave - * 2 yr data

SFA - Chip SFA Rating
MAT - Maturity Rating

Planted May 10, 1994
Harvested Sept. 21, 1994

Table 5. **1994 ADAPTATION TRIAL**

(140 days)

Line	CTW/ACRE US#1	CTW/ACRE TOTAL	% DISTRIBUTION[1] US#1	Bs	As	OV	PO	SPEC GRAV	SFA	INTR. QUALITY[2] HH	VD	IBS	BC	TOT	MAT
NY101	616	685	90	6	75	15	4	1.078	-	2	0	0	0	40	4.0
ND01496-1	529	572	93	4	63	30	3	1.089	1.0	14	0	0	0	41	4.0
AC83306-1	491	584	84	5	67	17	10	1.081	3.0	9	5	0	0	40	4.0
ATLANTIC	472	523	90	7	74	16	3	1.095	2.0	17	0	0	0	31	3.5
B0493-8	468	540	87	9	64	22	4	1.078	-	2	0	0	0	37	2.5
B0257-12	457	532	86	4	73	13	10	1.086	3.0	1	0	0	0	40	3.0
B0405-4	418	496	84	7	76	9	9	1.099	2.0	10	1	1	3	27	5.0
AF1470-17	398	563	71	7	50	21	23	1.063	4.5	4	0	4	7	40	2.0
B0564-9	398	453	88	8	67	21	4	1.074	3.5	27	0	0	0	40	3.0
MSA105-1	386	456	85	5	59	25	10	1.081	2.0	29	0	0	0	38	4.0
CO80011-5	383	448	86	8	60	25	6	1.068	-	3	0	0	0	40	3.0
B0339-1	362	463	78	20	70	8	2	1.080	-	18	0	0	0	26	2.5
B0585-1	357	448	80	8	65	15	12	1.076	1.5	0	4	0	2	33	2.5
MSB106-8	355	400	89	6	71	18	5	1.084	-	39	0	0	0	40	4.0
SNOWDEN	351	427	82	13	77	5	4	1.088	-	1	0	0	1	20	2.5
B9922-11	350	417	84	12	73	11	4	1.086	-	18	0	0	2	32	4.0
B0174-16	333	408	82	9	74	7	9	1.101	3.0	6	0	0	0	24	2.0
MSC103-2	323	385	84	4	48	36	12	1.075	-	5	0	1	0	40	4.0
NT-1	322	361	89	8	81	9	2	1.092	1.5	8	0	0	1	24	3.5
NDA2031-2	307	453	68	28	66	1	4	1.078	1.0	1	1	0	0	6	3.0
MSC125-1	304	368	83	4	44	38	13	1.079	1.0	1	0	0	1	40	5.0
MSB107-1	301	330	91	5	62	29	4	1.074	1.5	0	0	0	1	40	3.0
B0257-9	300	363	83	6	68	15	11	1.080	1.5	6	0	1	1	27	2.0
MSB094-1	281	356	79	15	69	10	6	1.082	3.0	5	0	0	0	23	3.0
MSB105-3	279	320	87	7	75	13	6	1.078	2.0	0	0	0	0	28	3.0
MSA097-1Y	279	356	79	6	55	23	15	1.075	3.5	0	0	0	0	40	2.0
B0585-5	279	392	71	6	57	14	22	1.075	1.5	23	0	1	0	36	3.0
SUPERIOR	278	353	79	11	73	6	10	1.072	-	4	0	0	0	17	2.0
MSC086-3	276	335	82	9	63	19	9	1.066	3.0	2	0	1	0	39	2.5
AF1433-4	264	330	80	13	61	19	7	1.073	-	0	0	2	0	31	2.0
MSB083-1	256	311	82	14	76	7	4	1.079	2.5	0	0	0	0	17	3.0
MSA091-1	253	364	69	10	54	15	21	1.088	1.5	1	4	1	8	34	3.0
MSA071-1	245	344	71	25	70	1	4	1.090	1.0	0	0	0	0	4	2.0
MSC135-5	237	264	90	7	80	10	3	1.079	1.0	6	0	0	2	22	3.5
MSB1254-1	235	262	89	6	67	22	5	1.083	1.0	0	0	0	1	31	4.0
MSC147-3	230	268	86	8	76	10	6	1.079	3.0	3	1	0	0	14	3.0
MSC029-1R	209	266	79	11	51	28	10	1.084	-	9	0	1	0	40	5.0
MSB095-2	208	258	81	17	71	9	2	1.075	2.0	4	1	0	0	21	2.5
ND860-2	195	294	66	24	66	0	10	1.082	1.5	0	0	0	0	1	1.0
MSB0952-1	188	284	66	31	65	1	3	1.089	3.0	0	0	0	0	5	3.0
MSB110-3	186	238	78	8	63	15	14	1.087	1.5	15	0	0	3	31	4.0
MSB027-1R	169	240	70	18	55	15	12	1.073	-	11	0	1	0	20	1.0
MSC135-2	146	208	70	12	59	12	17	1.070	2.0	10	0	0	0	13	3.0
LSD	77	77						0.0045							

[1]Size

US#1 - A's + OV's
B's - < 2"
A's - 2-3.25"
OV - > 3.25"
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center
TOT - Total Tubers Cut

SFA - Chip SFA Rating
MAT - Maturity Rating

Planted May 9, 1994
Harvested Sept. 26, 1994

Table 6 ADVANCED SELECTIONS DEVELOPED AT MSU IN TISSUE CULTURE

CLONE		SP GR	USE	SCAB	1995 PLANS
A091-1	RW	1.088	CHIP	MR	GROWER
B076-2	RW	1.097	CHIP	R	GROWER/ REGIONAL
B007-1	OBL	1.076	TABLE	MS	MSU/ REGIONAL
B073-2	RW	1.082	CHIP	MS	MSU TRIALS
B106-7	OBL	1.070	TABLE	MR	MSU TRIALS
B110-3	RW	1.087	CHIP	MR	MSU TRIALS
B095-2	RW	1.075	TABLE	MR	GROWER
B107-1	RW	1.074	TABLE	MS	GROWER
B0952-1	OV	1.089	CHIP	MR	GROWER
B027-1R	RUS	1.073	TABLE	MS	GROWER
B083-1	RW	1.079	CHIP	MR	GROWER

Table 7 NEXT GENERATION OF MSU ADVANCED SELECTIONS

CLONE	SP GR	SFA	SCAB	MAT	INTERNALS
MSNT-1	1.092	1.5	3.0	3.5	GOOD
C125-1	1.079	1.0	3.0	5.0	EXC
C029-1R	1.084	--	2.5	5.0	GOOD
C135-5	1.079	1.0 CC	2.5	3.5	GOOD
B1254-1	1.083	1.0 CC	2.5	4.0	EXC
A097-1Y	1.075	--	1.5	2.0	EXC
C086-3	1.066	--	2.0	2.5	EXC
B105-3	1.078	2.0	4.0	3.0	EXC
B040-3*	1.072	2.0	1.0	3.0	GOOD
B116-1Y	1.067	--	1.5	1.5	EXC
B057-2	1.075	--	3.0	3.0	GOOD
C084-1	1.074	--	1.5	5.0	EXC
C098-2*	1.075	1.0 CC	2.0	3.0	--
C120-1Y	1.073	--	1.0	4.5	GOOD
C121-7*	1.080	1.5	3.0	2.0	GOOD
C122-1*	1.081	1.0	1.5	2.5	--
C125-8*	1.067	--	1.0	1.5	--
C126-6	1.072	--	2.5	2.5	--
C127-3	1.085	1.0 CC	3.5	3.5	--
C128-1	1.068	--	1.0	4.0	GOOD
C129-9	1.077	--	2.5	3.5	--
C148-1	1.062	--	1.5	4.0	--
D001-3Y*	1.079	--	3.0	3.5	--
D040-3	1.075	1.0 CC	3.0	3.0	GOOD
D040-4Y*	1.092	--	3.0	3.0	--

* - Excellent appearance
cc - cold-chipper

Table 8. **NORTH CENTRAL REGIONAL TRIAL**

(143 days)

Line	CTW/ACRE		% DISTRIBUTION[1]					SPEC	SFA	INTR. QUALITY[2]					MAT
	US#1	TOTAL	US#1	Bs	As	OV	PO	GRAV		HH	VD	IBS	BC	TOT	
RED PONTIAC	512	612	84	5	52	32	11	1.068	4.5	26	0	0	0	40	4.0
W1149	467	520	90	5	63	27	5	1.095	1.5	31	0	0	0	40	5.0
MN15220	424	535	79	9	59	20	12	1.067	4	0	0	0	0	40	3.0
FONTENOT	368	418	88	8	72	16	4	1.080	-	6	0	0	1	32	3.0
MN12823	368	428	86	5	53	33	9	1.078	2.0	4	0	0	9	40	3.5
P83-6-18	317	470	67	23	61	6	9	1.083	2.0	6	0	0	0	23	2.0
MN13540	297	384	77	17	72	5	6	1.070	1.5	1	0	2	0	15	4.0
W1100	296	407	73	25	72	1	3	1.065	3.0	0	0	0	0	2	2.0
ND2417-6	275	367	75	17	70	5	8	1.078	1.5	0	1	0	0	7	3.0
RED RUBY	275	408	67	18	67	1	15	1.067	-	0	0	0	0	2	2.0
NORCHIP	259	361	72	13	70	1	15	1.082	2.0	0	0	0	0	5	2.0
DR NORLAND	253	325	78	16	77	1	6	1.061	3.5	0	0	0	0	2	1.0
W1099	243	330	74	23	66	8	4	1.071	3.5	2	0	0	0	21	2.5
ND2471-8	236	312	75	14	70	5	11	1.083	1.5	6	1	0	0	15	2.0
R. BURBANK	228	397	57	30	55	2	13	1.084	3.0	4	0	1	0	8	4.0
R. NORKOTAH	201	322	62	27	59	4	11	1.073	3.5	6	0	0	0	9	2.0
P84-13-12	173	246	70	23	70	1	6	1.086	1.0	1	0	0	0	1	2.0
LSD	76	80						0.003							

[1]Size

US#1 - A's + OV's
B's - < 2"
A's - 2-3.25"
OV - > 3.25"
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center
TOT - Total Tubers Cut

SFA - Chip SFA Rating
MAT - Maturity Rating

Planted May 9, 1994
Harvested Sept. 29, 1994

Table 9. **EUROPEAN VARIETY TRIAL**

(134 days)

	CTW/ACRE		% DISTRIBUTION[1]					SPEC		INTR. QUALITY[2]					
Line	US#1	TOTAL	US#1	Bs	As	OV	PO	GRAV	SFA	HH	VD	IBS	BC	TOT	MAT
MORNING GOLD	493	570	87	8	80	6	5	1.076	3.5	11	2	2	0	20	3.0
BRODICK	445	545	82	11	74	7	7	1.080	1.5	19	0	12	0	28	3.0
SANTE	433	538	80	14	77	3	6	1.081	2.5	0	1	0	0	16	2.0
AGRIA	393	502	78	11	69	10	11	1.077	2.0	25	0	0	0	29	3.0
FIANNA	370	474	78	15	76	2	7	1.088	1.0	0	1	0	0	6	2.0
PENTA	366	462	79	15	77	2	5	1.075	3.0	1	3	1	0	7	3.0
MORENE	341	431	79	11	76	4	9	1.084	3.5	3	5	0	0	15	5.0
SPUNTA	328	395	83	6	57	26	11	1.062	-	4	1	0	0	40	2.5
ESTIMA	317	400	79	14	74	5	7	1.073	4.0	0	1	2	0	17	2.0
DESIREE	314	412	76	15	72	4	8	1.080	-	1	0	0	0	14	3.0
DUNDROD	309	389	79	17	74	6	4	1.067	1.5	1	0	0	0	16	2.0
AVANTI	270	398	68	28	67	1	4	1.066	2.5	1	0	0	0	2	3.0
SAGINAW GOLD	269	346	78	17	74	4	5	1.077	2.0	0	0	0	0	12	1.0
MICHIGOLD	266	348	76	19	70	6	5	1.086	-	3	1	1	1	10	1.5
YUKON GOLD	233	276	85	10	69	15	6	1.077	-	15	5	1	0	20	1.0
HERTHA	171	313	55	38	55	0	8	1.084	1.5	0	0	0	0	0	3.0
LSD	80	84						0.003							

[1]Size

US#1 - A's + OV's
B's - < 2"
A's - 2-3.25"
OV - > 3.25"
PO - Pick outs

[2]Quality

HH - Hollow Heart
VD - Vascular Discoloration
IBS - Internal Brown Spot
BC - Brown Center
TOT - Total Tubers Cut

SFA - Chip SFA Rating
MAT - Maturity Rating

Planted May 10, 1994
Harvested Sept 21, 1994

Table 10. **UPPER PENNISULA TRIAL**

(141 days)

Line	CTW/ACRE		PERCENT DISTRIBUTION[1]					SPEC
	US#1	TOTAL	US#1	Bs	As	OV	PO	GRAV
PRESTILE	433	453	96	2	74	22	2	1.077
AC PTARMIGIN	404	419	97	2	64	33	1	1.073
RANGER R.	368	399	92	6	62	30	2	1.081
A84180-8	360	389	93	7	72	21	0	1.080
R. BURBANK	352	389	91	8	65	25	2	1.080
GOLDRUSH	349	368	95	5	68	27	0	1.074
CO083998-1	343	350	98	2	61	37	0	1.083
PORTAGE	343	382	90	10	76	14	0	1.079
A7961-1	323	336	96	4	71	25	0	1.088
CRESTONE R.	307	331	93	8	78	14	0	1.073
R. NORKOTAH	250	260	96	3	71	25	1	1.076
CHALEUR	146	159	92	8	83	9	0	1.076

[1]Size

US#1 - A's + OV's
B's - < 2"
A's - 2-3.25"
OV - > 3.25"
PO - Pick outs

Planted May 14, 1994
Harvested Oct. 3, 1994

Table 11 1994 Fusarium Dry Rot Evaluations

CLONE	RATING	CLONE	RATING	CLONE	RATING	CLONE	RATING
34-6	0.0	LEMHI R	3.1	AF1060-2	5.5	191-11	7.8
ND860-2	0.2	MSA071-1	3.1	FL1839	5.5	ATLANTIC	7.8
P88-15-1	0.2	P88-9-8	3.1	MSB0952-1	5.5	HLG1-2	7.8
B0257-9	0.3	193-16	3.1	W1100R	5.5	ST. JOHNS	7.9
MSC125-8	0.4	144-06	3.2	133-208	5.7	W5337-3	7.9
151-16	0.5	NORCHIP	3.2	A82119-3	5.7	HLG-T450	8.0
SNOWDEN	0.5	MSNT-1	3.3	FIANNA	5.7	NY102	8.0
133-103	0.6	P88-12-4	3.3	B0339-1	5.8	W2595-7	8.2
B9922-11	0.6	PEMBINA CHI	3.3	M6	5.8	ESTIMA	8.3
P88-13-4	0.8	MS716-15	3.4	MSB110-3	5.8	HLG-120	8.4
P84-13-12	0.9	MSD040-4RY	3.4	MSB027-1R	5.9	MICHIGOLD	8.5
W1149	0.9	MSB054-4	3.6	133-10	6.0	NIPIGON	8.5
MSC129-9	1.0	MSC121-7	3.6	B0405-4	6.0	SPUNTA	8.5
R. NORKOTAH	1.0	MSB049-1	3.7	MN13540	6.0	HLG-297	8.6
SUPERIOR	1.0	SUPERIOR	3.7	MSC125-1	6.0	NDA2031-2	8.6
B0257-12	1.1	ATLANTIC	3.8	A81473-2	6.1	MSC103-2	8.7
MSC126-6	1.1	FL1833	3.8	MORENE	6.1	PRESTILE	8.8
MSA089-1	1.2	MSB094-1	3.8	FL1533	6.2	B0493-8	8.9
MSC148-1	1.2	MSD016-6	3.8	MSD001-3Y	6.2	CHALEUR	8.9
133-227	1.4	MSC086-7	4.0	A082611-7	6.3	SAGINAW G	9.0
SUPERIOR	1.4	MSD024-2RD	4.0	MSA097-1Y	6.3		
MIRTON PEAR	1.5	C0083008-1	4.2	AVANTI	6.4		
AGRIA	1.8	MSB1254-1	4.2	Y245-7	6.4		
MSC029-1R	1.8	MORNING GOL	4.4	DUNDROD	6.5		
34-8	1.9	MSB095-2	4.4	MSC147-3	6.5		
PENTA	1.9	CENTURY R	4.5	MSB116-1Y	6.6		
A84180-8	2.0	ONAWAY	4.5	AC NOVACHIP	6.7		
ONAWAY	2.1	YUKON GOLD	4.5	ATLANTIC	6.8		
HLG-244	2.2	HLG-1-1	4.6	RED RUBY	6.8		
P83-6-18	2.2	MSB076-2	4.6	AF875-15	6.9		
B0585-5	2.3	ND2417-6	4.6	C080011-5	6.9		
ITASCA	2.3	133-143Y	4.7	PORTAGE	6.9		
SNOWDEN	2.3	B0564-9	4.7	MSB106-8	7.0		
A7961-1	2.6	MSA105-1	4.7	ND01496-1	7.0		
MSB040-3	2.6	013-19	4.8	MSB007-1	7.1		
132-238	2.7	133-17	4.8	NY84	7.1		
AF1433-4	2.7	MSC135-2	4.8	NY95	7.1		
GOLDRUSH	2.7	SANTE	4.8	AF1470-17	7.2		
MS700-70	2.7	DESIREE	4.9	R. BURBANK	7.2		
MSA091-1	2.8	MSC120-1Y	5.1	MSB105-3	7.3		
ND2471-8	2.8	W1099	5.1	B0585-1	7.4		
B0174-16	3.0	NY101	5.3	MSB083-1	7.4		
MSB123-5	3.0	RANGER R	5.3	MSC135-5	7.5		
MSD018-2RD	3.0	AC83306-1	5.4	MSB107-1	7.6		
A8495-1	3.1	MSC086-3	5.4	CRESTONE R	7.7		
BRODICK	3.1	AC PTARMIGI	5.5	HERTHA	7.7		

0 = no infection

9 = complete infection

Table 12 SCAB TRIAL: 1994

MSU SOILS FARM

CLONE	RATING	CLONE	RATING	CLONE	RATING	CLONE	RATING
A7961-1	1	AF875-15	2	AVANTI	3	AC NOVACHIP	4
A81473-2	1	B0564-9	2	B0257-9	3	AF1060-2	4
AF1433-4	1	DR NORLAND	2	FIANNA	3	AF1470-17	4
B9922-11	1	FONTENOT	2	FL1833	3	B0257-12	4
B0339-1	1	HERTHA	2	MC.BLACK	3	B0493-8	4
BRODICK	1	MICHIGOLD	2	MSA071-1	3	ESTIMA	4
C0008011-5	1	MIRTON PEARL	2	MSB007-1	3	MS716-15	4
C0083008-1	1	MN13540	2	MSB027-1R	3	MSA105-1	4
LEMHI R.	1	MORENE	2	MSB057-2	3	MSB105-3	4
MN15220	1	MS700-70	2	MSB100-3	3	MSC121-8	4
MSB040-3	1	MSA089-1	2	MSC086-7	3	ND2471-8	4
MSB076-2	1	MSA091-1	2	MSC103-2	3	NIPIGON	4
MSB106-7	1	MSA110-2	2	MSC121-7	3	RANGER R.	4
MSC120-1Y	1	MSB094-1	2	MSC125-1	3	ROSE GOLD	4
MSC125-8	1	MSB0952-1	2	MSD001-3Y	3	ND01496-1	4.5
MSC128-1	1	MSB095-2	2	MSD016-6	3	RED GOLD	4.5
ONAWAY	1	MSB123-5	2	MSD024-2	3	B0585-1	5
P84-13-12	1	MSC086-3	2	MSD040-3	3	MSC024-2	5
PEMBINA CHIPPE	1	MSC098-2	2	MSD040-4	3	MSC123-8	5
PRESTILE	1	MSC116-4	2	NDA2031-1	3	R.PONTIAC	5
RED RUBY	1	MSC147-3	2	NT-1	3		
SUPERIOR	1	NY102	2	P88-12-4	3		
A8495-1	1.5	R.BURBANK	2	P88-9-8	3		
AC PTARMIGAN	1.5	SNOWDEN	2	PENTA	3		
CHALEUR	1.5	A082611-7	2.5	RUSSIAN BLUE	3		
CRESTONE R.	1.5	A82119-3	2.5	SAG.GOLD	3		
GOLDRUSH	1.5	ATLANTIC	2.5	ST.JOHNS	3		
MN15111	1.5	B0585-5	2.5	W1100R	3		
MSA097-1Y	1.5	CENTURY R.	2.5	W1149	3		
MSB049-1	1.5	DUNDROD	2.5	AC83306-1	3.5		
MSB083-1	1.5	FL1533	2.5	AGRIA	3.5		
MSB110-3	1.5	FL1839	2.5	B0174-16	3.5		
MSB116-1Y	1.5	ITASCA	2.5	B0405-4	3.5		
MSC084-1	1.5	MN12823	2.5	MSC118-1	3.5		
MSC108-2	1.5	MORN. GOLD	2.5	MSC127-5	3.5		
MSC122-1	1.5	MSB106-8	2.5	MSD018-2RD	3.5		
MSC135-2	1.5	MSB107-1	2.5	MSD030-3	3.5		
MSC148-1	1.5	MSB1254-1	2.5	ND2417-6	3.5		
NORCHIP	1.5	MSC029-1R	2.5	ND860-2	3.5		
NY101	1.5	MSC126-6	2.5	P83-6-18	3.5		
NY84	1.5	MSC129-9	2.5	PORTAGE	3.5		
NY95	1.5	MSC135-5	2.5	SANTE	3.5		
P.VIKING	1.5	P88-15-1	2.5				
R.NORKOTAH	1.5	W1099	2.5				

1 = Little to no infection

5 = > 25% surface coverage with deep pits

1994 BLACKSPOT SUSCEPTIBILITY STUDY

A. SIMULATED BRUISE SAMPLES

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
ADAPTATION									
AF1433-4	21	3	1				25	84	0.200
MSB027-1R	16	6	3				25	64	0.480
MSB105-3	16	6	2	1			25	64	0.520
MSB095-2	10	7	3				20	50	0.650
B0257-12	11	10	3	1			25	44	0.760
NDA2031-2	13	6	2	2	1		24	54	0.833
MSC103-2	12	6	3	4			25	48	0.960
MSC086-3	10	7	6	2			25	40	1.000
B0585-1	8	10	5	2			25	32	1.040
SUPERIOR	10	5	5	5			25	40	1.200
AF1470-17	11	2	9	2	1		25	44	1.200
MSA091-1	9	4	9	3			25	36	1.240
MSC147-3	10	5	5	4	1		25	40	1.240
B0257-9	12	4	3	3	3		25	48	1.240
MSB0952-1	11	7	4	4	1	1	28	39	1.286
NY101	8	5	8	3	1		25	32	1.360
MSB094-1	8	7	6	1	2	1	25	32	1.400
MSA105-1	10	4	5	4	1	1	25	40	1.400
AC83306-1	9	3	3	1	2	2	20	45	1.500
MSC125-1	7	4	2	3	2	1	19	37	1.579
B0585-5	8	6	4	3	3	1	25	32	1.600
MSB110-3	5	8	4	7	1		25	20	1.640
C080011-5	8	3	6	5	2	1	25	32	1.720
MSA097-1Y	7	2	5	6	2		22	32	1.727
B0174-16	3	7	11	1	2	1	25	12	1.800
MSB107-1	7	5	5	3	4	1	25	28	1.800
MSB083-1	5	4	6	7	2	1	25	20	2.000
ND01496-1	7	4	5	2	5	2	25	28	2.000
B0493-8	3	5	8	4	4	1	25	12	2.160
B0564-9	4	3	8	5	3	2	25	16	2.240
MSC135-2	2	1	3	3	3		12	17	2.333
MSC029-1R	4	1	7	8	5		25	16	2.360
ATLANTIC	6	2	5	4	5	3	25	24	2.360
SNOWDEN	2	2	7	6	4	4	25	8	2.800
B0339-1	4	2	2	7	3	6	24	17	2.875
MSC135-5	3	2	5	7	5	5	27	11	2.889
B9922-11		1	7	9	4	4	25	0	3.120
MSB1254-1	2	1	4	6	6	6	25	8	3.240
MSNT-1	3		4	5	5	7	24	13	3.250
ND860-2	1	2	4	5	5	8	25	4	3.400
B0405-4	0	1	4	5	9	6	25	0	3.600
MSB106-8	2	1	2	2	7	11	25	8	3.760

[a] Average Number of Bruises Per Tuber

A. SIMULATED BRUISE SAMPLES CONTINUED

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
DATE OF HARVEST: LONG									
ITASCA	24	1					25	96	0.040
R. NORKOTAH	19	5	1				25	76	0.280
GOLDRUSH	18	4	2	1			25	72	0.440
A84180-8	17	4	3	1			25	68	0.520
CENTURY R	16	7		1	1		25	64	0.560
A81473-2	15	6	2	2			25	60	0.640
R. BURBANK	13	6	5		1		25	52	0.800
A7961-1	9	10	6				25	36	0.880
A8495-1	6	11	4	4			25	24	1.240
C0083008-1	8	8	6	1	2		25	32	1.240
CRESTONE R	7	5	8	3	1	1	25	28	1.560
A82199-3	6	3	9	5	2		25	24	1.760
RANGER R	1	2	9	6	6	1	25	4	2.680
A082611-7	3	4	3	6	6	3	25	12	2.680
DATE OF HARVEST: ROUND WHITE									
CHALEUR	25						25	100	0.000
AC PTARMAGIN	19	6					25	76	0.240
FL1533	19	4	2				25	76	0.320
PORTAGE	19	4	1	1			25	76	0.360
ST. JOHNS	16	4	5				25	64	0.560
SUPERIOR	14	7	2		1		24	58	0.625
NY84	12	6	5	2			25	48	0.880
AF1060-2	16	2	4	1	1	1	25	64	0.880
FL1839	10	8	6		1		25	40	0.960
AC NOVACHIP	8	11	3	2	1		25	32	1.080
MSB007-1	9	9	4	2		1	25	36	1.120
ONAWAY	12	4	4	4	1		25	48	1.120
PRESTILE	7	10	4	4			25	28	1.200
MN15111	6	9	8	2			25	24	1.240
ND2417-6	8	7	5	5			25	32	1.280
MS700-70	8	5	8	4			25	32	1.320
SNOWDEN	5	6	7	5	2		25	20	1.720
ATLANTIC	5	5	8	5	2		25	20	1.760
AF875-15	6	7	4	4	3	1	25	24	1.760
NY95	3	8	4	7	2	1	25	12	2.000
ND2471-8	5	2	6	10	2		25	20	2.080
MSB076-2		4	10	7	3	1	25	0	2.480
FL1833		3	9	8	5		25	0	2.600
NY102	3	3	1	7	8	3	25	12	2.920

[a] Average Number of Bruises Per Tuber

A. SIMULATED BRUISE SAMPLES CONTINUED

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
EUROPEAN									
SPUNTA	22	3					25	88	0.120
YUKON GOLD	22	2		1			25	88	0.200
PENTA	16	8	1				25	64	0.400
HERTHA	14	8	3				25	56	0.560
AGRIA	14	5	6				25	56	0.680
SANTE	11	9	3	1	1		25	44	0.880
AVANTI	11	2	3	3			19	58	0.895
FIANNA	12	5	5	2	1		25	48	1.000
DESIREE	8	8	8	1			25	32	1.080
ESTIMA	10	4	4	6	1		25	40	1.360
SAGINAW GOLD	10	3	5	3	3	1	25	40	1.560
MORENE	5	5	9	4	0	1	24	21	1.667
MICHIGOLD	4	6	6	6	3		25	16	1.920
DUNDROD	0	1	6	7	5	6	25	0	3.360
BRODICK			1	2	2	20	25	0	4.640
MORNING GOLD				3	1	21	25	0	4.720
NORTH CENTRAL									
DR NORLAND	18	6	1				25	72	0.320
P83-6-18	19	4	1	1			25	76	0.360
RED RUBY	7	8	4	1	5		25	28	1.560
FONTENOT	5	6	8	5	1		25	20	1.640
MN13540	3	4	9	3	3		22	14	1.955
P83-13-12	2	3	6	9	5		25	8	2.480
MN12823		3	8	10	3	1	25	0	2.640
W1100R	2	4	7	4	4	4	25	8	2.640
W1149	2			1	3	15	21	10	4.286
SFA									
ND2676-10	18	5	2				25	72	0.360
NDA2031-2	9	8	5	3			25	36	1.080
ND01496-1	8	7	7	3			25	32	1.200
SUNCRISP	8	5	8	3	1		25	32	1.360
NY95	4	10	7	4			25	16	1.440
ATLANTIC	10	2	4	6	3		25	40	1.600
SNOWDEN	3	4	5	9	3	1	25	12	2.320
AF875-15	6	2	2	8	5	2	25	24	2.400
NORCHIP	2	3	8	7	5	2	27	7	2.593
ND2471-8	1	2	7	4	7	4	25	4	3.040
ND2417-6	1	1	4	9	8	2	25	4	3.120
NY102		2	7	6	3	7	25	0	3.240
B0178-34			4	4	6	11	25	0	3.960

[a] Average Number of Bruises Per Tuber

1994 BLACKSPOT SUSCEPTIBILITY STUDY

B. CHECK SAMPLES

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
ADAPTATION									
AF1470-17	24	1					25	96	0.040
AF1433-4	24	1					25	96	0.040
SUPERIOR	22	3					25	88	0.120
MSB107-1	22	3					25	88	0.120
NDA2031-2	20	4					24	83	0.167
ND01496-1	20	5					25	80	0.200
MSB095-2	21	3	1				25	84	0.200
B0585-5	20	3	2				25	80	0.280
MSB0952-1	21	2	1	1			25	84	0.280
B0174-16	18	6	1				25	72	0.320
B0339-1	18	6	1				25	72	0.320
B0585-1	19	4	2				25	76	0.320
MSB094-1	19	4	1	1			25	76	0.360
MSB027-1R	19	4	1	1			25	76	0.360
MSA091-1	20	2	2	1			25	80	0.360
ATLANTIC	20	3	1		1		25	80	0.360
NY101	18	4	2	1			25	72	0.440
MSB105-3	16	6	3				25	64	0.480
MSA097-1Y	14	2	2		1		19	74	0.526
SNOWDEN	15	7	1	2			25	60	0.600
MSB110-3	15	6	3	1			25	60	0.600
B0257-9	16	4	3	1	1		25	64	0.680
MSC103-2	11	9	3	2			25	44	0.840
B0257-12	12	1	5	1	1		20	60	0.900
MSA105-1	11	6	6	2			25	44	0.960
MSNT-1	13	3	6	3			25	52	0.960
B0493-8	11	3	6	4		1	25	44	1.280
AC83306-1	10	2	5	2		2	21	48	1.333
MSB1254-1	5	7	6	4	3		25	20	1.720
MSC029-1R	7	3	7	4	2	2	25	28	1.880
MSB106-8	5	4	7	3	3	3	25	20	2.160
ND860-2	5	2	3	9	3	3	25	20	2.480
B0405-4	1	2	1	8	5	8	25	4	3.520
B9922-11	1	3	4	4		13	25	4	3.520

[a] Average Number of Bruises Per Tuber

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
DATE OF HARVEST: LONG									
ITASCA	25						25	100	0.000
R. NORKOTAH	23	2					25	92	0.080
R. BURBANK	22	3					25	88	0.120
A84180-8	24		2				26	92	0.154
CENTURY R.	22	2	1				25	88	0.160
A7961-1	23	1		1			25	92	0.160
C0083008-1	20	5					25	80	0.200
GOLDRUSH	21	3	1				25	84	0.200
A81473-2	20	4	1				25	80	0.240
A82119-3	20	3	2				25	80	0.280
A8495-1	20	4		1			25	80	0.280
CRESTONE R.	17	2	3	2		1	25	68	0.760
A082611-7	9	2	7	4	3		25	36	1.600
C080011-5	8	4	2	5	4	2	25	32	1.960
RANGER R.	7	1	4	5	4	4	25	28	2.400
DATE OF HARVEST: ROUND WHITE									
CHALEUR	24	1					25	96	0.040
ST. JOHNS	24	1					25	96	0.040
SUPERIOR	23	2					25	92	0.080
FL1533	22	3					25	88	0.120
FL1839	24			1			25	96	0.120
MN15111	21	4					25	84	0.160
MS700-70	21	4					25	84	0.160
AC PTARMAGIN	21	4					25	84	0.160
NY95	20	4	1				25	80	0.240
PORTAGE	19	5	1				25	76	0.280
PRESTILE	20	3	2				25	80	0.280
AC NOVACHIP	21	2	1	1			25	84	0.280
SNOWDEN	17	7	1				25	68	0.360
FL1833	18	5	2				25	72	0.360
NY84	19	3	3				25	76	0.360
MSB007-1	16	6	3				25	64	0.480
ONAWAY	17	3	4	1			25	68	0.560
ND2471-8	16	4	3	2			25	64	0.640
ATLANTIC	14	4	5	2			25	56	0.800
AF875-15	12	6	2	4	1		25	48	1.040
ND2417-6	12	5	2	3	3	0	25	48	1.200
NY102	11	3	5	4	2		25	44	1.320
AF1060-2	7	5	6	4	1	2	25	28	1.720
MSB076-2	3	3	5	5	5	4	25	12	2.720

[a] Average Number of Bruises Per Tuber

B. CHECK SAMPLES CONTINUED

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
EUROPEAN									
DESIREE	25						25	100	0.000
YUKON GOLD	25						25	100	0.000
MICHIGOLD	25						25	100	0.000
HERTHA	25						25	100	0.000
PENTA	25						25	100	0.000
FIANNA	25						25	100	0.000
SANTE	25						25	100	0.000
AGRIA	25						25	100	0.000
SPUNTA	25						25	100	0.000
MORENE	22	1					23	96	0.043
ESTIMA	23	2					25	92	0.080
SAGINAW GOLD	22	2	1				25	88	0.160
AVANTI	22	2	1				25	88	0.160
MORNING GOLD	19	2	3	1			25	76	0.440
DUNDROD	11	3	7	3		1	25	44	1.240
BRODICK	1	2	0	4	3	15	25	4	4.040
SFA									
ND01496-1	25						25	100	0.000
NY95	25						25	100	0.000
NDA2031-2	25						25	100	0.000
ND2676-10	23	1	1				25	92	0.120
ND2417-6	22	1	2				25	88	0.200
NY102	22	1	2				25	88	0.200
SNOWDEN	19	4	2				25	76	0.320
NORCHIP	19	2	2	1	1		25	76	0.520
SUNCRISP	18	4		2	1		25	72	0.560
ATLANTIC	16	3	5	1			25	64	0.640
B0178-34	12	9	3	1			25	48	0.720
ND2471-8	15	4	3	1	1	1	25	60	0.880
AF875-15	9	5	5	4	1	1	25	36	1.440

[a] Average Number of Bruises Per Tuber

1994 BLACKSPOT SUSCEPTIBILITY STUDY

A. SIMULATED BRUISE SAMPLES

VARIETY	NUMBER OF SPOTS PER TUBER 0	1	2	3	4	5+	TOTAL TUBERS	% BRUISE FREE	AVE[a]
ADAPTATION									
AF1433-4	21	3	1				25	84	0.200
MSB027-1R	16	6	3				25	64	0.480
MSB105-3	16	6	2	1			25	64	0.520
MSB095-2	10	7	3				20	50	0.650
B0257-12	11	10	3	1			25	44	0.760
NDA2031-2	13	6	2	2	1		24	54	0.833
MSC103-2	12	6	3	4			25	48	0.960
MSC086-3	10	7	6	2			25	40	1.000
B0585-1	8	10	5	2			25	32	1.040
SUPERIOR	10	5	5	5			25	40	1.200
AF1470-17	11	2	9	2	1		25	44	1.200
MSA091-1	9	4	9	3			25	36	1.240
MSC147-3	10	5	5	4	1		25	40	1.240
B0257-9	12	4	3	3	3		25	48	1.240
MSB0952-1	11	7	4	4	1	1	28	39	1.286
NY101	8	5	8	3	1		25	32	1.360
MSB094-1	8	7	6	1	2	1	25	32	1.400
MSA105-1	10	4	5	4	1	1	25	40	1.400
AC83306-1	9	3	3	1	2	2	20	45	1.500
MSC125-1	7	4	2	3	2	1	19	37	1.579
B0585-5	8	6	4	3	3	1	25	32	1.600
MSB110-3	5	8	4	7	1		25	20	1.640
C080011-5	8	3	6	5	2	1	25	32	1.720
MSA097-1Y	7	2	5	6	2		22	32	1.727
B0174-16	3	7	11	1	2	1	25	12	1.800
MSB107-1	7	5	5	3	4	1	25	28	1.800
MSB083-1	5	4	6	7	2	1	25	20	2.000
ND01496-1	7	4	5	2	5	2	25	28	2.000
B0493-8	3	5	8	4	4	1	25	12	2.160
B0564-9	4	3	8	5	3	2	25	16	2.240
MSC135-2	2	1	3	3	3		12	17	2.333
MSC029-1R	4	1	7	8	5		25	16	2.360
ATLANTIC	6	2	5	4	5	3	25	24	2.360
SNOWDEN	2	2	7	6	4	4	25	8	2.800
B0339-1	4	2	2	7	3	6	24	17	2.875
MSC135-5	3	2	5	7	5	5	27	11	2.889
B9922-11		1	7	9	4	4	25	0	3.120
MSB1254-1	2	1	4	6	6	6	25	8	3.240
MSNT-1	3		4	5	5	7	24	13	3.250
ND860-2	1	2	4	5	5	8	25	4	3.400
B0405-4	0	1	4	5	9	6	25	0	3.600
MSB106-8	2	1	2	2	7	11	25	8	3.760

Funding: Federal Grant

THE EFFECT OF SEED CLASS ON THE PERFORMANCE OF ATLANTIC AND SNOWDEN

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Introduction

Tissue culture technology combined with limited generation seed potato production has dramatically increased throughout the U.S. during the past decade. Seed stocks of known disease freedom can now be rapidly propagated and increased. From a commercial growers perspective, very little research has been conducted to determine the true yield potential that can be expected. There have been many inferences made regarding perceived benefits from lower years-in-the-field seed, however, unless all variables of length of growing season, storage, handling, seed warming and seed size are not a factor, the results may not be valid. Dr. Robert Coleman at the University of Wisconsin has a similar study underway using Red Norland, Atlantic and Superior. He noted seed lots closer to tissue culture emerged faster and appeared more vigorous early in the season, however, final stand at six weeks after planting was not affected by years in the field. He also noted that yields of U.S. No. 1 potatoes declined linearly at rates between 2 to 3% per year for Red Norland and Atlantic. Yields of Superior declined for the first three years and then appeared to level off.

Procedure

In the late spring of 1991, greenhouse tubers, year 1 and year 2 seed was obtained for Atlantic and Snowden varieties. The seed was grown at the Lake City Experiment Station under uniform conditions, harvested and stored uniformly. The growing crop was monitored for any visual symptoms of diseases. Following storage at 40°, the seed was removed in 1992, warmed, cut to a uniform size and hand planted at the MSU Montcalm Research Farm. Each variety was planted as a separate, randomized complete block with six replications. Each plot was 23 feet in length. Planting and harvest dates were similar for each of the three years.

New greenhouse tubers of Atlantic and Snowden were obtained in 1992 and were again increased at the Lake City Station along with Nuclear and GI tubers retained from the previous years crop. The process was repeated in 1993 providing consistent seed stocks for the three year study.

Results

Visual observations of the plantings in 1992, 1993 and 1994 showed no marked or consistent differences in stand or vigor. There was no evidence of any visual disease symptoms in 1992 and 1993, however, there was evidence of Verticillium wilt noted in 1994 which is attributed to the erratic growing season. The incidence was fairly general and did not relate to any specific seed class. It appeared to be field related and was most severe in the Snowden trial.

The yield results for the three year study for Atlantic and Snowden are shown in Table 1. For Atlantic, there was a 10% yield reduction for Generation I and II when compared with nuclear planted seed. Yield results were very similar between Generation I and Generation II. For Snowden, there was only a 3% yield reduction for Generations I and II when compared with Nuclear seed.

Table 1. Marketable and total yield of Atlantic and Snowden when planted to different seed classes.

Seed Class Planted	Year	Atlantic (cwt/A)		Snowden (cwt/A)	
		No. 1	Total	No. 1	Total
Nuclear	1992	416	438	214	285
	1993	478	508	427	474
	1994	408	458	305	364
Average		434	468	315	374
Gen I	1992	395	408	198	261
	1993	399	432	418	464
	1994	376	429	300	366
Average		390	423	305	364
Gen II	1992	366	386	193	253
	1993	425	448	415	451
	1994	375	433	311	374
Average		389	422	306	359

Funding: MPIC

MID SEASON NITROGEN MANAGEMENT COMPATIBLE WITH HIGH POTATO YIELD, TUBER QUALITY AND ENVIRONMENTAL CONSTRAINTS 1994

M. L. Vitosh, G. H. Silva, D. R. Smucker and D. A. Hyde

INTRODUCTION

Our approach to N management research is based on increasing the efficiency of both soil N and fertilizer N to ultimately achieve an overall reduction in N fertilizer use on potatoes. Previous research has shown that split applications of N, with a portion applied at planting and the balance applied during the growing season, is more efficient than a large one time application. However, research has also indicated that even with moderate to high N application rates prior to tuber initiation, full season potato varieties can still be subjected to late season N deficiencies. Faced with the likelihood of economic yield losses, many Michigan growers resort to N applications in July and August, to maintain healthy foliage activity for an extended period of time.

Currently, there is a debate as to whether or not late season N applications are effective in improving yield and quality. Some growers who have used late season N have experienced problems with delayed vine senescence and lack of response to vine killers. A reasonably accurate time limit for N application needs to be established. In addition there are concerns that mid to late season N may also enhance N losses to the environment.

Our strategy for determining in-season N requirements relies heavily on petiole sap nitrate testing. A critical level of 1000 ppm has been established as an adequate mid-season nitrate N level and the test is now calibrated for several potato varieties. This test can serve as a valuable decision support tool for supplementary N application to potatoes.

Specific Objectives:

(a) To establish a time frame during which N applications to potatoes are profitable;

(b) To study the impact of mid-season N application on sap nitrate N, potato yield, and tuber quality;

(c) To asses the environmental impact of mid-season N application as it relates to residual soil nitrate N and leaching losses.

MATERIALS AND METHODS

A nitrogen fertilizer trial was conducted at the Montcalm Research Farm on a Mcbride sandy loam soil under irrigation. Seven N treatments (Table 1) were evaluated on 2 varieties, Snowden and R. Burbank. Treatments 1, 2, and 3 received 280 lb N/A, but the times of application were different. Treatments 4, 5, and 6 received 160 lb N/A with different times of application. Treatment 7 received 80 lb N/A at planting, with additional N requirements being based on the petiole sap nitrate test. All N treatments were evaluated in a randomized complete block design with 4 replications. The N source at planting was urea (46-0-0). The balance of N was supplied as ammonium nitrate (34-0-0). At planting, P and K (0-26-26) was applied at the rate of 115 lb/A, according to MSU recommendations. The soil pH was 5.7. The soil test at planting showed 2.5 ppm NO_3-N (10 lb N/A) and 3.5 ppm NH_4-N (14 lb N/A) in the top foot.

Petiole samples from all plots were taken once a week starting on June 28, and continued for 6 consecutive weeks. The samples were taken in the morning hours and consisted of 15-20 petioles from the fourth or fifth fully expanded leaf. The sap was squeezed in a zip lock bag and mixed with an extraction solution consisting of aluminum sulfate and boric acid. The nitrate N concentration was determined with a Hach-one ion-specific electrode. At harvest, soil samples were taken to a depth of 2 feet, in 1 foot increments, to assess soil N residue in each treatment.

RESULTS AND DISCUSSION

The trial was harvested on Sept 12. Tubers were graded according to size to determine the percent of US # 1 and total yield. Specific gravity was determined by weighing tuber samples in air and water.

Sap nitrate N in response to N fertilizer rate and time of application

The sap nitrate N (SNN) concentration for treatments that received 280, 160, and 190 lb N/A are shown in Figures 1, 2, and 3, respectively. The SNN level was below the adequate range on June 28 and July 5 in all 7 treatments. The 1994 season was characterized by an unusually wet summer. Between May 5 and June 30, 8.5 inches of rainfall was received at the site (Figure 4). A large portion of fertilizer N was applied during this period. Presumably, much of this N was lost from the root zone due to leaching. To raise SNN levels to the adequate range, 40 lb N was applied through the irrigation system to all treatments on July 9.

The SNN concentration in T1, T2 and T3 (280 lb N/A), showed a period of recovery on July 19 (Figure 1) when it reached the adequate range. T1 which received no further N after July 9, showed a steady decrease in SNN concentration after July 19. The supplementary N in T2 and T3 helped to maintain satisfactory SNN levels for the balance of the season. Nitrogen application to T3 on August 2 showed up in the August 9 sap test. The overall SNN levels for T4, T5, and T6 (160 lb N/A) were lower compared to T1, T2, and T3 (Figure 2). July 19 was the only date when the SNN concentration reached the adequate range during the season.

T7 received supplementary N on June 30 following the June 28 SNN test raising the SNN concentration to the adequate range on July 12 (Figure 3). An additional 40 lb N/A was applied through the irrigation system on July 9 and helped to maintain the SNN level in the adequate range until July 26. On August 2, the SNN level for this treatment dropped below the adequate range at which time an additional 30 lb N/A was applied. On Aug 9, the SNN level was elevated to the borderline range.

Of all the N treatments, only T2 and T3 produced mean SNN greater than 1000 ppm (Tables 2 and 3).

Nitrogen fertilizer rate and tuber yield

The US #1 yield for Snowden at 280 lb N/A was significantly higher compared to 160 and 190 lb N/A (Table 2). The oversized tuber yield and specific gravity was also substantially higher with higher N rates. The US #1 yield in Russet Burbank at 280 lb N/A was significantly higher than 160 lb N, but not 190 lb N/A. The higher N rates also increased Russet Burbank tuber size. The time of N application within each N rate (160 or 280 lb/A) did not significantly affect tuber yield.

Soil N Residue

Soil test data at harvest showed greater N residues in treatments where N fertilizer was applied late compared to early (Tables 2 and 3). Those treatments that received split N particularly on August 2, had the most residual N at harvest time. This N is very susceptible to leaching during winter and early spring.

CONCLUSIONS

Sap nitrate N level in plant tissue early in the growing season just after tuber initiation, is critically important for high quality tuber yields. Levels should be maintained at or above 1000 ppm for at least 40 days after tuber initiation. Ideally, treatment 7 should give the best results, but due to the extreme wet conditions in 1994, it was difficult to maintain the SNN level above 1000 ppm. Under more normal conditions, however, we believe that sap nitrate testing will provide growers with the best information to minimize their N fertilizer inputs and reduce potential leaching losses. Applications of N in August probably have little affect on tuber yields and quality, and will only add to potential nitrate leaching losses after harvest. The planting of cover crops immediately after harvest should help to reduce nitrate leaching losses. Ideally, these cover crops should be established without additional N fertilizer to maximize the recovery of residual N.

Table 1. Nitrogen application rate and schedule - Montcalm 1994

Treat. #	5/5[1]	6/14[2]	6/30	7/9[3]	7/12	8/2	Total
	------------------------------lb/A -----------------------						lb/A
1	80	160	-	40	-	-	280
2	80	80	-	40	80	-	280
3	80	80	-	40	40	40	280
4	40	80	-	40	-	-	160
5	40	40	-	40	40	-	160
6	40	40	-	40	20	20	160
7	80	-	40	40	-	30	190

[1]At planting; [2]At tuber initiation; [3]Unscheduled application due to low sap nitrate levels.

Table 2. Mean sap nitrate N, tuber yield, specific gravity and soil nitrate N at harvest - Snowden 1994

Treat #	Mean Sap nitrate N (ppm)	Tuber Yield Oversized	US # 1	Total	Specific Gravity	Soil N03 residue lb/A-2ft
		----------------- cwt/A ----------------				
1	907 b[1]	49.0 a	316.0 a	336.4 a	1.082 a	60 b
2	1108 a	45.4 a	326.7 a	351.5 a	1.079 ab	124 a
3	1076 a	30.4 ab	296.8 a	320.6 a	1.081 a	123 a
4	754 c	11.1 b	203.8 c	226.2 c	1.077 b	59 b
5	906 b	18.6 b	227.7 bc	252.6 bc	1.076 b	77 b
6	781 c	12.1 b	202.3 c	221.8 c	1.077 b	78 b
7	972 b	25.4 b	253.6 b	281.0 b	1.080 ab	82 b

[1]Treatment means followed by different letters are significantly different (p=0.05).

Table 3. Mean sap nitrate N, tuber yield, specific gravity and soil nitrate N at harvest - R. Burbank 1994

Treat #	Mean Sap nitrate (ppm)	Tuber Yield Oversized	US # 1	Total	Specific Gravity	Soil N03 residue lb/A-2ft
		---------------- cwt/A --------------				
1	997 bc[1]	12.7 abc	186.7 a	255.0 a	1.079 a	63 d
2	1115 a	16.2 a	198.2 a	259.6 a	1.076 ab	102 ab
3	1083 ab	14.9 ab	193.6 a	266.9 a	1.078 ab	119 a
4	749 d	5.6 c	130.9 c	189.3 c	1.077 ab	58 d
5	922 c	7.4 bc	148.5 bc	210.6 bc	1.076 ab	66 cd
6	737 d	4.6 c	130.4 c	198.3 c	1.075 b	89 bc
7	963 c	14.3 ab	178.6 ab	245.0 ab	1.079 a	75 cd

[1]Treatment means followed by different letters are significantly different (p=0.05).

Fig 1. Petiole sap nitrate N in treatments 1, 2 and 3 receiving 280 lb N/A

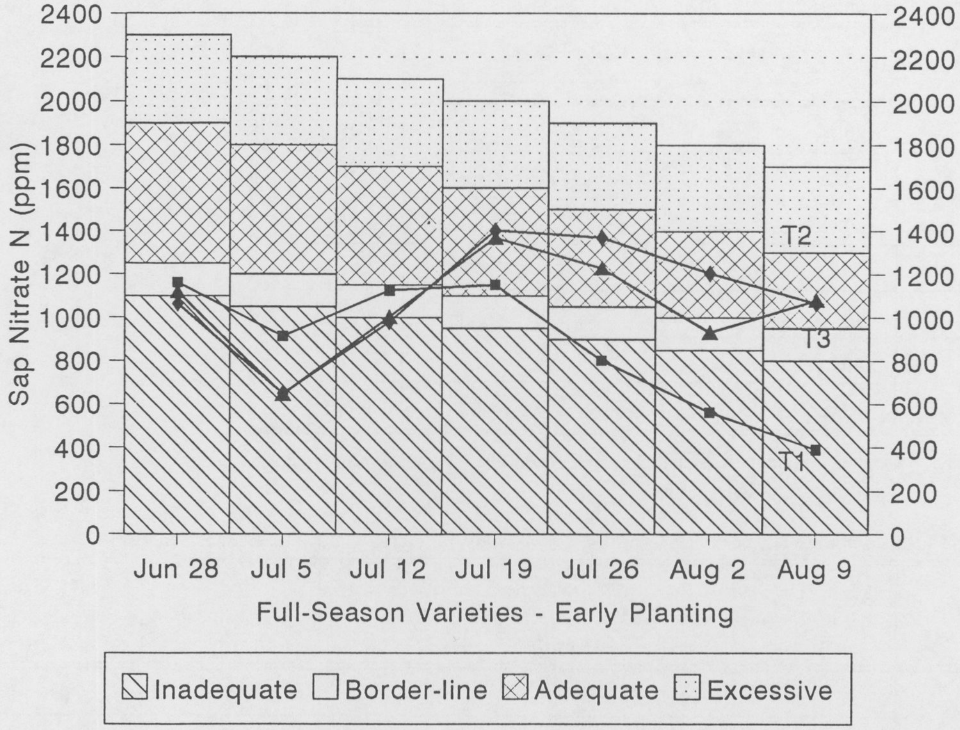


Fig 2. Petiole sap nitrate N in treatments 4, 5, and 6 receiving 160 lb N/A

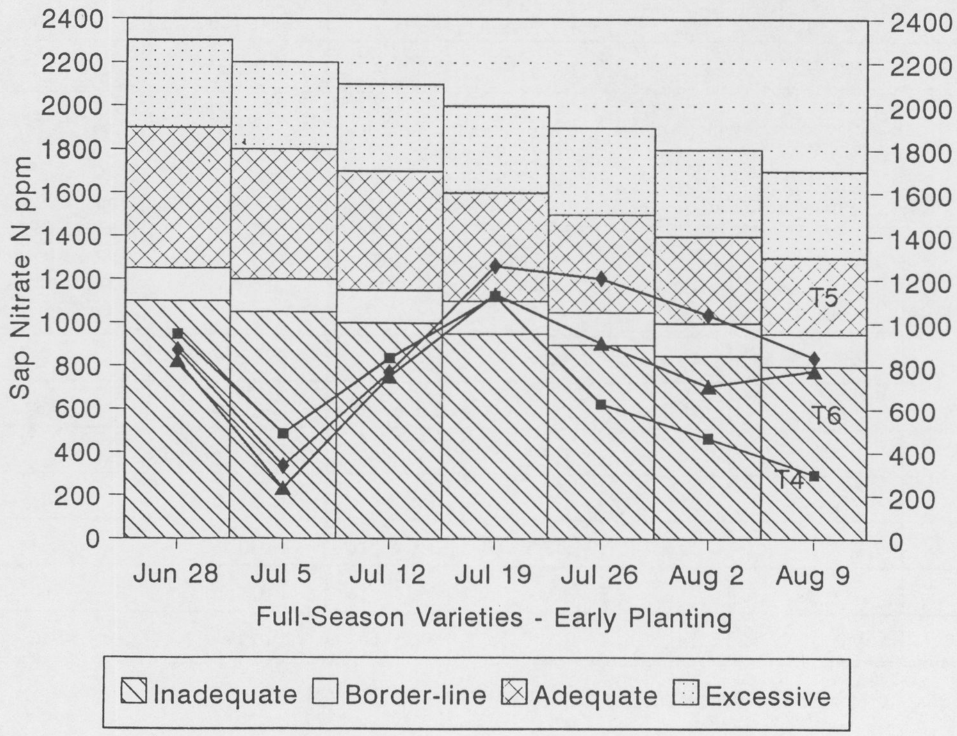


Fig 3. Petiole sap nitrate N in treatment 7 receiving 190 lb N/A

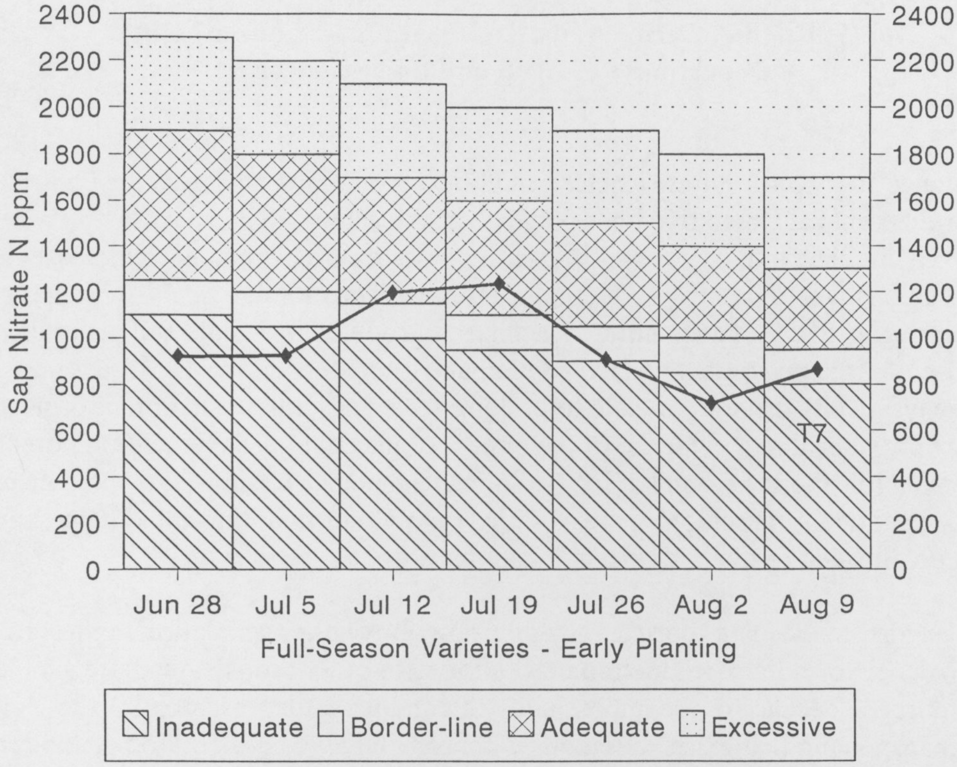
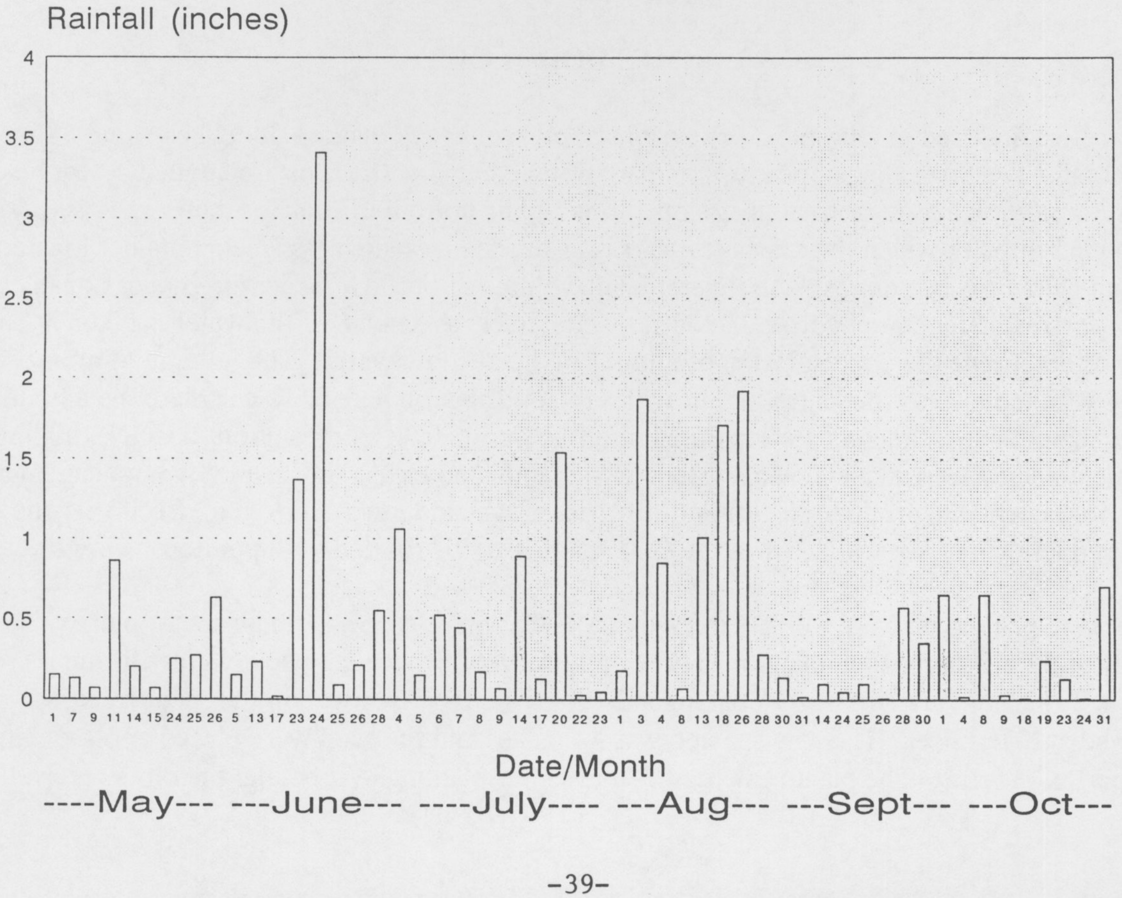


Fig. 4. Daily rainfall at the Montcalm Research Farm

May-Oct. 1994



Funding: MPIC

EFFECTS OF NITROGEN FERTILIZER MANAGEMENT ON NITRATE LEACHING

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This study was designed to monitor nitrate leaching in potato production to assess the contribution of various nitrogen fertilizer management practices on yields and leaching. The study is timely because potato production is relatively inefficient in use of N fertilizer and nitrates are beginning to increase in relatively shallow aquifers in regions where potato production is intense. The ultimate goal is to help develop nitrogen fertilizer strategies that minimize nitrate leaching to groundwater while still maintaining acceptable profitability. The use of large permanently installed drainage lysimeters allows the direct measurement of nitrate leached. The lysimeters make it possible to do long-term and year around monitoring of nitrate leaching. This study provides direct evidence of the impact of nitrogen management on potential groundwater contamination and the results of long-term management decisions. As the concern for groundwater quality in agricultural regions increases, this type of information should help quantify the actual contribution on nitrogen fertilizer to groundwater nitrates.

The study is also designed to evaluate the accuracy of crop-soil-weather simulation models to predict the yield and nitrogen balance for potato production in rotation with other crops. Accurate simulation models are needed for this purpose because of the impossibility to conduct actual research for the wide variation in soils, weather and management that exists in regions within Michigan where potato production is important. The goal for the simulation models is to be able to take the known soil properties of any farm field and the known year-to-year weather variability of the region and evaluate how various management practices will affect long-term yields, profitability and nitrate leaching.

METHODOLOGY

Two lysimeters are used in this study. They consist of steel boxes that are 48 inches wide, 68 inches long and 6 feet tall. The boxes have open tops and are installed so that the tops are about 1.5 feet below the ground surface allowing for normal tillage operations. The bottom of each lysimeter is closed except for a small opening through which the drainage water is channeled to a stainless steel container located to the side of and below the bottom of the lysimeter. The volume of outflow is measured occasionally while the drainage water is being pumped from the outflow container. A sample of the water is taken at each pumping to determine the concentration of nitrates in the outflow water. The volume of drainage, combined with the nitrate concentration, provides the information needed to calculate the amount of nitrate lost to leaching. The lysimeters are separated into two treatments, a conventional (CON), high nitrogen management and a better management system (BMS) intended to use the best known management practices for acceptable production without using excessive amounts of nitrogen. Each year the BMS plot has received less nitrogen fertilizer than the CON plot. Corn is rotated with potatoes every three years.

Potatoes were planted on May 5, 1994 following a 1993 potato crop. Both lysimeter plots were planted identically at the recommended plant density with the variety Snowden, a new variety for chip processing released in 1992. A starter fertilizer containing 36 lbs. N/acre was spread in the seedbed along with the recommended K fertilizer. The row spacing was 34 inches and the seed were placed approximately 12 inches apart in the row. The plants emerged 27 days after planting. At hilling, the plots received a sidedressing of 72 lbs/acre N. The CON plot received an additional 90 lbs/acre at a second sidedressing. The BMS plants received no additional fertilizer, following a strategy using a tactical "window" plot as detailed in the next paragraph.

To schedule nitrogen on the BMS plots, a small tactical window plot was established in the field containing the BMS lysimeter, but not over the lysimeter. The window plot received only the 36 lbs/acre preplant N treatment. When the window plot plants first became N deficient, as observed by their color and smaller size, some of the window plants were analyzed for N content to determine the total N amount they had taken up to that time. The amount of N found in the plants(51 lbs/acre) in addition to the 72 lbs/acre already applied to the BMS plot at hilling was considered adequate for producing yields of 400 cwt/acre if none was lost by leaching. Thus, no second sidedressing was applied.

Yield measurements were taken from an area directly over the top of each lysimeter and from two random sampling areas in larger locations of the plots.

FIELD RESULTS - 1994

This was not the best growing season for potato production at this location because of unusually high precipitation in June, July and August. The potato vines in the plot area were affected by verticillium wilt beginning about July 5, causing them to defoliate prematurely and reduce yields. The BMS yield averaged 323 cwt/acre with 258 cwt/acre #1 grade. The CON treatment yielded 360 cwt with 260 cwt/acre #1 quality. Thus the two treatments produced approximately the same marketable yields although the CON received 100 lbs/acre more N fertilizer. Because the lysimeter area is relatively small, these yield differences might be due to natural variation in soil, pest problems, or plant density, but it could represent a response to the mild end of season nitrogen deficit as compared to the well fertilized CON plants.

Drainage quantities for the two lysimeters was almost identical for the entire year totaling approximately 21 inches. The lysimeters are situated in similar soil profiles and received equal irrigation.

Nitrate leaching data are depicted in Figs. 1 and 2. During the course of the study, up until harvest, the concentration of nitrate in both lysimeters was about the same. The similarity in concentrations is thought to be the result from the 1993 treatments which were only 40 lbs/acre different in N fertilizer application and a potato N uptake difference of 22 lbs/acre in favor of the CON treatment. Thus, the N input minus the harvested N output (Table 1) was only 18 lbs/acre different in 1993. Furthermore, the fertilizer minus harvested N in 1993 of approximately 120 lbs/acre for both treatments caused the nitrate concentration and leaching to increase greatly following the mid-June rains of 1994. Previous years data have shown large differences in concentration between the treatments with the BMS always being lower when yields are about the same as found in this year, but the fertilizer rates were quite different than those of 1994. It is highly likely that the concentration difference will be different after sufficient water has drained through the soil to move the nitrates that are in the lower soil depths out of the profile and into the lysimeter drainage container. That will likely occur in the spring and summer of 1995 unless rains and snow are unusually high during the winter and spring of 1995. Leaching of N as measured with the lysimeters during 1994 has shown that the BMS plots had 52 lbs/acre leached and the CON plots had 57 lbs/acre leached. These figures may be somewhat inexact because the concentration of N since October 1994 has not yet been analyzed but extrapolated from August and September data.

Figure 1. Leaching nitrate concentration obtained for CON and BMS lysimeters. Montcalm Experiment Farm, 1994.

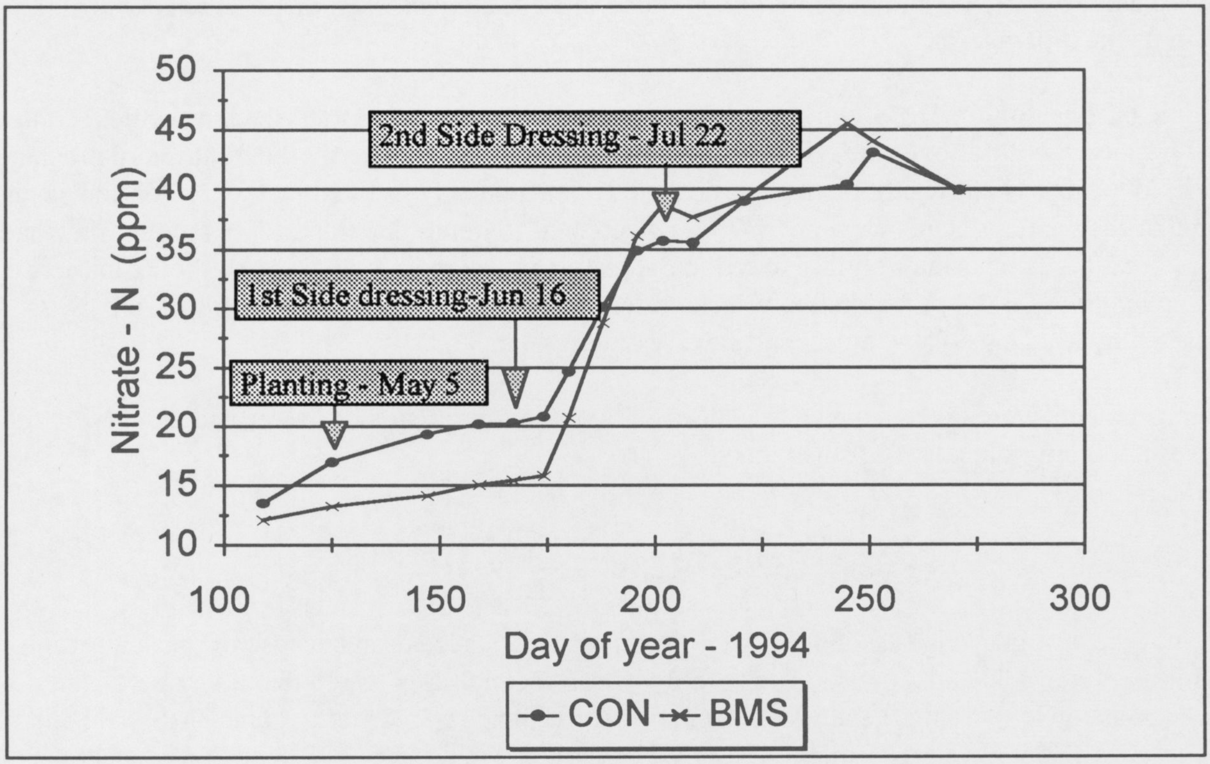
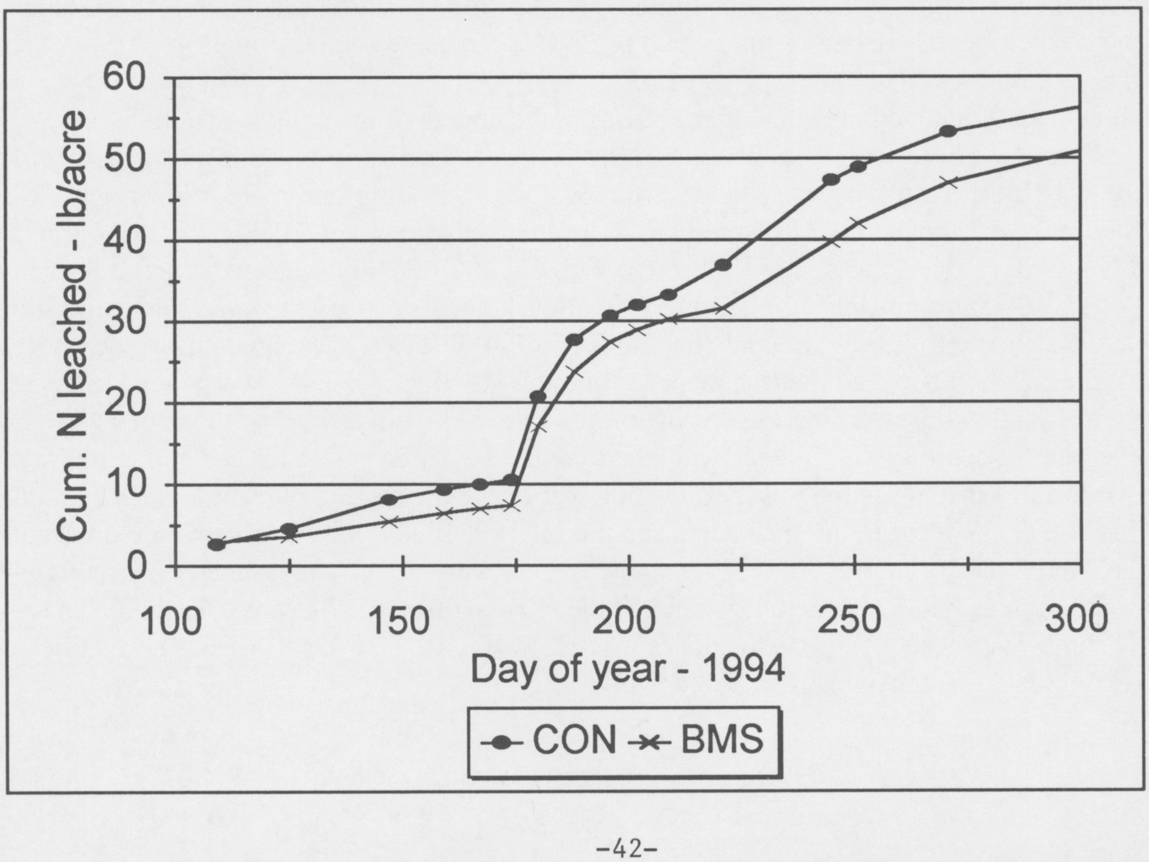
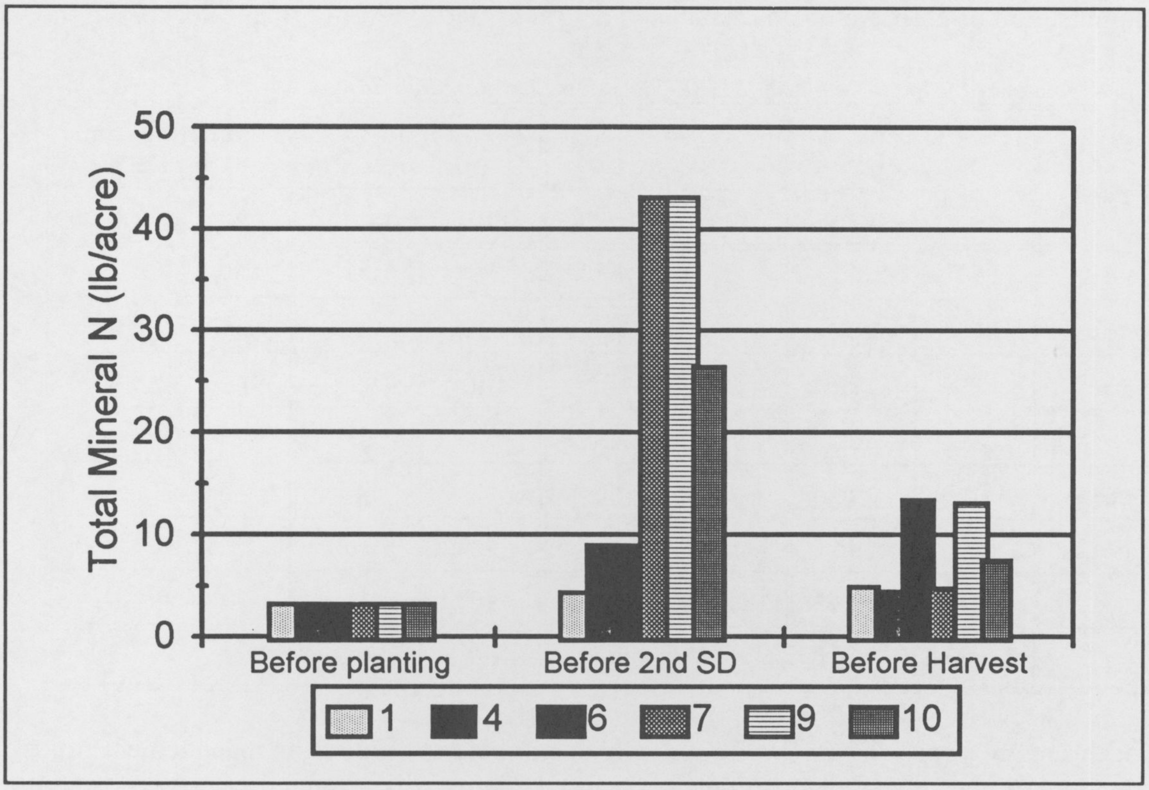


Figure 2. Cumulative nitrogen leached obtained for CON and BMS lysimeters. Montcalm Experiment Farm, 1994.



Measurements of soil NO_3 - N were made in plots near the lysimeter on three occasions during the year. The plots were a part of a tactical window study to determine how best to interpret and use tactical windows information. The results are shown in Fig. 3. The entire field was quite low in nitrates before the season began. The soil measurements indicate the response to different fertilizer applications. The significance of these data is that the almost 8 inches of rain that fell before the second sidedressing did not leach all the nitrogen out of the upper 18 inches of the soil because there were differences in soil nitrates related to the fertilizer treatment.

Fig. 3. Soil available N ($NO_3 + NH_3$) content (0-16 in) for six different nitrogen treatments: 1 - (36-0-4); 4 - (36-54-0); 6 - (36-54-36); 7 - (36-90-0); 9 - (36-90-54); 10 - (36-144-0). Numbers within parenthesis are N (lbs/acre applied at preplant, hilling and second sidedressing) Montcalm Experiment Farm, 1994.



MAIN RESULTS: 1988-1994

Studying data complied over a long period of time gives a better perspective on long-term trends and impacts than a single year study can. The goal of this study has always been to demonstrate that a reduction in nitrate leaching is possible by implementing more conservative fertilizer management. The study has been successful in that we have been able to significantly reduce nitrate leaching. However, what we have called the BMS treatments for the potatoes has usually resulted in unacceptably reduced yields when compared to the conventional CON treatments until this year. Diseases or other crop management problems have also caused a yield reduction for both the BMS and the CON treatments. We continue to seek the best methods for determining the BMS and believe the window plot concept may be the key to acceptable conservative fertilizer input strategies. The window plot strategy has been successful on seed corn and shown a capability to significantly reduce nitrate leaching. More work needs to be done to find the most simple window plot approach that can be used successfully on farm fields.

A summary of the annual results of the components of the N balance of potatoes and corn grown on the lysimeter since 1988 are shown in Table 1. As can be noted, the annual leaching and uptake data have been quite variable. The leaching variability results from quite large differences in rainfall amounts, especially during the non-growing season when large quantities of water drain through the soil, taking the nitrates that are in the upper part of the profile. Within all the variation, however, there has been a consistent reduction in nitrate losses resulting from the N treatments, averaging 25 lbs/acre annually more on the CON than the BMS plots. It should also be noted that there are relatively large leaching losses, even with lower inputs of N fertilizer. Leaching has averaged 82 lbs/acre for the BMS treatment. If potato yields had been nearer the average farm yield, it is highly probable that leached N would be lower in both treatments. The most significant result from this seven year research is the finding that the average annual leached N on the higher N level CON trateament was almost equal to the fertilizer input minus the harvested output. For plots that have slightly lower yields because of more conservative fertilizer management, the leaching is greater than the N input minus output to the field. The source of this N is probably a combination of N receipt from rainfall and net removal of N from organic sources in the soil.

TABLE 1. Annual N balance for lysimeter plots for 1988- 994. Montcalm Research farm.

Year	Crop Type	Fertilizer N lbs/acre		Harvest N lbs/acre		Leached N lbs/acre		Fert-Harvest lbs/acre	
		BMS	CONV	BMS	CONV	BMS	CONV	BMS	CONV
1988	Pot.	110	200	80	81	58	73	30	119
1989	Corn	130	200	100	106	200	215	30	94
1990	Pot.	110	193	68	102	110	160	42	91
1991	Pot.	125	200	51	79	74	84	74	121
1992	Corn	90	230	93	80	56	117	-3	150
1993	Pot.	158	196	46	68	23	40	112	128
1994	Pot.	107	196	111	133	52	57	-4	63
Averages		119	202	78	93	82	107	40	109

The results of this study, especially the 1994 results, indicate that better nitrogen management can reduce nitrate leaching. BMS management has produced a marked decrease in nitrate concentration and total losses most of the time. Use of tactical window plots seems to be a realistic method to determine the amount of fertilizer to use on a second, after hilling sidedress application. Further research and demonstrations using all techniques possible to assist in determining the balance between input and acceptable profitability is needed.

Funding: Nowlin Chair

MANAGEMENT OF THE NITROGEN FERTILIZATION BY WINDOW PLOTS

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ABSTRACT

Nitrate contamination of ground water is becoming a serious problem and agriculturists and environmentalists have been focusing their attention on improving nitrogen (N) fertilizer management strategies. The objective of this study was to evaluate the value of window plots as a tool to optimize the third N fertilizer application for potatoes. This third application follows an application at planting, and at hilling. A window plot is one that received less fertilizer than the remainder of the field when the plants in the window plot become deficient. Their N uptake time will serve as an indication of the amount of fertilizer N is needed for the third application. The N window technique uses changes in leaf color as the key parameter in determining when N deficiency occurs in the window plot.

The field experiment was conducted in 1994 at the Montcalm Research Farm in Entrican, Mich. The soil is a sandy-loam, typical of many potato fields in this region. The variety used was Snowden, a late maturing variety for chip processing. Ten different N treatments were used. Three were considered as window plots, with a low N fertilizer level (36-0; 36-40; 54-0 lbs/acre at planting and hilling). The others were tested as potential optimum N fertilization management. For the two first applications, three plots received a total of 90lbs N/acre, three others received 126 lbs N/acre, and the last plot received 180 lbs N/acre. According to the leaf color in the three window plots, and their N uptake, the other seven plots received a third application. Total N for these treatments were 90, to 180 lbs/acre.

Unfortunately, verticilium disease caused premature defoliation of the plots, resulting in no measureable response of the third application. The results showed that the first two N applications influenced the tuber's size, but not the number.

Keywords: Potato, N, fertilization, plant response fertilization, N window, timing, *Solanum tuberosum.*

INTRODUCTION

Applying N in possible excess has been one common way to ensure good yields. It is an inexpensive insurance to guard against any N deficit that might occur during the growing season. For potato, crop recovery of fertilizer N is generally low (Legg, 1982). Much of this non-recovered fertilizer N is lost from denitrification, immobilization or by leaching out of the root zone to eventually reach the groundwater (Keeny, 1982). Today, the nitrate contamination of groundwater is an important pollution problem. Although legislation set an upper limit of 10 ppm in Michigan's public drinking water, many sites are over that limit. In Montcalm County, in Central Michigan, 7% of the wells were above the limits in 1984 (Vitosh, 1985).

High nitrates in groundwater results from a combination of soil and weather conditions and the kind of cultivated crops grown in the region. In 1990, ten thousand four hundred acres, or more than 5% of the total cropland, were used for potato production (Chase, 1992). Nitrate problems often occur with this crop due to the shallow depth of the crop's root system (Bishop and Grimes, 1978) and planting in a sandy soil which is the most appropriate for tuber growth. In addition, potatoes are susceptible to drought and water stress (Augustin, 1977) and the required irrigation (Ojala, 1990) increases the N leaching risk (Roberts, 1972; Painter, 1973).

Nitrogen management is based on stage of potato development and physiological responses to available soil N (Westermann, 1985, 1988). Thus, to optimize N uptake, potato fertilization is split into three applications: at planting, at hilling and a second side dressing (Krishnappa, 1990). The third application is usually done about 80 days after planting (DAP), which corresponds with the beginning of tuber bulking stage. Sixty to 70% of the total N uptake by the crop occurs through early and mid-tuber bulking (Ojala, 1990). Thus, the third application of N fertilizer must be added by the beginning of bulking to be available for the plant at the right time.

The aim of this study was to optimize the third N application according to the N window method. This is a qualitative way to estimate the N status of the crop, because N stress causes leaf discoloration. With an increasing N deficiency, leaves become more and more chlorotic (Ojala,1990). Such a window is created by reducing the rate of application of N on a small area of the field. If the foliage discoloration does not become visible on the window plots by the second sidedressing date, additional N is not needed. (Vos and Marshall,1993).

MATERIALS AND METHODS

Field plots were established at the Montcalm potato research farm, near Entrican, Mich., in 1994, on a McBride sandy loam soil. The variety used was Snowden, a new variety for chip processing released in 1992 that was estimated to be 60% of the Michigan chip potato acreage that year. Ten different N amounts were applied as given in to Table 1. Plots 1 to 3 were used as experimental N window plots, with low N levels (36-0-0; 54-0-0; 36-36-0; lbs N/acre, at planting, at hilling, and second side dressing). Two N levels, 90 and 126 lbs/acre after the first side dressing, were tested. A last treatment received 180 lbs N/acre to allow potential yield.

According to a light green appearance of the leaves on the three first treatments, a second side dressing was applied on the tested treatments, as shown in Table 1.

Table 1. Nitrogen amount (lb/acre) per treatment. Montcalm Experiment Farm, 1994.

1994 Treatment	Planting Day 0	1st Sidedressing Day 42	2nd Sidedressing Day 78	Total
1	36	0	0	36
2	54	0	0	54
3	36	36	0	72
4	36	54	0	90
5	36	54	18	108
6	36	54	36	126
7	36	90	0	126
8	36	90	27	153
9	36	90	54	180
10	36	144	0	180

For each treatment, three replications were used, on a randomized complete block design. Potatoes followed a first year potatoes, on blocks 1 and 2, and maize, on block 3. Individual plots were 4 rows wide by 10 plants long, including 2 border rows and 2 border plants at the extremity of each row. Seed pieces were hand-planted on May 5, to a 4 inch depth. Emergence was 27 DAP. Row spacing was 34 inches and seed spacing was 12 inches apart. N applications were hand-made on the rows, with ammonium-sulfate [18-9-9] at planting and with urea [41-00-00] for the two side dressings (followed by irrigation). All preplant treatments, 215 lbs/acre of potash [0-0-54], and postplant treatments (herbicides and pesticides), were determined according to the recommendations found in Michigan State University Extension bulletins. Irrigation was supplied with overhead sprinkling. The vines were killed 111 DAP and tubers were manually harvested 126 DAP, September 8. The N soil content was studied for six treatments at three times, with the KCl extraction method. Soil samples were taken on each 8 inches down to 32 inches, two times on the row for each plot, on the three replications per treatments. Stem samples were collected every week, one per replication for each treatment study, and N was analyzed with the Kjeldahl Test. A notation for the color stress intensity was established using a scale 0 to 30, as a function of the percentage of chlorotic leaves and of the yellowish intensity, for each treatment. Each plot received a notation from 0 -all leaves having a green (138-A, 137-B, R.H.S. Color Chart)- to 30 when 100% of the leaves were light green (146-D).

The statistical analysis was a two-way analysis of variance over the replication and the treatment variables. Significantly different means ($P<0.05$) between treatments were separated using the Duncan's Multiple Range Test except for use of the Least Significant Difference Test when less than six treatments were included.

Assuming that fertilizer N becomes available soon after application, the available soil N (A) for the plant results from soil gains and losses, which can be given by :

$$A = F + M - I - L - V - U$$

where F is fertilization amount, M is the mineralization of the organic matter, I is immobilized by micro-organisms or clay, L is leached, V is volatilized, and U is plant uptake. All factors except F and U are difficult to determine, and have large variability from one year to the next. The N window method assumes that M, I, L, V, and U are the same in the main field and on the window plot until the deficiency occurs.

To decide the management of the second side dressing, we considered F as the N amount on the main field after the first side dressing (F = 90 or 126 lbs/acre, see Table 1). The window plots received F-X (X = 18, 36 and 54 or 90) lbs/acre. According to the potato growth stage, it is possible to evaluate the daily N uptake rate (r) on both plots and determine how many days (X/r) N is still available for the plant if none is lost by other processes. The beginning of tuber bulking initiation was around 45 DAP (Oliveira, unpublished). An average N uptake rate of 2.7 lb. N/acre/day was assumed during this stage (Ojala, 1990).

RESULTS AND DISCUSSION

Table 2 shows harvest data for all treatments. Tuber total and US#1 (> 2 inches) yields had the tendency to increase by N fertilization, from 224 to 350 cwt/acre for the total yield, and 115 to 295 cwt/acre for the US#1 yield. However, no significant yield difference between treatments, 4 and higher, were shown. Only the three window plots differed significantly, with low yields as expected. N treatments did not affect the dry-matter percentage which varied between 21.09 to 23.45%.

Yellowish upper leaves were first observed on June 23, (50 DAP) on the window plots 1 and 2, and 71 DAP on plot 3 (Fig. 1). By this day, plots 1, 2 and 3 had each received 36, 54, and 72 lbs. N/acre. On plots 4, 5 and 6 that had each received 90 lbs N/acre, a discoloration was not expected for at least a week and it was not expected on plots 7, 8, 9 and 10 for an even longer time. However, six days later all plots but plot 10, had upper leaves that were yellowish possibly because of the large leaching losses. If tested treatments are interpreted correctly, only the two first N applications, at planting and at hilling, were effective. Soil N analysis, shown in Fig. 2 helps confirm that fact. Two sets of treatments, (6, 7 and 9, 10), received a total amount of 126 and 180 lbs N/acre. However this was split in three applications for the first treatment, and in two for the second. During the N stress, observed before the second side dressing, the plants were more susceptible to diseases (Ojala, 1990), such as verticillium (Davis, 1994). In fact, signs of verticillium appeared around 60 DAP, and increased after that time. This disease probably decreased the capacity of the plant to uptake the N that was available in the soil.

Figure 1. Leaf discoloration intensity for different N treatments. Color stress intensity is built on a scale considering 0 for all leaves having a green 138-A, 137-B (R.H.S. color chart) and 30 for all leaves having a green 146-D.

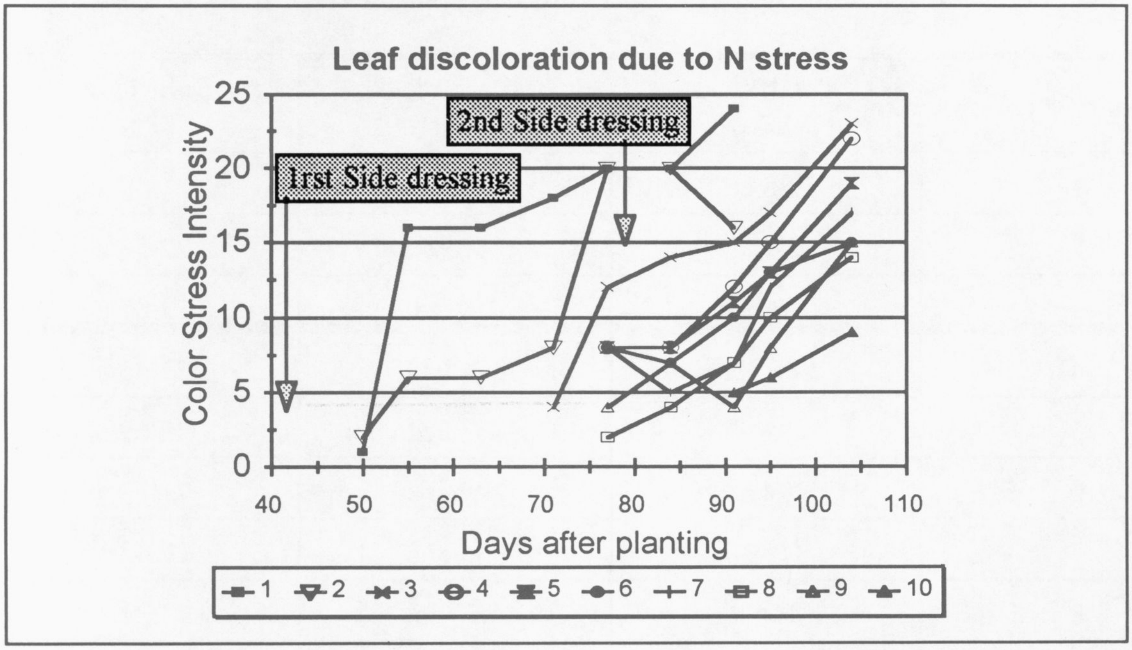
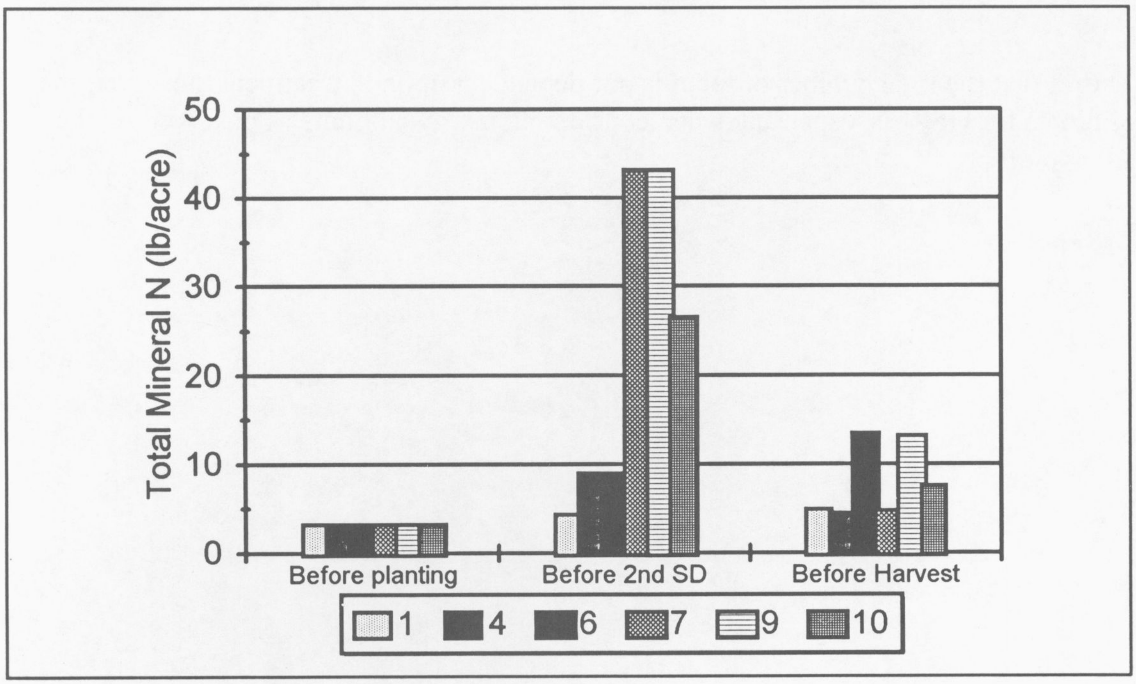


Figure 2. Soil N content (0-16 inches) for treatments 1, 4, 6, 7, 9 and 10. Montcalm Experiment Farm, 1994.



The light greenness for the plots 6 and 9 was not influenced by a second side dressing (Fig. 1). By comparing this with treatments 7 and 10, the yield was less when the N application was split into three applications. This comparison and the fact that there was no significant difference between treatments 4,5,6,7,8 and 9 confirms the inefficiency of the second side dressing (Table 2) in this case. This would likely not be true had the verticillium problem not been so great.

Table 2. Average yields and dry matter for the different treatments.

Treatment Number	Total Yield cwt/acre	US #1 Yield cwt/acre	Dry Matter %
1	228 cd	150 de	21.09 a
2	224 d	115 e	22.58 a
3	272 bcd	192 cd	22.07 a
4	286 abc	214 bcd	23.45 a
5	297 ab	217 bcd	22.69 a
6	294 ab	229 abc	21.79 a
7	311 ab	235 abc	22.42 a
8	344 a	279 ab	23.21 a
9	321 ab	259 abc	22.49 a
10	350 a	295 a	22.56 a

Means with different letters within the columns are significantly different (Duncan's Test, p=0.05)

Table 3 shows that the total number of tuber is not dependent upon N treatment, however, the number of tubers for US#1 is, especially when considering low N amounts as observed on the three window plots.

Table 3. Number of tubers per plant as influenced by different nitrogen management treatments.

Treatment	Total Number of Tubers per Plant	US #1 Number of Tubers per Plant	% US #1
1	9.6 a	4.2 bc	40
2	10.2 a	3.0 c	29
3	9.6 a	4.4 b	46
4	10.0 a	5.5 ab	55
5	10.8 a	5.4 ab	50
6	10.0 a	5.5 ab	55
7	11.6 a	5.9 a	51
8	10.3 a	6.6 a	64
9	11.0 a	6.5 a	59
10	9.6 a	6.3 a	65

Means with different letters within the columns are significantly different (Duncan's Test, p=0.05).

Due to disease caused by verticillium for this experiment, we could not fully prove that the window plots are efficient to optimize the third N application. Additional research must be done on the problem in timing difference between the appearance of light greenness on window plots and on tested treatments according the pedoclimatic conditions. Care should be exercised with the use of window plots on places with a potential to develop N deficiency related diseases.

The suitability of this method for practical use still needs to be evaluated, and a better understanding is necessary of how fast plants can take up additional N from different forms and sources of sidedressing.

REFERENCES

Augustin, J.,R.E. McDole, G.C. Painter. 1977. Influence of Fertilizer, Irrigation, and Storage Treatments on Nitrate-N Content of Potato Tubers. Am. Potato J 54 : 152-136.

Bishop, J.C., D.W., Grimes. 1978. Precision Tillage Effects on Potato Root and Tuber Yield. Am. Potato J 55 : 65-69.

Chase, R.W. 1992. Potatoes. Michigan State University. Special Report 54.

Davis, J.R. et al.. 1994. Interactive Effects of Nitrogen and Phosphorus on Verticillium Wilt of Russet Burbank potato. Am. Potato J 71 : 467-481.

Gomez, K. and A., 1984. Statistical Procedures for Agricultural research.

Extension bulletin E-550A. 1992. Cooperative Extension Service, MSU. Fertilizer Recommendations for Field Crops in Michigan.

Extension bulletin 312. 1994. Cooperative Extension Service, MSU. Insect, Disease and Nematode Control for Commercial Vegetables.

Keeney, D.R. 1982. Nitrogen Management for Maximum Efficiency and Minimum Pollution. *In*: Nitrogen in agricultural soils.(F.J. Stevenson, Ed.). Agronomy 22: 605-650.

Krishnappa, K.S., P.M., Gowda, H.V., Sulladmath. 1980. Influence of Split and Foliar Application of Nitrogen on Potato Yield in Sandy-loam Soils of Karnataka. J. Indian Potato Ass. 7 (2) : 79-83.

Legg, J.O., J.J. Meisinger. 1982. Soil Nitrogen Budgets. In : Nitrogen in agricultural soils (F.J. Stevenson, Ed.). Agronomy 22: 503-566.

Ojala, J.C., J.C. Stark, G.E. Kleinkopf. 1990. Influence of Irrigation and Nitrogen Management on Potato Yield and Quality. Am. Potato J 67 : 29-43.

Painter, C.G., D.V. Naylor. 1973. Loss of Nitrate-Nitrogen and Soil Sediments from Water Run-off and Movement of Nitrate-Nitrogen in Soil From Furrow Irrigation of Potatoes in Southwestern Idaho. University of Idaho Agri Exp Sta Progress Re No.166.

R.H.S. Colour Chart. from the Royal Horticultural Society LONDON.

Roberts, S., J.E. Middleton. 1972. Environmental Consideration in Nitrogen-Irrigation Management for Potato Production on Sandy Soil. Proc Annu Pac Northwest Fert Conf 23 : 53-62.

Vitosh, M.L. 1985. Nitrogen Management Strategies for Potato Producers. Extension Bulletin WQ09. Michigan State University, East Lansing, MI, USA.

Vos, J., B., Marshall. 1993. Nitrogen and Potato Production : Strategies to Reduce Nitrate Leaching. 12th triennial conference of the European Association for Potato Research, Paris, France, 18-23 July 1993 :101-110.

Westermann, D.T., G.E. Kleinkopf. 1985. Nitrogen Requirements of Potatoes. Agron J 77 : 616-621.

Westermann, D.T., G.E. Kleinkopf, L.K. Porter. 1988. Nitrogen Fertilizer Efficiencies on Potatoes. Am. Potato J 65 : 377-386.

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Colorado Potato Beetle Management
1994 Potato Research Report

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Summary:

Colorado potato beetle research in 1994 focused on 1) Limiting dispersal of overwintered Colorado potato beetle from rotated fields and to new potato fields, 2) Factors influencing overwintering survival and spring emergence of Colorado potato beetle and 3) Evaluation of insecticides for control of Colorado potato beetle.

The size, type (species), and density (within-row and row spacing) of the rotational crop influenced the ability of overwintered Colorado potato beetles to disperse from the rotated field and find new potatoes. Host plants (volunteer potatoes) in the rotated field delayed and reduced dispersal from the field. An integrated "managed rotation" system that included a densely-planted rotational crop, volunteer potatoes in the rotational crop, and weekly treatments of "barrier rows" of potatoes with repellent fungicides both reduced colonization of rotated potatoes and restricted movement of colonizing Colorado potato beetles.

In studies of the effect of soil type and presence or absence of cover on overwintering survival of Colorado potato beetle, survival was very low. The highest survival was in muck soil. In laboratory studies, both the temperature at which beetles overwintered and the length of diapause influenced overwintering survival.

Several different insecticides showed good control of Colorado potato beetle larvae. These treatments included both preplant and foliar Admire, Agri-Mek, Cryolite 96WDG, fipronil, preplant fosthiazate with foliar treatments of Asana and piperonyl butoxide, and Raven (2 qt/A). The plots in which these treatments were applied resulted in significantly fewer large larvae than untreated plots and all had 5% or less defoliation. Yield was highest in fosthizate (6.4 lb AI/acre) with 4 foliar applications of Asana and PB0 and Admire (preplant). Increased yield in fosthiazate plots may have been due, in part, to nematode control provided by this chemical. The yield in Agri-Mek, Cryolite 96WDG and M-Trak treated plots may have been lower due to a high number of potato leafhoppers.

Factors influencing dispersal of postdiapause Colorado potato beetles

In 1994, we concluded a project on making crop rotation a more effective management tool for Colorado potato beetle. Research has focused on learning what factors influence the ability of overwintered Colorado potato beetles to disperse from rotated fields and find and colonize new potato fields. Crop rotation is one of the most effective cultural controls of Colorado potato beetles. Adult beetles overwinter in the soil, and when they emerge in the spring they must move to a food source. Rotation, in effect, removes their food source and forces overwintering Colorado potato beetles to find new food. However, crop rotation has it's limits, especially when the new potato field is close to the rotated field. In such cases, it takes little time for Colorado potato beetles to find the new field. In addition, crop rotation alone may increase the spread of insecticide resistance by forcing beetles to disperse. We have, in essence, been looking for ways to reduce or delay the beetles' ability to find and colonize new potato fields and to keep more of the beetles in the rotated field. We have investigated how the size, type (species), and density (both within-row density and row spacing) of the rotational crop affects the ability of Colorado potato beetle to disperse from the rotated field. We have researched the ability of host plants (volunteer potatoes) to keep overwintered Colorado potato beetles in the rotated field rather than dispersing to the new potatoes. And, we have studied the ability of potentially repellent fungicides to limit movement of Colorado potato beetles in potatoes.

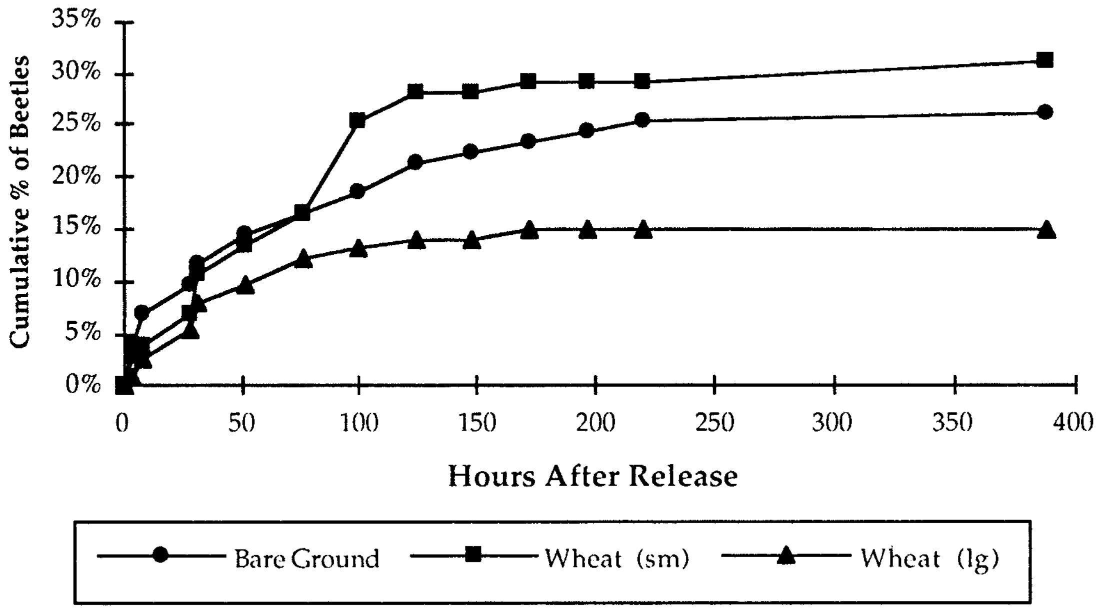
Crop rotation continues to be an effective management tool for Colorado potato beetle, especially with the registration of Admire. Rotation of potato fields into a dense, early-emerging crop, such as wheat or rye and including a food source (such as volunteer potatoes or tuber) in the rotated crop can reduce Colorado potato beetle dispersal out of the crop, thus reducing colonization of new potato fields and limiting the spread of any resistance genes.

Type and Size of Rotational Crop. The effect of the type (species) of rotational crop planted, and the size of that crop, on dispersal of overwintered Colorado potato beetles out of the rotational field was investigated in field and greenhouse experiments in 1992 and 1993. Marked beetles were released in the center of experimental plots containing peas, wheat, corn, or bare ground. Plots were surrounded by potatoes. Both the plots and surrounding potatoes were searched at intervals for marked beetles.

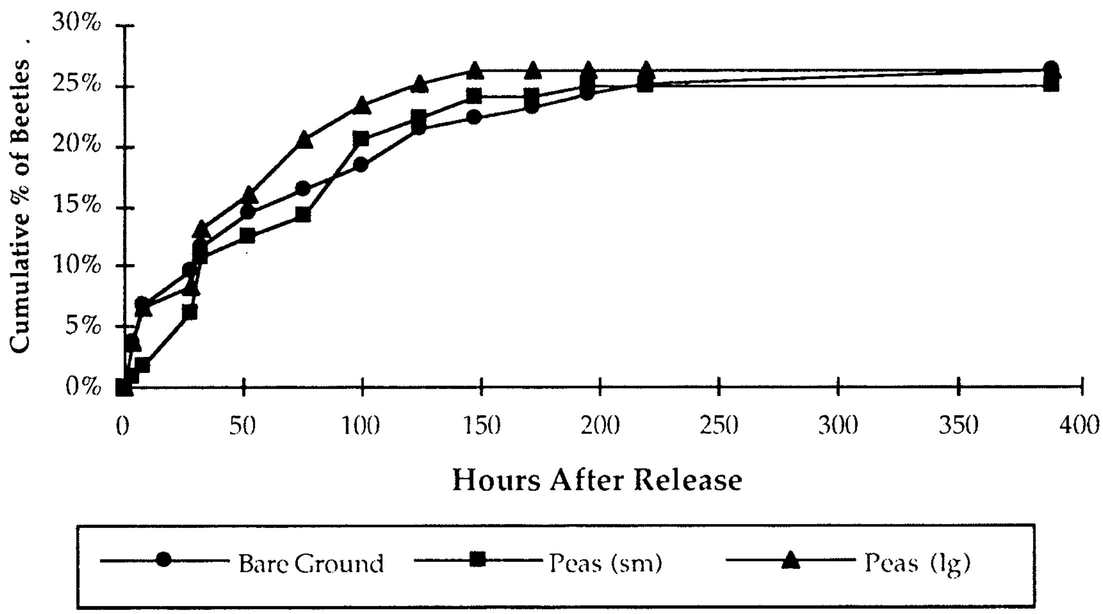
Crop size affected Colorado potato beetle dispersal from rotated fields by both walking and by flight. The effect was dependent on the type of crop and the mode of movement. Dispersal by flight out of plots and colonization of surrounding potatoes was inhibited by larger size in wheat plots, but size increased dispersal by flight out of corn and pea plots. Larger size in these latter two crops may have provided a better "platform" for flight initiation for the beetles. Larger size inhibited dispersal by walking out of corn, peas and wheat in greenhouse experiments, but had the same effect only in pea plots in field experiments.

The effect of crop type (species) on Colorado potato beetle was dependent on the size of the plants and the mode of movement. In general, however, wheat inhibited Colorado potato beetle dispersal more than peas or corn.

In sum, both rotational crop type and size influence the Colorado potato beetles ability to disperse from the rotational crop and find new potato fields. The exact effect depends on an interaction of the crop type, size and the beetle's mode of movement. Overall, densely-planted crops, such as wheat, seem to reduce dispersal the most. Fall-planted wheat or rye grass would be a good rotational crop for potato fields that were heavily infested with Colorado potato beetles the previous season, as these crops are both densely-planted and would be fairly large in the spring by the time the beetles start emerging from overwintering.



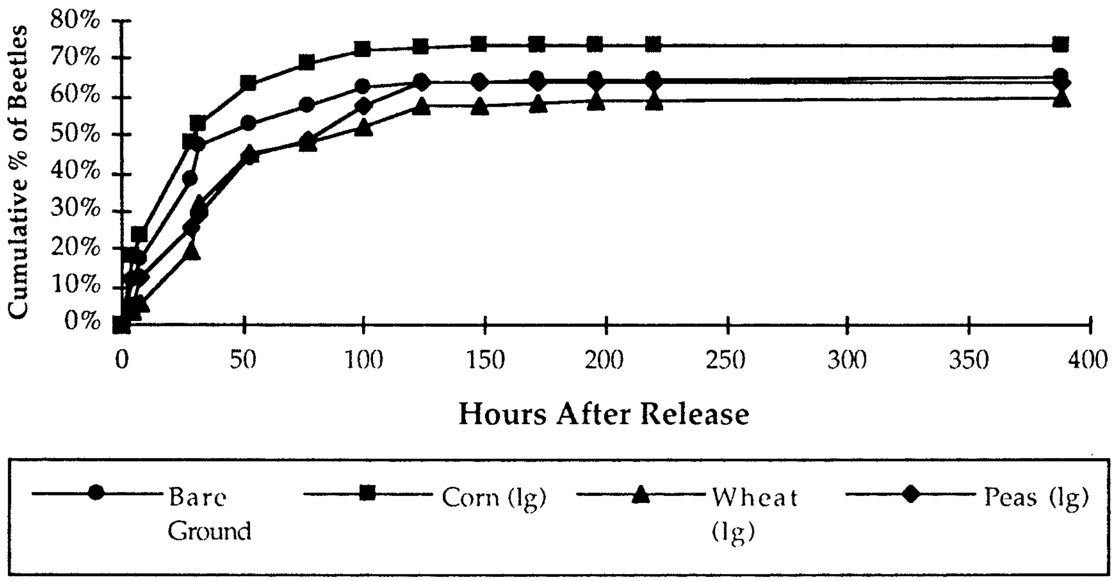
Cumulative percent of Colorado potato beetles released into plots containing small wheat, large wheat, or bare ground that reached surrounding potatoes by flying.



Cumulative percent of Colorado potato beetles released into plots containing small peas, large peas, or bare ground that reached surrounding potatoes by flying.

Effects of Increased Size of Rotational Crops on Colonization of Nearby Potatoes by Overwintered Colorado potato beetle

	Flying Only	Walking Only	Walking and Flying
Peas	increase	decrease	decrease
Wheat	decrease	increase	no difference
Corn	slight increase	increase	increase

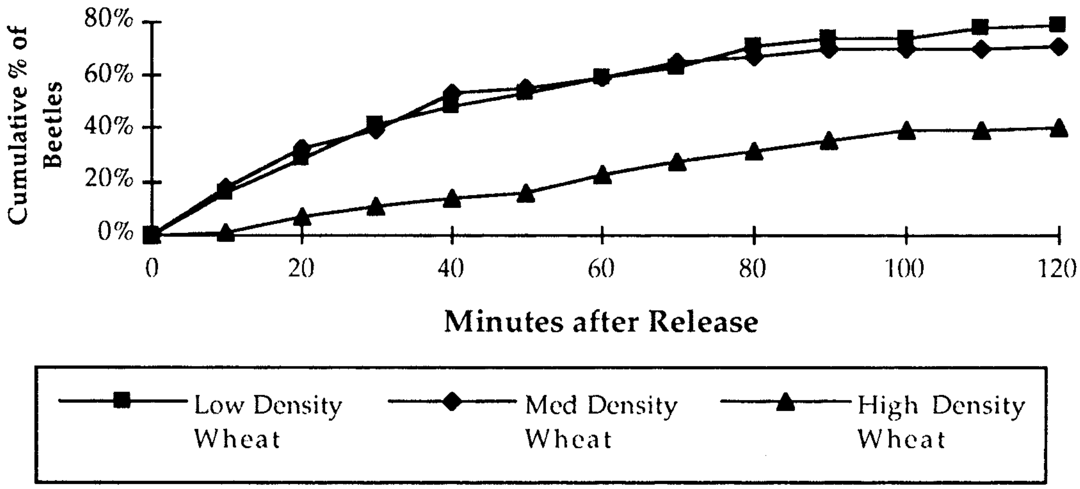


Cumulative percent of Colorado potato beetles released into plots containing corn, wheat, peas, or bare ground that reached surrounding potatoes by walking and/or flying.

<u>**Density of Rotational Crop**</u>. Because of the apparent effect of crop density we noted in previous experiments (see above), in 1994, we directly tested the effect of rotational crop density on Colorado potato beetle dispersal out of the crop. Colorado potato beetles were released in the center of simulated rotated fields (wooden arenas, 0.9 m x 0.9 m), in the greenhouse. Arenas were made of four pine boards, 2.5 cm x 20.3 cm x 0.9 cm nailed together to form a frame. Black visquine was stapled to the inner side of the frame and painted with Fluon® to prevent beetles from climbing out of the arena The arena floor consisted of nine rows of nine each of square green plastic pots (10.2 cm) filled with standard potting soil. Potting soil was added to overflowing, so that the edges of the pots did not show. Some of the pots contained plants, depending on the treatment. Each pot on the outer edge of each arena contained a sprig of potato. At 10 minute intervals following release, both the "field" and the surrounding potatoes were searched for marked beetles. All beetles found on potatoes were removed. The experiment continued for 2 hr. Every time the experiment was performed, each arena contained a different treatment. Treatments were replicated by repeating them on three different days.

The first experiment tested the effect of wheat density on Colorado potato beetle dispersal. Each arena contained seven rows of wheat. Within-row wheat density was 2 plants, 4 plants, and 16 plants per 10.2 cm of row for the low, medium and high-density treatments, respectively.

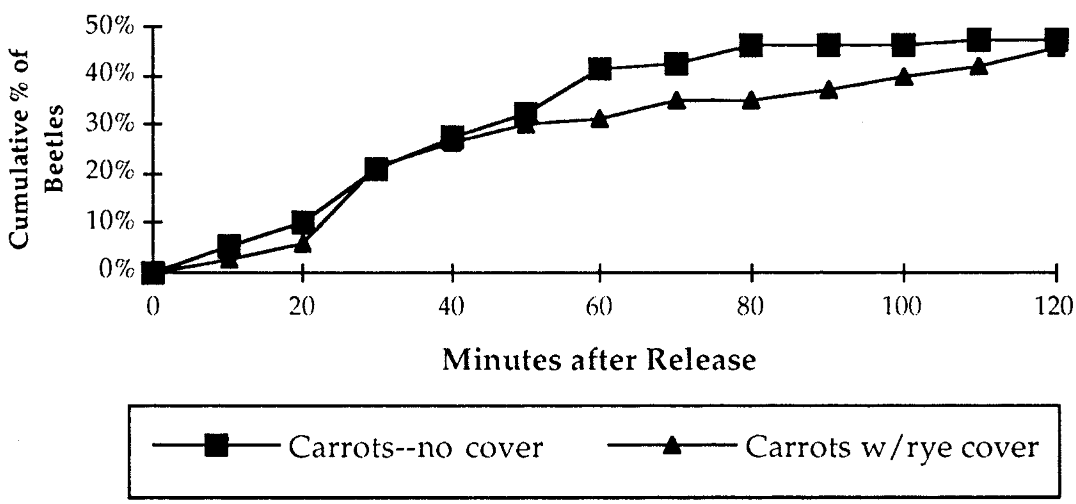
The high density wheat dramatically delayed and reduced Colorado potato beetle dispersal out of the plot. There were no differences between low and medium density wheat.



Cumulative percent of Colorado potato beetles released into arenas containing wheat planted at different within-row densities that reached surrounding potatoes

The second experiment tested the effect of a rye-intercrop with carrots. The rye treatment contained four rows of carrots alternating with rows of rye. The no-cover treatment contained four rows of carrots only. Within and between-row carrot density was the same in both treatments. There was, therefore, twice as many plant rows (carrots + rye) in the rye treatment than in the no cover treatment.

Rye interplanted with carrots delayed and reduced dispersal of Colorado potato beetles out of the plot. This indicates that both within-row plant density and row spacing has the potential to affect Colorado potato beetle dispersal.

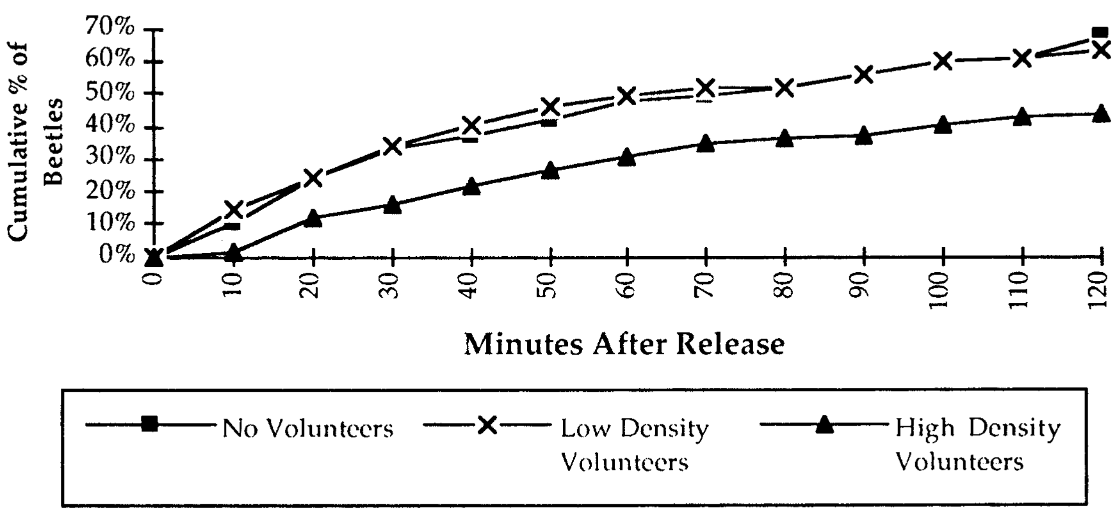


Cumulative percent of Colorado potato beetles released into arenas containing carrots either interplanted with rows of rye, or without, that reached surrounding potatoes.

These results, taken with previous results, indicate that densely-planted rotational crops reduce Colorado potato beetle dispersal from rotated fields and colonization of new potato fields. Dense planting reduces dispersal, in part, by increasing the Colorado potato beetles time "exploring" the rotational plants. A higher percentage of beetles in the plot at any given time were found climbing on plants (vs. on the soil) in more dense plantings. These results may also help explain why wheat seems to be more effective at inhibiting Colorado potato beetle dispersal, as wheat is typically planted more densely (both within and between rows) than the other crops tested. It also suggest that dense intercroppings, such as rye with carrots, may also reduce or delay beetle dispersal.

Effect of Hosts in Rotational Crop. In 1994, we continued our investigations on the effect of hosts (potatoes) in the rotational crop on dispersal by Colorado potato beetle. Experiments were conducted in the greenhouse. Wooden arenas, described above, were modified so that they were 1.8 m x 0.9 m. Inner walls were treated with black visquine and Fluon ®, as described above. Inside the arena, five rows of corn (17 plants per row) alternated with four rows of potting soil alone. The four rows of bare soil in each arena contained either six potato sprigs (high density volunteers), two potato sprigs (low density volunteers), or no potatoes (no volunteers). Perpendicular to the corn rows, at one end of the arena was a row of nine potato plants. Marked beetles were released on the opposite side of the arena. Arenas and potatoes were checked at 10 minute intervals for marked beetles. Any marked beetles found on the end row of potatoes were removed.

The presence of six potato sprigs in the arena (high density volunteers) dramatically reduced and delayed the number of beetles reaching the potatoes. This result, in combination with results from previous experiments we have reported previously, shows that the presence of food (volunteer potatoes in particular) in the rotational crop has the effect of retaining the beetles in the rotational crop and preventing or delaying their arrival at the new potato field.



Cumulative percent of marked Colorado potato beetles released into simulated corn fields containing no volunteer potatoes, a low density (2) of volunteer potatoes, or a high density (6) of volunteer potatoes that moved out of the corn field and reached a row of potatoes.

Crop Rotation Systems to Reduce Colorado Potato Beetle Dispersal:

We conducted field experiments in 1994 integrating several factors that we had found to influence Colorado potato beetle dispersal. Experiments were conducted at the MSU Montcalm Research Farm, Entrican, MI. Plots were set up along the border of rotated rye potato fields. The rye field had been in potatoes in 1993, and had been planted to rye in the Fall of 1993. The rows of rye ran parallel to the rye/potato border. The potato field had not been in potatoes in 1993. Twelve rows of potatoes (Snowden) were planted parallel to the rye-potato border. Each plot was 12m along the potato-rye border, with 3m between plots. There were two treatments, with four replications per treatment.

Treatments consisted of managed rotation and conventional rotation. In the managed rotation, the rye field was left intact, and two rows of volunteer potatoes, 20 cm plant spacing, were planted in the rye parallel to the rye-potato border 1.5m and 3m from the rye border. In addition, the third, fourth and fifth rows of potatoes were sprayed at weekly intervals with Kocide DF ® (3 lb/Acre at 50 gpa) with a hand-held CO_2 sprayer. Previous experiments had shown this compound to be the most effective of those tested at serving as a barrier to Colorado potato beetle movement into potatoes.

Conventional rotation treatment had nothing sprayed on the potatoes, no volunteers in the rye and ca 2/3 of the rye was removed, to represent a less dense planting of rye.

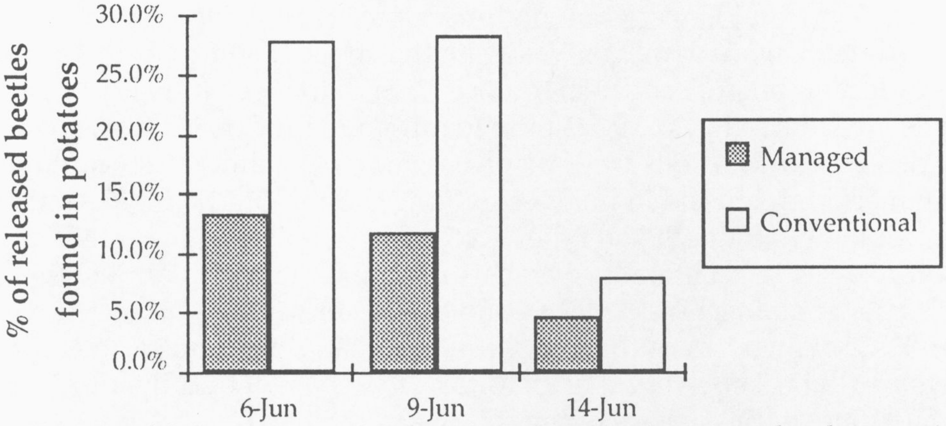
To discourage beetle movement from plot to plot, the 3 m border between plots in the rye was hoed.

Beetles were collected from the research farm, marked according to date and plot, and released at a point in the center of the plot and 20 ft from the rye-potato border. Six rows of the potatoes opposite each plot were searched for marked beetles at various intervals following the releases.

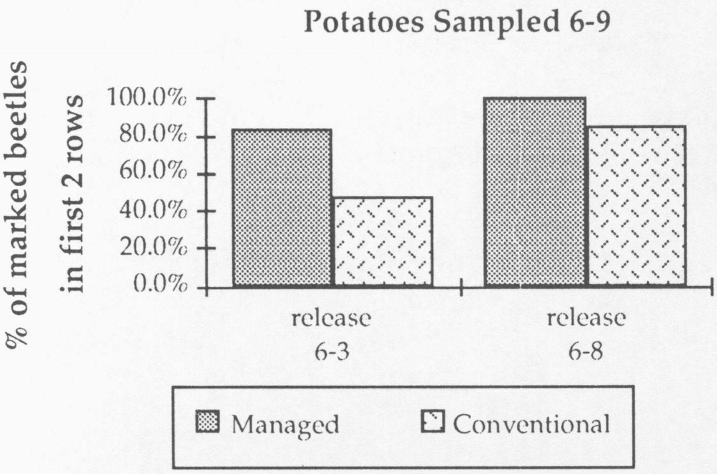
Results were very promising. More marked beetles from conventional rotation plots were found in potatoes than from the managed rotation. This includes both beetles found in potatoes opposite from the rye plots they were released into and beetles that were found opposite plots other than the ones they were released into (indicating that these beetles traveled farther). These effects lasted quite a while. For example, differences were still apparent up to eleven days after the beetles were released. These plots were very small, compared to commercial potato fields, and we might expect even larger effects in these situations.

These results indicate that the combination of denser rye and volunteer potatoes in the rye inhibited dispersal of the beetles from the rye. We believe that the denser rye, in addition to inhibiting dispersal, may have increased beetle mortality in the rotational crop.

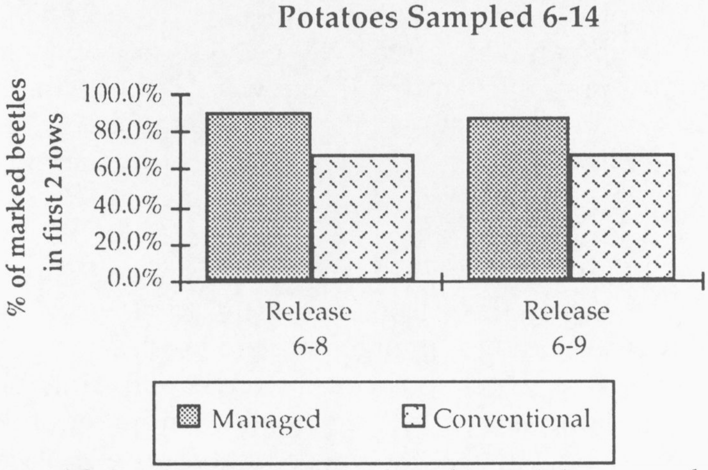
Of the beetles found in the potatoes, a higher percentage were found on rows 1 and 2 in the managed rotation than in the conventional rotation. This indicates that the copper fungicide served as a "barrier" to beetle dispersal into the potatoes. While this "barrier" did not prevent all beetles from crossing, it did have an impact. Such a "barrier" could serve to confine a most of the colonizing Colorado potato beetles to the field borders. Control measures could then be concentrated on these areas, saving both time and money.



Percent of Colorado potato beetles released into rye in managed and conventional rotations that were found on potatoes on different days. Beetles were released on June 3.



Percent of Colorado potato beetles released into rye in managed and conventional rotations that were found on the first two rows of potatoes on June 9. Rows 3,4 and 5 of the potatoes were sprayed with a repellent fungicide (Kocide DF) on June 8.



Percent of Colorado potato beetles released into rye in managed and conventional rotations that were found on the first two rows of potatoes on June 14. Rows 3,4 and 5 of the potatoes were sprayed with a repellent fungicide (Kocide DF) on June 8.

Effect of Soil Type and Cover Crop on Emergence from Diapause:

Experiments were done to investigate the effect of soil type and cover on timing of Colorado potato beetle emergence from diapause. In Fall 1993, soil was collected. from Montcalm Co., MI (sandy loam), Ingham Co., MI (clay loam,) and Clinton Co., MI (muck).. Soils were placed in large (46.2 liter) trash containers, and these containers were placed in holes dug in the ground on the MSU campus. There were nine containers for each soil type. Rye seed was planted in 6 of the containers of each soil type Three containers of each soil type remain unplanted. Pre-diapause beetles (120 per container) were placed on the soil surface and provided with food (cut tubers). Containers were covered with fiberglass screening secured with elastic. Containers were checked every day, or so, for dead beetles and the number of living beetles remaining on the surface of the soil was recorded.

Screen covers were removed during the winter and replaced in the spring. A few of the containers flooded during Winter and Spring of 1994, and these were not included in the data. Containers were checked for beetles several times each week beginning in May. All living and dead beetles found on the soil surface were collected.

Percent emergence (of the number of living beetles going into diapause in the fall) was extremely low. Percentages ranged from 5.7% (for muck soil with no cover) to 0.8 % (for sandy loam soil with no cover).

Average Percent Emergence from Diapause of Colorado Potato Beetles

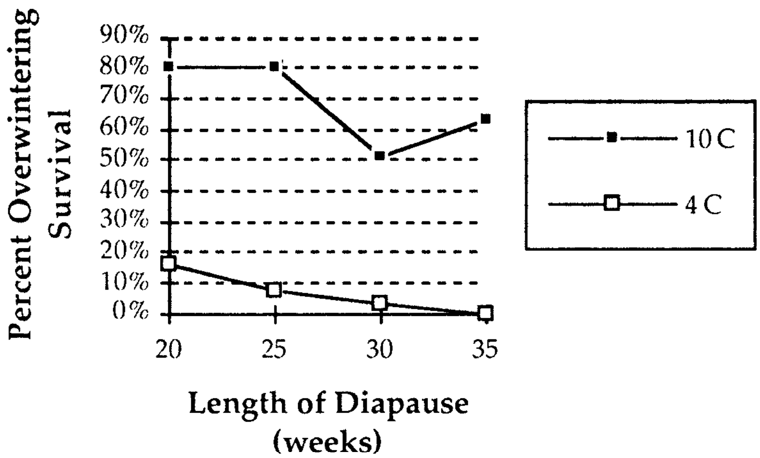
Soil Type	With Rye Cover	Without Cover
Clay	1.1%	2.0%
Sandy Loam	2.4%	0.8%
Muck	4.8%	5.7%

Effect temperature and length of diapause on overwintering survival and spring emergence of Colorado potato beetle.

In fall of 1993, field-collected, pre-diapause beetles (50 per container) were placed on standard potting soil contained in clay pots. The pots were covered with fiberglass screening and placed in a growth chamber (11 C, 8:16 L:D). Beetles that did not enter diapause were removed after 1 week. Pots were then assigned to a treatment and placed in a growth chamber. There were eight treatments, including: diapause temperatures (4 C or 10 C) and 4 lengths of diapause (20, 25, 30, and 35 weeks). There were 3 replications per treatment and each replication had 1 to three pots per replication.

In the spring and summer of 1994, pots were removed at the appropriate times, the soil watered lightly, and the pots left at room temperatures. Pots were checked every day for beetles on the soil surface. After three weeks, pots were emptied and the soil was searched for living and dead beetles.

Both the temperature at which the beetles were kept during diapause and the length of diapause affected the survival. A much higher number of beetles survived at the higher temperature (10C) than at the lower temperature. Survival decreased with length of diapause at both temperatures.



Percent survival of diapausing Colorado potato beetles stored at different temperatures for different lengths of time.

Results are too preliminary to extend to the field. However, these results do suggest some interesting questions. Obviously, Colorado potato beetles in overwintering diapause in the field do survive at temperatures of 4C and lower. Perhaps it is the length of time (20 weeks) at such a low temperature that causes such high mortality. Also, in our experiment beetles were exposed to constant temperatures once they entered diapause, and this is obviously not the case in the field. These results do suggest, however, that in years when the winter is long and beetles are in diapause for extended periods of time that survival is lower. This has not been tested in the field.

Evaluation of insecticides for Colorado potato beetle control. 'Snowden' variety potatoes were used to test nineteen insecticides for control of Colorado potato beetle at the MSU Montcalm Research Farm in Entrican, MI. Potatoes were planted on 4 May (12 inches apart, 34 inch spacing in plots 40 feet long by three rows wide). Two treatments were applied on the day of planting: fosthiazate in-furrow treatments were incorporated into the soil through rototill and an Admire treatment was applied in-furrow on the potato seed with a CO_2 backpack sprayer (8005 flat fan single nozzle, 30 psi). Foliar treatment applications were applied on 16, 23 June, 1 and 7 July using a tractor-mounted sprayer (30 gal/acre, 40 psi). Preplant fosthiazate treated plots also received foliar treatments of Asana and piperonyl butoxide (PBO). Rain occurred on the 24 June and 7 July within hours after spraying. Two randomly selected plants from the middle row of each plot were sampled for Colorado potato beetle on 21 and 28 June, 5 and 12 July. Defoliation assessment was done on 28 June, 5, 8 and 12 July. Plots were sprayed 13 July with Imidan and PBO (except for two of the Agri-Mek plots) to control summer adults emerging from poor treatments and migrating toward other research plots. All plots were sprayed for the same reason with Agri-Mek on 23 July and 11 August. Potatoes in the middle row of each plot were harvested on 2 September.

The number of large Colorado potato beetle larvae per plant peaked around 21 June. The seasonal mean of large larvae was higher in untreated than any of the treated plots. A number of treated plots had significantly fewer large larvae than untreated plots including those sprayed with both preplant and foliar Admire, Agri-mek, Cryolite 96WDG, fipronil, fosthiazate (12.8 lb AI/acre) with foliar Asana and PBO, fosthiazate (6.4 lb AI/acre) with 4 applications of foliar Asana and PBO, and Raven (2 qt/A). The seasonal means for these treatments were all under 10 large larvae per plant. Defoliation ratings over the season show higher damage in untreated plots than treated. After 5 July, untreated plots were almost entirely defoliated and the number of larvae decreased with the decrease in food supply. Plots treated with insecticides which resulted in significantly fewer large larvae than untreated plots all had 5% or less seasonal defoliation, as well as plots treated with Fosthiazate (3.2, 4.8 and 6.4 lb AI/acre) with 3 applications of foliar Asana and PBO. Yield was significantly lower in untreated plots than in any of the treated plots. Fosthiazate (6.4 lb AI/acre) with 4 applications of foliar Asana and PBO and Admire (preplant) had the highest yields. Increased yield in fosthiazate plots may have been due, in part, to nematode control provided by this chemical. The yield in Agri-Mek, Cryolite 96WDG and M-Trak treated plots may have been lower due to high numbers of potato leafhoppers. These plots had significantly higher numbers of potato leafhoppers than untreated plots.

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Treatment	Rate lb (AI)/acre	Mean no. of potato leaf hoppers/plant ± SEM[1]				
		21 Jun	28 Jun	5 Jul	12 Jul	Seasonal
Untreated		0.0 ± 0.0	2.8 ± 2.4	0.0 ± 0.0	0.0 ± 0.0 a	0.7 ± 0.6 abcde
Imidan 70WP &	1.0	0.0 ± 0.0	0.5 ± 0.5	0.0 ± 0.0	0.0 ± 0.0 a	0.1 ± 0.1 a
piperonyl butoxide (PBO)	0.5					
Imidan 70WP,	1.0	0.0 ± 0.0	1.3 ± 1.2	0.5 ± 0.5	1.0 ± 1.0 abc	0.7 ± 0.4 abcde
PBO & Sevin XLR Plus	0.5, 1.5					
AC303,630	0.01	0.3 ± 0.3	0.0 ± 0.0	0.5 ± 0.5	0.0 ± 0.0 a	0.2 ± 0.2 a
AC303,630	0.05	0.3 ± 0.3	0.0 ± 0.0	0.5 ± 0.5	1.0 ± 1.0 abc	0.4 ± 0.3 abcd
AC303,630	0.75	0.5 ± 0.3	0.5 ± 0.5	0.5 ± 0.5	0.3 ± 0.2 ab	0.4 ± 0.2 abcde
Admire 240FS[2]	0.2	0.5 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0 a	0.1 ± 0.1 a
Admire 240FS,	0.05,	0.0 ± 0.0	0.3 ± 0.2	0.0 ± 0.0	1.0 ± 1.0 abc	0.3 ± 0.2 abc
Silwet L-77	8 fl oz/100 gal					
Agri-mek 0.15	0.01	0.0 ± 0.0	0.8 ± 0.7	0.0 ± 0.0	5.5 ± 3.2 d	1.6 ± 0.8 bcdef
Align (ATI-720F)	15.0 g	0.5 ± 0.5	2.0 ± 2.0	0.3 ± 0.2	1.0 ± 0.7 abc	0.9 ± 0.5 abcdef
Cryolite 96WDG	11.5	0.3 ± 0.3	1.8 ± 1.7	0.0 ± 0.0	8.5 ± 7.8 bcd	2.6 ± 1.9 cdef
Fipronil 80WG (EXP60720A)	0.05	0.0 ± 0.0	1.3 ± 0.7	3.5 ± 2.1	2.5 ± 1.5 abcd	1.8 ± 0.7 def
Fosthiazate 900 EC (ASC-66824)[2],	3.2,	0.0 ± 0.0	1.8 ± 1.4	0.3 ± 0.3	0.0 ± 0.0 a	0.5 ± 0.4 abcde
Asana & PBO[3]	0.05, 0.5					
Fosthiazate 900 EC (ASC-66824)[2],	4.8	0.3 ± 0.3	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0 a	0.1 ± 0.1 a
Asana & PBO[3]	0.05, 0.5					
Fosthiazate 900 EC (ASC-66824)[2],	6.4	0.3 ± 0.3	0.8 ± 0.7	0.0 ± 0.0	0.0 ± 0.0 a	0.3 ± 0.2 ab
Asana & PBO[3]	0.05, 0.5					
Fosthiazate 900 EC (ASC-66824)[2],	12.8	0.3 ± 0.3	0.3 ± 0.2	0.3 ± 0.2	0.0 ± 0.0 a	0.2 ± 0.1 a
Asana & PBO[3]	0.05, 0.5					
Fosthiazate 900 EC (ASC-66824)[2],	6.4	0.0 ± 0.0	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0 a	0.1 ± 0.1 a
Asana & PBO[4]	0.05, 0.5					
M-Trak	2 qts form	0.5 ± 0.5	3.8 ± 1.7	1.0 ± 1.0	3.8 ± 2.2 cd	2.3 ± 0.5 f
Raven	1 qt form	0.0 ± 0.0	2.8 ± 0.9	0.3 ± 0.2	0.8 ± 0.7 abc	0.9 ± 0.4 abcdef
Raven	2 qt form	0.5 ± 0.5	4.0 ± 2.6	2.0 ± 0.8	1.5 ± 0.9 abcd	2.0 ± 0.9 ef

Means within a column followed by different letters are significantly different ($P < 0.05$, Fisher's Protected LSD).

[1]Data transformed for analysis with Log (x+1).

[2]Treatment applied at planting.

[3]Foliar treatment started on 2nd spray date; 23 Jun.

[4]Foliar treatment started on 1st spray date; 16 Jun.

Treatment	Rate lb (AI)/acre	Seasonal Mean Number of CPB ± SEM[1] Egg Masses	Small Larvae	Large Larvae	Adults
Untreated		0.1 ± 0.1 ab	13.7 ± 5.3 bcd	31.78 ± 8.1 j	0.8 ± 0.4 ab
Imidan 70WP &	1.0	0.2 ± 0.1 abc	10.29 ± 4.9 bcd	16.13 ± 4.5 fgh	0.5 ± 0.2 ab
piperonyl butoxide (PBO)	0.5				
Imidan 70WP,	1.0	0.1 ± 0.0 a	9.4 ± 4.9 bcd	21.8 ± 7.2 ghi	0.3 ± 0.1 a
PBO & Sevin XLR Plus	0.5, 1.5				
AC303,630	0.01	0.3 ± 0.2 abcde	20.4 ± 3.4 d	21.8 ± 4.5 ij	0.9 ± 0.4 abc
AC303,630	0.05	0.5 ± 0.2 cdefg	9.1 ± 1.7 bcd	22.8 ± 6.2 hij	0.5 ± 0.2 ab
AC303,630	0.75	0.4 ± 0.1 abcdef	7.5 ± 2.5 bcd	8.5 ± 3.7 def	1.4 ± 0.8 abc
Admire 240FS[2]	0.2	0.6 ± 0.2 defg	0.4 ± 0.1 a	0.1 ± 0.0 a	1.8 ± 0.4 d
Admire 240FS,	0.05	0.7 ± 0.2 efg	7.6 ± 0.5 bcd	2.5 ± 1.5 abc	0.9 ± 0.2 bcd
Silwet L-77	8 fl oz/100 gal				
Agri-mek 0.15	0.01	0.8 ± 0.2 fg	13.6 ± 4.5 bcd	1.0 ± 0.6 ab	0.5 ± 0.2 ab
Align (ATI-720F)	15.0 g	0.3 ± 0.1 abcde	15.6 ± 6.4 bcd	16.8 ± 3.6 hij	0.3 ± 0.1 a
Cryolite 96WDG	11.5	0.9 ± 0.3 g	6.8 ± 5.3 ab	1.7 ± 0.3 bcd	1.3 ± 0.3 cd
Fipronil 80WG (EXP60720A)	0.05	0.2 ± 0.1 abcd	6.9 ± 2.1 bcd	9.0 ± 5.2 cde	0.6 ± 0.2 ab
Fosthiazate 900 EC (ASC-66824)[2],	3.2	0.5 ± 0.2 cdefg	6.7 ± 4.5 bc	15.2 ± 6.4 fgh	0.9 ± 0.3 abc
Asana & PBO[3]	0.05, 0.5				
Fosthiazate 900 EC (ASC-66824)[2],	4.8	0.4 ± 0.1 bcdef	8.1 ± 2.4 bcd	15.7 ± 5.2 fgh	0.7 ± 0.3 abc
Asana & PBO[3]	0.05, 0.5				
Fosthiazate 900 EC (ASC-66824)[2],	6.4	0.6 ± 0.2 defg	5.2 ± 3.3 ab	10.0 ± 4.1 efg	0.3 ± 0.1 a
Asana & PBO[3]	0.05, 0.5				
Fosthiazate 900 EC (ASC-66824)[2],	12.8	0.3 ± 0.1 abcde	7.3 ± 4.4 abc	2.4 ± 1.1 bc	0.5 ± 0.2 ab
Asana & PBO[3]	0.05, 0.5				
Fosthiazate 900 EC (ASC-66824)[2],	6.4	0.4 ± 0.2 abcdef	5.6 ± 2.8 bc	4.1 ± 1.3 cde	0.8 ± 0.2 abc
Asana & PBO[4]	0.05, 0.5				
M-Trak	2 qts form	0.2 ± 0.1 abcde	16.4 ± 5.8 cd	12.7 ± 2.2 hij	0.5 ± 0.2 ab
Raven	1 qt form	0.2 ± 0.1 abc	12.8 ± 5.2 bcd	13.7 ± 2.9 hij	0.3 ± 0.1 a
Raven	2 qt form	0.1 ± 0.1 ab	9.2 ± 3.7 bcd	7.5 ±1.6 efgh	0.6 ± 0.1 abc

Means within a column followed by different letters are significantly different (P< 0.05, Fisher's Protected LSD).
[1]Data transformed for analysis with Log (x+1).
[2]Treatment applied at planting.
[3]Foliar treatment started on 2nd spray date; 23 June.
[4]Foliar treatment started on 1st spray date; 16 June.

Treatment	Rate lb (AI)/acre	Yield ± SEM[1] Size A	Size B	Mean % Defoliation 21 Jun	28 Jun	5 Jul	12 Jul	Season
Untreated		7.3 ± 3.1 a	3.3 ± 0.8	53.8	81.3	87.5	91.3	78.4
Imidan 70WP &	1.0	56.6 ± 8.8 defg	3.6 ± 0.3	8.5	7.5	10.0	6.3	8.1
piperonyl butoxide (PBO)	0.5							
Imidan 70WP,	1.0	46.3 ± 9.0 bcdef	4.6 ± 0.6	8.8	18.8	27.5	8.0	15.8
PBO, Sevin XLR Plus	0.5, 1.5							
AC303,630	0.01	24.5 ± 4.3 b	5.3 ± 0.6	13.8	45.0	56.3	82.5	49.4
AC303,630	0.05	38.3 ± 6.3 bcde	6.0 ± 1.0	28.8	42.5	36.3	20.0	31.9
AC303,630	0.75	40.3 ± 12.9 bcd	4.6 ± 0.7	11.8	8.8	17.5	5.8	10.9
Admire 240FS[2]	0.2	67.9 ± 8.6 ef	4.1 ± 0.4	0.0	0.0	0.5	0.0	0.1
Admire 240FS,	0.05,	61.3 ± 3.7 def	4.5 ± 0.4	0.0	1.3	4.3	1.3	1.7
Silwet L-77	8 fl oz/100 gal							
Agri-mek 0.15[3]	0.01	38.2 ± 0.8 bcdef	5.5 ± 0.5	0.3	0.0	4.3	0.0	1.1
Align (ATI-720F)	15 g	35.3 ± 3.9 bcde	5.9 ± 0.1	5.0	9.5	42.5	28.8	21.4
Cryolite 96WDG	11.5	41.1 ± 4.6 bcdef	4.4 ± 0.4	1.3	1.3	6.3	5.0	3.4
Fipronil 80WG (EXP60720A)	0.05	64.5 ± 7.8 def	4.1 ± 0.6	1.8	0.0	4.8	0.0	1.6
Fosthiazate 900 EC (ASC-66824)[2],	3.2	52.5 ± 7.8 cdef	4.9 ± 0.4	4.3	1.3	8.8	0.0	3.6
Asana & PBO[4]	0.05, 0.5							
Fosthiazate 900 EC (ASC-66824)[2],	4.8	56.0 ± 7.6 def	4.8 ± 1.1	7.5	5.0	10.0	0.0	5.6
Asana & PBO[4]	0.05, 0.5							
Fosthiazate 900 EC (ASC-66824)[2],	6.4	55.0 ± 7.5 def	3.9 ± 0.4	3.5	2.5	2.78	0.0	2.2
Asana & PBO[4]	0.05, 0.5							
Fosthiazate 900 EC (ASC-66824)[2],	12.8	57.8 ± 5.5 def	4.0 ± 0.8	0.5	0.0	2.0	0.0	0.6
Asana & PBO[4]	0.05, 0.5							
Fosthiazate 900 EC (ASC-66824)[2],	6.4	72.3 ± 5.4 f	4.3 ± 0.3	0.5	0.0	1.5	0.0	0.5
Asana & PBO[5]	0.05, 0.5							
M-Trak	2 qts form	41.1 ±10.9 bcde	4.3 ± 0.1	2.8	7.3	27.5	22.5	15.0
Raven	1 qt form	31.6 ± 9.4 bc	4.6 ± 0.5	5.5	16.3	28.8	33.8	21.1
Raven	2 qt form	28.0 ± 4.4 bc	4.9 ± 0.7	2.3	7.5	16.8	8.8	8.8

Means within a column followed by different letters are significantly different (P< 0.05, Fisher's Protected LSD).
[1]Data transformed for analysis with Log (x+1).
[2]Treatment was applied at planting.
[3]Yield means calculated from 2 plots, instead of 4.
[4]Foliar treatment started on 2nd spray date; 23 June.
[5]Foliar treatment started on 1st spray date; 16 June.

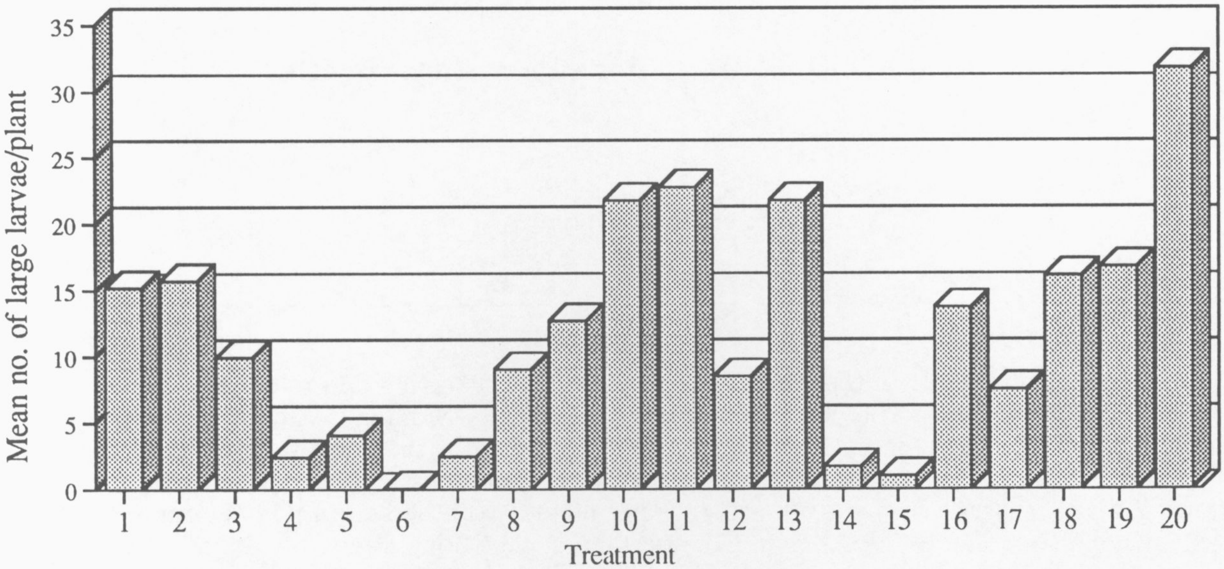

Figure 1. Mean no. of large CPB larvae during the season for 4 sample dates.

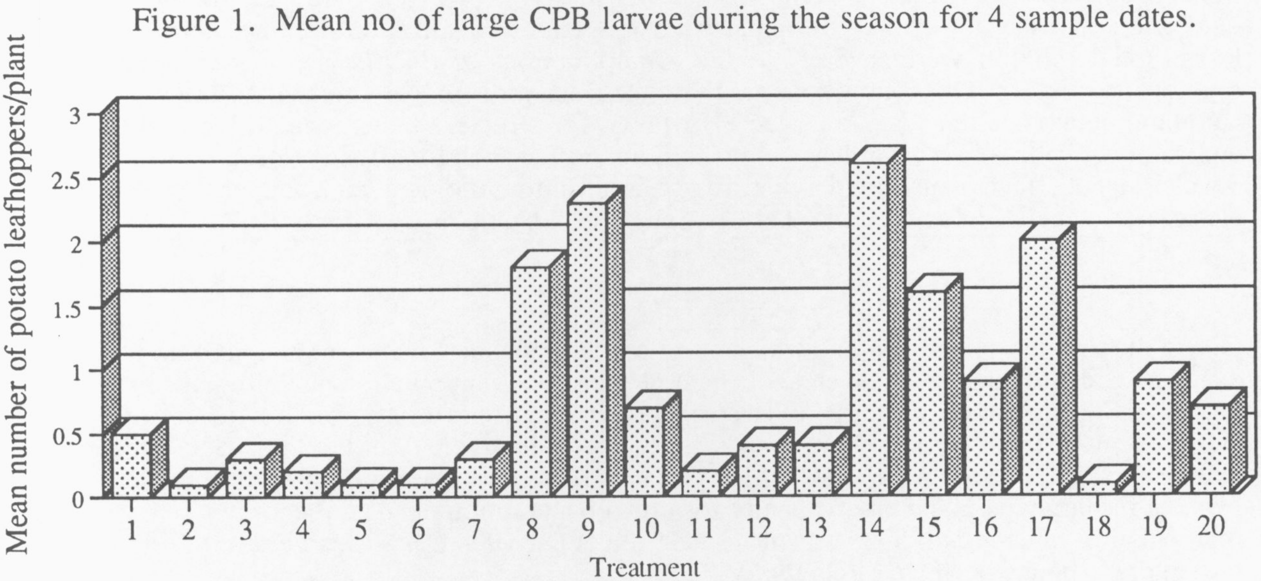

Figure 2. Mean no. of potato leafhopper during the season for 4 sample dates.

TREATMENTS:
1 = Fosthiazate 900EC (3.2 lb AI/acre) & 3 appl's Asana & PBO
2 = Fosthiazate 900EC (4.8 lb AI/acre) & 3 appl's Asana & PBO
3 = Fosthiazate 900EC (6.4 lb AI/acre) & 3 appl's Asana & PBO
4 = Fosthiazate 900EC (12.8 lb AI/acre) & 3 appl's Asana & PBO
5 = Fosthiazate 900EC (6.4 lb AI/acre) & 4 appl's Asana & PBO
6 = Admire 240FS (preplant)
7 = Admire 240FS & Silwet (foliar)
8 = Fipronil 80WG (Exp 60720A)
9 = M-Trak
10 = Imidan 70WP, PBO & Sevin XLR
11 = AC303,630 (0.05 lb AI/acre)
12 = AC303,630 (0.75 lb AI/acre)
13 = AC303,630 (0.01 lb AI/acre)
14 = Cryolite 96WDG
15 = Agri-Mek
16 = Raven (1 qt/acre)
17 = Raven (2 qt/acre)
18 = Imidan 70WP & PBO
19 = Align (ATI-720F)
20 = Untreated

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Biological Control of Colorado Potato Beetle

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Summary

Biological control of Colorado potato beetle by naturally-occurring and released natural enemies was studied at two locations in Michigan. At the Montcalm Co. site, beetle pressure was much less than at the Allegan Co. site because the field was somewhat isolated from last year's potatoes. At the Allegan Co. site, numbers of egg masses peaked at over 2.5 egg masses per plant (60 - 80 eggs per plant). Numbers of biological control agents were also higher at the Allegan Co. site than at the Montcalm Co. site and were timed to correspond to peak egg laying and larval activity. However, there were too many eggs and small larvae for the biological control agents to control and numbers of large larvae and defoliation were severe, in spite of applications of *Bacillus thuringiensis* and cryolite insecticides. Our conclusions are that numerous predators are present and feed on Colorado potato beetle eggs and larvae. However, for effective management, biological control must be linked with other management tactics, especially effective crop rotation. Availability of effective insecticides that are not harmful to biological control agents would also greatly benefit biological control of Colorado potato beetle.

One of the first steps in developing a biocontrol or integrated pest management program for a crop is to identify and evaluate endemic natural enemies. Manipulation and integration of biocontrol agents into a sustainable pest management program is possible if there are sufficient numbers of natural enemies or if there is a wide diversity of naturally occurring enemy species. The temporal distribution of natural enemies, their relationship to the life cycle of the target pest, and their capacity for prey consumption needs to be known before manipulation can be tried. This was the foundation of our 1994 field research on control of the Colorado potato beetle in Michigan.

Our primary objectives were to identify potential natural enemies, monitor their abundance, identify temporal relationships with the Colorado potato beetle, and evaluate their effectiveness. In addition, we examined the potential of ground beetles as predators of Colorado potato beetle larvae in the laboratory.

Materials & Methods

Experiments were conducted at 4L Farms in Allegan County and the McCarthy Farm in Montcalm County. Fertilization, herbicide, fungicide, and cultivation followed normal practices. Insecticide applications were limited as much has possible to insecticides not toxic to natural enemies. Insecticides were applied at 4L Farms on June 16 (M-Trak), June 22 (Cryolite), July 6 (dimethoate for leafhoppers and Cryolite), July 16 (Agri-Mek on 1/2 of field most heavily infested with adult potato beetles) and August 2 (Agri-Mek). The McCarthy Farm was sprayed on June 21 (Cryolite), July 19 (Imidan, methyl parathion, Guthion, & PBO) and July 27 (Agri-Mek).

The two sites provided contrasts in soil type, potato variety, rotation history, and Colorado potato beetle infestation. The site at 4L Farms was a 3 acre field of muck soil planted with 'Atlantic' potatoes on May 5. The field was bordered by homes and corn fields to the east and west, a road to the south and a drainage ditch and corn fields to the north. The southeast corner was shaded by 2 large trees. In 1993 this field had been corn, surrounded on three sides by large fields of potatoes. In 1994 this was the only potato field within approximately 1/2 mile. 4L Farms regularly uses a rotation of corn followed by potatoes in this field. At the McCarthy Farm the plot was 32 rows wide by 60 m (200') long (0.44 acre), sandy loam soil, planted with 'Gold Rush' potatoes in the northeast corner of a 60 acre field. The 32 rows on the eastern side of the field were 'Gold Rush' and the remainder of the field was russets. Our plot was bordered on the north and east by a hedgerow of trees and shrubs and was bisected by a pathway for irrigation machinery. Potatoes had not been planted in this field since 1990 and it was planted in wheat in 1993. The nearest potatoes were in an organic garden north of the field, and a large field about 1/2 mile to the southwest.

Temporal distribution of Colorado potato beetle and predators. Once or twice per week 60 to 128 plants were examined at each site for Colorado potato beetles, lacewings, lady beetles, ground beetles, damsel bugs, stink bugs, and harvestmen (daddy longlegs). Egg masses were recorded as either normal, damaged by predators or "blasted" (covered with soil). Two types of egg predation, chewing and sucking, are readily distinguished by the remains of the egg shell. Eggs attacked by predators with chewing mouth parts (e.g., ground beetles and lady beetles) are usually ripped open and the egg shell is not totally consumed. Eggs sucked dry by predators with sucking mouth parts (e.g., stink bugs, damsel bugs and lacewing larvae) have the egg shell intact and it appears collapsed or deflated. Because some eggs become deflated naturally and an early hatching potato beetle larva will cannibalize nearby eggs, egg masses were only considered preyed upon if the majority of the eggs were damaged in the same way and small larvae were not present nearby.

The mean number per plant of each stage of Colorado potato beetle, mean number per plant of each category of egg mass condition, the mean number per plant of predators observed, and the percent of the total predators observed for each predator type or species was calculated for each sampling date. The association between each type of predator and egg masses and small larvae was tested using Spearman's correlation.

On July 6, 145 Colorado potato beetle larvae (3rd & 4th instars) were collected from the 4L Farms field and reared through to adults in the laboratory to detect parasitism by the tachinid fly, *Myiopharus doryphorae* . We placed approximately 20 larvae each in pots filled with soil and fed the larvae potato leaves daily. After the larvae pupated, we watered the soil daily. The number of potato beetle adults or flies emerging was recorded.

Mass release of lacewing eggs and larvae. We evaluated the impact of the lacewing, *Chrysopa rufilabris* , with mass releases of eggs from Biofac Inc., Mathis, TX. By the time we received the eggs, a few had already hatched so our releases included first instar larvae. Releases were made June 21 to August 5, whenever eggs were available from the supplier (Table 1). The eggs arrived mixed with bran flakes which were sprinkled directly on potato plants. Releases were made in the morning on days when maximum temperatures were not expected to be over 80°F. Monitoring was done with the regular whole plant sampling.

Table 1. Lacewing release dates and amounts.

Date	No. eggs	No./acre
4L Farms		
21 June	30,000	10,000
15 July	50,000	16,667
22 July	50,000	16,667
28 July	45,000	15,000
4 August	45,000	15,000
McCarthy Farm		
29 July	5,000	11,200
5 August	5,000	11,200

Egg mass chronology. Thirty-four plants at 4L Farms and 16 plants at the McCarthy Farm were selected on June 7 and June 16, respectively, for egg mass timing, egg hatch and predation surveys. On each sampling date each plant was checked for new egg masses, the status of old egg masses, and the presence of predators. New egg masses were marked with a narrow strip of orange plastic flagging tape that was marked with a unique location code and tied to the leaf petiole. Previously marked egg masses were checked for signs of hatching, predation or other damage. An egg mass was recorded as hatched if there were no eggs remaining and there were small larvae present on the same or nearby potato stems. Egg masses were determined to be preyed upon as described above. The mean numbers of hatched, unhatched, normal and chewed egg masses per plant and the cumulative number of egg masses per plant were calculated. Data for predators used in graphs with egg mass means was from random plant sampling or traps because predators were rarely observed on the plants used for the chronology study.

Ground beetle and harvestman sampling. Two types of traps were placed at random sites in each field. Burlap traps were used primarily to monitor the ground beetle *Lebia grandis*, a known Colorado potato beetle predator. These traps consisted of a 30 x 46 cm (12" x 18") piece of burlap wound loosely around and tied to a 46 x 2.5 x 1 cm (18" x 1" x 0.5") long wooden stake. The stake was pushed into the soil so the burlap was flush with the soil. The burlap was untied and unwound during sampling and the numbers of ground beetles and other predators were recorded. Plastic cottage cheese containers (0.5 liter) were used as pitfall traps. Each cup was placed in the soil so the lip of the cup was even with the soil level. A 50:50 mixture of propylene glycol and water was poured into each cup to the 2 cm level. A rain shield made from an 18 cm (7") square of aluminum flashing with a 10 cm nail secured to each corner was placed over the trap and pushed into the soil until it was 1-2 cm above the lip of the cup. Traps were replaced on each sampling date. We combined some predators (e.g., ground beetles) into composite groups based on size and coloration because we were not able to identify all of them to species immediately. Specimens have been kept for future identification to species.

On June 28 and July 1, 6, 25 & 28 at 4L Farms and July 20 & 26 at the McCarthy Farm, traps were replaced with cups containing dry soil or cardboard squares to collect live ground beetles for laboratory studies. Dry traps were collected after 3-7 days. Not all beetles could be processed on the day they were brought into the lab. Ten of the 25 ground beetles collected on July 1 and all 38 beetles captured on July 6 were placed in a growth chamber kept at 11°C for 4 and 2 days, respectively, until they could be set up and fed. Beetles collected on later dates were set up the day they were brought into the lab.

Ground beetle feeding experiment. Ground beetles were placed singly in 15 cm diam. petri dishes lined with filter paper, and assigned an identification code for record keeping and later identification. Each dish was supplied with a small fan of paper toweling for shelter and a 0.5 dram vial filled with water and plugged with cotton. They were given small (1st and 2nd instar) or large (3rd or 4th instar) Colorado potato beetle larvae each day. The number of prey given varied with availability of larvae and the size of the ground beetle being fed. Each day we recorded the number of dead potato beetle larvae, removed live larvae, and provided fresh larvae. After making observations on the feeding habits of ground beetles collected on July 1 & 6, we decided to discriminate between potato beetle larvae that were completely eaten (nothing or only parts of the skin left) and those not entirely eaten (larvae pierced or only partially eaten) for predators collected on later dates. The mean number of days until death of the predator, the mean number of larvae given, the percent completely eaten or partly eaten, and the mean number attacked (completely eaten plus partly eaten) per day were calculated.

Results and Discussion

Temporal distribution of Colorado potato beetles. Colorado potato beetle adults began infesting the field at 4L Farms about 1 week before the McCarthy Farm field (Fig. 1A). Beetles at 4L moved in from the northeastern corner, adjacent to corn fields that were planted in potatoes in 1993. A plastic-lined trench between the fields and volunteer potato plants in the corn fields kept some beetles from entering the biocontrol field. However, the adult infestation was severe because of the large number of acres surrounding our field that had been potatoes in 1993. The McCarthy field had fewer adults than 4L because it was more isolated from previous potato fields. There also were other large fields of potatoes in the surrounding area which helped dilute the infestation. The location of our plot in a corner of a field protected by large trees also contributed to its isolation. The numbers of summer adults at 4L were as much as 6 times higher than in McCarthy.

The large infestation of overwintered adults at 4L resulted in an enormous number of egg masses and subsequently, of small larvae (Figs. 1B, 2A). Egg mass and larval numbers were much lower at McCarthy. Egg laying peaked at 4L on June 10 and continued until mid-July, overlapping the emergence of summer adults. At McCarthy, egg laying peaked on June 13 and continued until about 20 July, just before summer adults emerged. Eggs were laid for 2 weeks before the first hatch at 4L, and at least 4 days before first hatch at McCarthy. Egg development was delayed by cool weather during early June. When the weather warmed up, however, a large number of eggs hatched a virtually the same time.

Numbers of small larvae increased sharply at 4L from June 14 until the peak at 22 larvae per plant on June 20 (Fig. 2A). Numbers decreased slowly until July 6. M-Trak applied on June 16 did not suppress the numbers of small larvae at 4L. The continual hatching of eggs, the short residual time of M-Trak, and rainfall probably diminished the effectiveness of this insecticide application. The Cryolite application on June 22 had little effect on numbers of small larvae and molting to later stages at this time may also account for part of the decrease. Rain fell shortly after the cryolite was applied which apparently affected its

The numbers of small larvae at McCarthy were much lower than at 4L (Fig. 2A). Small larvae at McCarthy peaked at 3 per plant on June 20, and they were suppressed for a short time after cryolite was sprayed on June 21. Numbers decreased and then slowly increased for 2 weeks after spraying, resulting in a second peak of 6.7 per plant on July 11. The application of several insecticides on July 19 brought the numbers of larvae down and numbers stayed low for the rest of the sampling period.

The numbers of large larvae at 4L increased after the M-Trak and cryolite sprays, as the remaining small larvae molted to later instars (Fig. 2B). It appears from Fig. 2B that the second cryolite spray on July 6 controlled large larvae because their numbers drop sharply. However, they were also entering the soil for pupation and within 6 days of this spray summer adults began to emerge.

The numbers of large larvae at McCarthy increased slowly after the first spray of cryolite, peaking at 8 per plant on July 11 (Fig. 2B). The effects on large larvae of the combination spray of July 19 are difficult to interpret for the same reasons stated above for 4L. However, a much smaller proportion of larvae made it to the adult stage at McCarthy than 4L: 1 adult emerged for every 7 larvae at McCarthy; 1 adult emerged for every 2.6 larvae at 4L.

Temporal distribution and association of predators with Colorado potato beetle. Lady beetles constituted the largest portion of predators observed on plants in both fields (Fig. 3 & 4). At 4L and McCarthy lady beetles made up 33-100% of all predators, and there were lady beetles present on most sampling dates. *Coleomegilla maculata* (10-spotted lady beetle) was the most abundant, followed by *Coccinella septempunctata* (7-spotted lady beetle) and *Hippodamia convergens* (convergent lady beetle).

At 4L, the 10-spotted lady beetle made up 25-96% of all predators on nine of eleven sampling dates (Fig. 3). It constituted 50-100% of all predators observed at McCarthy on seven of nine sampling dates (Fig. 4). It was most abundant during the early summer, with numbers dropping off around the end of June (Fig. 5). This species is known to feed on corn pollen (Smith 1961), which probably accounts for the decreasing numbers over the summer.

The 7-spotted lady beetle was the next most abundant lady beetle, composing 3-67% of predators found at 4L and 5-33% of those found at McCarthy (Fig. 4). The 7-spotted lady beetle was first reported at 4L on June 10 and was present through July 12 (Fig. 5). At McCarthy this lady beetle was observed from June 23 to July 5. The convergent lady beetle was seen only once, at 4L on June 28 (Fig. 5). Lady beetle larvae were found at 4L from June 21 to July 1, but were not reported from McCarthy.

The 10-spotted lady beetle was the only species observed actually eating Colorado potato beetle eggs or small larvae in the field. Consumption of Colorado potato beetle eggs and larvae was reported in previous studies in Michigan and Massachusetts. The first 10-spotted lady beetles were found in both fields within one week after the first eggs were laid. Peak incidence of 10-spotted lady beetles followed peak egg laying more closely at 4L than at McCarthy (Fig. 6).

Occurrence of the 10-spotted lady beetle at 4L and McCarthy was significantly correlated with the presence of Colorado potato beetle eggs ($r_S = 0.55$, $p = 0.0001$; $r_S = 0.63$, $p = 0.0001$, respectively) (Fig. 6). Activity of the 10-spotted lady beetle was associated with the incidence of eggs damaged by chewing at both farms (4L: $r_S = 0.80$, $p = 0.0005$;

McCarthy: $r_S = 0.86$, $p = 0.0001$) (Fig. 6). There was a significant association between the incidence of the 7-spotted lady beetle and the occurrence of eggs of the Colorado potato beetle at 4L ($r_S = 0.52$, $p = 0.0181$) but not at McCarthy. Both the 10-spotted and 7-spotted lady beetles were correlated with numbers of small larvae at 4L ($r_S = 0.53$, $p = 0.0468$; $r_S = 0.61$, $p = 0.0001$, respectively), but not at McCarthy. These lady beetles are the most prevalent and possibly the most important predators of Colorado potato beetles during peak egg laying and hatching of larvae. The convergent lady beetle was observed only on July 28 at 4L, and it was significantly associated with the presence of eggs on that date ($r_S = 0.73$, $p = 0.28$).

Other predators that were found on plants include harvestmen (daddy longlegs), the spined soldier bug (*Podisus maculiventris*) damsel bugs (family nabidae), and the ground beetle, *Lebia grandis* (Figs. 3,4). Harvestmen were found on potato plants more often in the McCarthy field (six of nine dates, Fig. 4). These predators represented between 4.5-66.7% of the total predators on these dates. Harvestmen were observed on only three of nine dates at 4L (Fig. 3) but were very abundant in pitfall traps (see later discussion). They constituted 6.7-12.5% of the total number of predators on plants on those dates. Although our specimens have not been identified to species, Drummond et al. (1990) found that *Phalagium opilio* (L.) was abundant in potato fields at the MSU Kellogg Biological Station, which is about 20 miles from the 4L field. *P. opilio* feeds on eggs and small larvae of the Colorado potato beetle. The numbers of harvestmen and Colorado potato beetle larvae or eggs were not significantly correlated at either site (Fig. 7 & 8), although both predator and prey were often present at the same time. Plant sampling is probably not the best way to detect or assess the activity of these predators since many more harvestmen were collected in pitfall traps than were observed on plants.

The spined soldier bug was reported at 4L on six dates from June 17 to July 12 and at McCarthy on June 13, June 30 and July 11 (Figs. 3,4). At 4L 3.3-25% of all predators found on plants were spined soldier bugs (Fig. 3). They constituted 14.3-85.7% of predators at McCarthy. We saw it feeding on small and large Colorado potato beetle larvae several times. However, the numbers we found (< 0.12 per plant) were far below the number of 3 or more per plant recommended for biocontrol of Colorado potato beetle larvae.

Over the entire summer at 4L, spined soldier bug numbers were not significantly correlated with numbers of Colorado potato beetle eggs or larvae. They were often present at the same time as eggs and larvae (Fig. 9 & 10), but not consistently. Spined soldier bug numbers were significantly correlated with undamaged eggs only on June 28 ($r_S = 0.71$, $p = 0.0353$). There was a significant correlation between spined soldier bug numbers and numbers of small larvae on July 12 and 21 ($r_S = 0.69$, $p = 0.0394$; $r_S = 0.80$, $p = 0.002$, respectively) and on July 21 they were correlated with numbers of large larvae ($r_S = 0.88$, $p = 0.001$).

Spined soldier bugs were observed on only three dates at McCarthy (Figs. 9 & 10). Their numbers were correlated with numbers of sucked eggs over the summer ($r_S = 0.96$, $p = 0.0204$), and on June 13 in particular ($r_S = 0.97$, $p = 0.0001$). There was no significant correlation with numbers of small larvae, but the correlation with numbers of large larvae was very close to being significant ($r_S = 0.67$, $p = 0.0593$). The most spined soldier bugs reported at McCarthy was during the peak occurrence of larvae on July 11 (Fig. 10), although the correlation on this date was not significant. As happened at 4L, the soldier bugs were often present at the same time as larvae, but not consistently. The impact of stink bugs on Colorado potato beetles was probably negligible in the two fields because of their low numbers, sporadic occurrence or late appearance. A different sampling method may provide a better assessment of the soldier bug population. This predator may be effective in mass release or augmentation programs because it is readily available through commercial sources and does overwinter in Michigan.

The more predacious stink bug specialized to feed on Colorado potato beetle eggs and larvae, *Perillus bioculatus*, was not observed in either field. Damsel bugs and the ground beetle *Lebia grandis*, a known specialist predator of Colorado potato beetle, were found only very occasionally on potato plants in either field (Figs. 3 & 4). The impact of these predators is considered negligible.

We found no tachinid parasites from the larvae collected at 4L. This parasite has been reported to be poorly synchronized with its host and it is usually has a very low density. Collection of several hundred larvae may be needed to have detected *M. doryphorae*.

Mass release of lacewing eggs and larvae. The native population of lacewings in these fields was extremely low. They were very rarely found on plants during the entire sampling period. We expected to be able to evaluate the effects of released lacewings on Colorado potato beetles because there were so few other predators in the fields during the release time. However, no lacewings were recorded from plant samples even after releases. This is not uncommon when eggs or newly hatched lacewings are released and the fate of the released lacewings is unknown. Lacewings do not appear to be valuable native predators of the Colorado potato beetle, nor do they seem to be useful or economical for a predator augmentation program.

Egg mass chronology. Egg laying began at 4L Farms began just before sampling started on June 7, leveled out between June 21 and 28 and ended by July 6 (Fig. 11A). Egg laying peaked on June 21 at three egg masses per plant. Egg masses began hatching at 4L around June 14, peaked on June 21, and finished hatching by July 6 (Fig. 11 A). A number of egg masses were in the field for over 1 week before hatching. Cool weather in late May and early June delayed egg hatch. A large number of egg masses hatched between 17 and 21 June and small larvae became a control problem at this time.

The pattern of egg laying at McCarthy was more erratic than at 4L, probably because adult numbers were reduced by insecticides on June 21 and July 11. Egg laying began before June 16, leveled out in late June, increased during early July and leveled out again from mid July to early August (Fig. 11A). Egg laying peaked on June 23, at two egg masses per plant, with another, smaller peak of 1.4 egg masses per plant on July 11. Egg masses were in the field for over a week before starting to hatch. Peak hatch occurred on June 23 and July 11.

The differences between 4L and McCarthy reflect different planting times and infestation rates. Potatoes at 4L were planted much earlier than at McCarthy and were well established by June 7. The potatoes at McCarthy had just broken through the soil by June 16. Beetles readily invaded the 4L site from adjacent fields previously planted to potatoes. Infestation was slower and at a lower level at McCarthy because beetles had to travel farther from overwintering sites. Insecticides that were effective against adults were used at McCarthy, thus reducing adult numbers and egg laying, while insecticide applications at 4L were aimed at larvae.

At 4L Farms the 10-spotted lady beetle was closely associated with chewed egg masses in early to mid-June (Fig. 11B). At McCarthy, the 10-spotted lady beetle was present at the same time as damaged egg masses but was also present when no chewed egg masses were reported (Fig. 11 B). The numbers of ground beetles and harvestmen found in traps at both sites did not follow the temporal distribution of chewed egg masses (Fig. 11B).

The egg mass chronology study was very time consuming, and little additional information was gained about egg predation over random whole plant sampling. Detection of egg mass predation was similar between marked plants in the egg mass chronology study and randomly selected plants (compare Fig. 6 and 11B). However, detection of egg mass predation during random sampling could have been improved with more employee experience.

Ground beetle and harvestman sampling. Burlap traps were not successful for monitoring *Lebia grandis*. However, harvestmen and spiders were found in them. *Lebia grandis*, although present in both fields, was probably too low in density to be monitored using widely spaced traps.

Lebia grandis was rarely found in pitfall traps in either field. The ground beetles found most often in pitfall traps were large black beetles in the genus *Pterostiches*. Early in the summer at 4L a few large black ground beetle in the genus *Scarites* were captured in traps. Large ground beetles were found in traps from late June until early August in both fields (Fig. 12). There was a peak of three per trap on July 6 at 4L, and a peak of one per trap at McCarthy on July 20. Numbers of large ground beetles were positively correlated with numbers of large potato beetle larvae at both farms (4L: $r_s = 0.80$, $p = 0.0162$; McCarthy: $rs = 0.74$, $p = 0.0341$), but not with numbers of small larvae. We found medium ground beetles throughout the sampling season at both farms. Peak numbers were 0.8 per trap at both farms, and the peak was about 2 weeks later at McCarthy than 4L. Numbers of medium ground beetles were positively correlated with numbers of small larvae at McCarthy ($r_s = 0.71$, $p = 0.0442$), but not with numbers of large larvae. There was no significant correlation with larvae at 4L. The numbers of small ground beetles fluctuated greatly in both fields, but we captured consistently more at McCarthy. Numbers of small ground beetles were positively correlated with numbers of small potato beetle larvae at 4L ($r_s = 0.76$, $p = 0.0228$), but not with numbers of large larvae. There was no significant correlation with numbers of larvae at McCarthy. Small- and medium-sized ground beetles were not as abundant in either field as large ground beetles and their numbers were much lower in dry pitfall traps (Fig. 12, dates marked with *). These beetles may have been eaten by larger ones or could have crawled out of the traps because of their small size.

Overall, there were more ground beetles captured at 4L than McCarthy (Fig 12). There are many possible reasons for this difference including soil type and prey availability. The muck soil at 4L was much more rich in biological terms than the sandy clay loam of the McCarthy Farm. Fluid-filled pitfall traps at 4L yielded many more types of arthropods (other than those reported here) than did traps at McCarthy. Numerous spiders, collembola, and centipedes were often seen on the soil during sampling at 4L. Therefore, a biological control program may be more successful when applied to potatoes planted in muck than other soil types. There were also many more Colorado potato beetles available for predators at 4L than McCarthy, so prey availability may also determine the population size of ground beetles. However, the correlation between the presence of Colorado potato beetle larvae and ground beetles does not prove a cause and effect relationship. The effects of these factors on ground beetle populations should be seriously considered for further research.

Harvestmen were frequently captured in fluid-filled pitfall traps, but their numbers were zero or very low in dry pitfalls (Fig. 13); they probably crawled out of the dry traps. The numbers of harvestmen captured in fluid-filled traps fluctuated considerably, so the temporal distribution was hard to summarize. Peak numbers were captured on June 28 at 4L, and on June 30 at McCarthy. However, a second peak occurred on August 11 at 4L, which may indicate the presence of a second generation of harvestmen in that field. Numbers were increasing at McCarthy in mid-July, so a second generation may have occurred there too. Numbers of harvestmen were significantly correlated with numbers of large larvae at McCarthy ($r_S = 0.70$, $p = 0.0477$), but not with numbers of small larvae. There was no significant correlation between numbers of larvae and harvestmen at 4L. Their relationship to Colorado potato beetle larvae needs further investigation. The numbers of harvestmen were comparable in both fields and their distribution in time was fairly consistent. This indicates that harvestmen could be a dependable natural component in a biological control program.

Ground beetle feeding experiment. Small, medium and large ground beetles were included in the feeding trial. Species names have not yet been determined. All but two of the 144 ground beetles tested attacked one or more Colorado potato beetle larva. The number of larvae attacked by each beetle per day ranged from 0.4 - 1.7. The beetles lived from 1 to 60 days in the lab. The most frequently captured ground beetles were from 4L Farms, and most of them were large black beetles in the genus *Pterostiches*. These will be the focus of our discussion on ground beetle feeding.

Sixty-five percent of the 117 *Pterostiches* observed lived for four or more days. Beetles that did not survive 4 or more days probably died from the stress of being captured. Beetles attacked Colorado potato beetle larvae in one of two ways: grabbing the larva with its mandibles, piercing the skin, and then walking away from it, letting the larvae bleed to death; or, piercing the skin and tearing the larva apart while eating it, feeding until only the heavily sclerotized parts were left. Either feeding method killed the larva. A dead larva was considered "attacked" for reporting purposes regardless of the method used to kill it. *Pterostiches* ground beetles attacked between 0.8 and 1.5 Colorado potato beetle larvae per day regardless of how long they lived(Fig. 14A). Some of the beetles ate more than one first instar or small second instar per day, however, most of the beetles were fed large second instars or third or fourth instars. Ground beetles collected on different dates attacked a similar number of larvae. The majority of ground beetles attacked 40%-100% of the food that was available (Fig. 14B).

These results indicate that ground beetles could contribute significantly to Colorado potato beetle control. Further information is needed to determine the rate of feeding on smaller Colorado potato beetle larvae and to document species-specific feeding habits. It is unlikely that ground beetles could be raised for mass release because of they often eat each other, especially when they are larvae, unless they are kept individually. Therefore, native populations would have to be sufficiently large to play a significant role in reducing Colorado potato beetle numbers. The effectiveness of ground beetles in biocontrol could be dependent on soil type, since more ground beetles were found at 4L Farms than at McCarthy. Crop rotation systems could be designed to encourage ground beetles by increasing the amount of ground cover or other means.

Conclusions and Recommendations

Naturally occurring biocontrol agents alone may not provide control of the Colorado potato beetle. In particular, when egg input is extremely high, as it was at 4L Farms, an enormous number of predators must be present to suppress subsequent Colorado potato beetle populations. Predator effectiveness could be increased by increasing predator numbers, decreasing Colorado potato beetle numbers, or both.

Timing of predator incidence is also very important. In a typical predator/prey model, there is a delay between the occurrence of prey and the arrival of predator. In the potato agroecosystem, this is especially important because the egg stage is the stage most often attacked by predators. Predators must be present at the same time eggs are starting to be laid and must continue to be present after eggs hatch. A complex of predators is needed for control of both eggs and larvae.

The 10-spotted lady beetle was the most abundant predator in the fields we studied and does have some promise for biocontrol. It occurs early in the season and both larvae and adults feed on eggs and small larvae of the Colorado potato beetle. Rotation of corn followed by potatoes would enhance the local population of 10-spotted lady beetles, as seen at 4L Farms. Corn planted close to potatoes would provide nutrients for reproduction of the lady beetle, but it also draws the lady beetles away from potatoes when the corn is tasseling. However, if Colorado potato beetles were under control by that time or if other predators were present, their absence would not have a great effect. If beetle numbers were not under control, however, other control measures would have to be implemented. If the 10-spotted lady beetle could be reared for mass release, or if native populations could be enhanced, it probably would provide good control of eggs and small larvae. However, the size of the Colorado potato beetle population definitely needs to be considered before relying on this lady beetle for biocontrol.

Lady beetles did not appear in the potato fields for about a two week period after adult Colorado potato beetle emergence. This provides a window of opportunity to control Colorado potato beetle adults without harming the lady beetles and possibly other native predators. The early application of an insecticide that is effective against adults would reduce the input of eggs and subsequent larvae, bringing the numbers down to a level at which native predators could provide control.

Other native predators, in particular stink bugs, harvestmen, and ground beetles could be valuable as biocontrol agents, but we need to do much more research on population size, temporal distribution, and feeding efficiency. Spined soldier bugs, which are available commercially, could be used in a mass release program. The effectiveness and economics of mass releases must first be evaluated. We need to explore the factors affecting the occurrence and abundance of harvestmen. The role of ground beetles in Colorado potato beetle control also needs more evaluation, particularly in muck soils where they are very abundant. Field experiments are needed to determined feeding under natural conditions. If ground beetles are feeding on one of every three larvae encountered, as seen in the laboratory, they could be an effective part of a biocontrol program.

Fig 1. Colorado potato beetle temporal distribution: (A) adults and (B) egg masses. spray applications at 4L Farms; Δ spray applications at McCarthy Farm. See text for explanation.

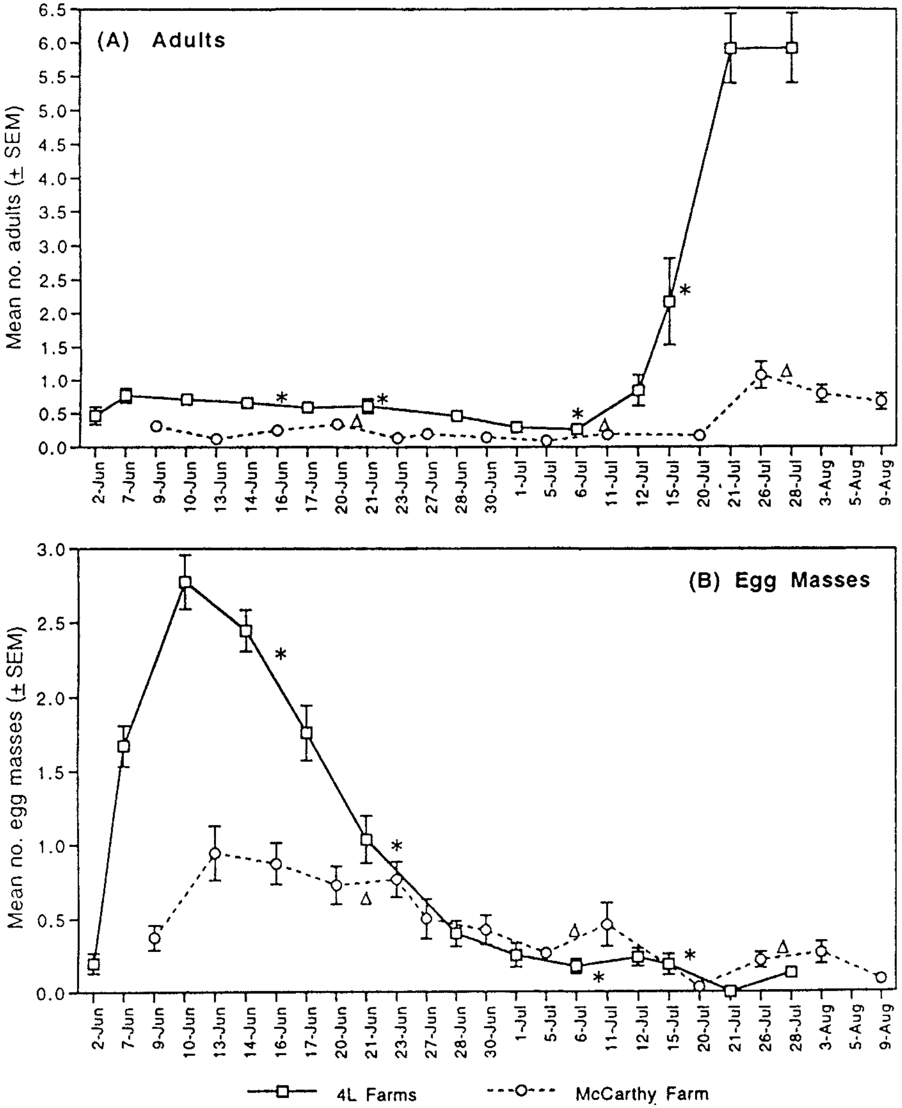


Fig. 2. Colorado potato beetle temporal distribution: (A) small and (B) large larvae. spray applications at 4L Farms; Δ spray applications at McCarthy. See text for explanation.

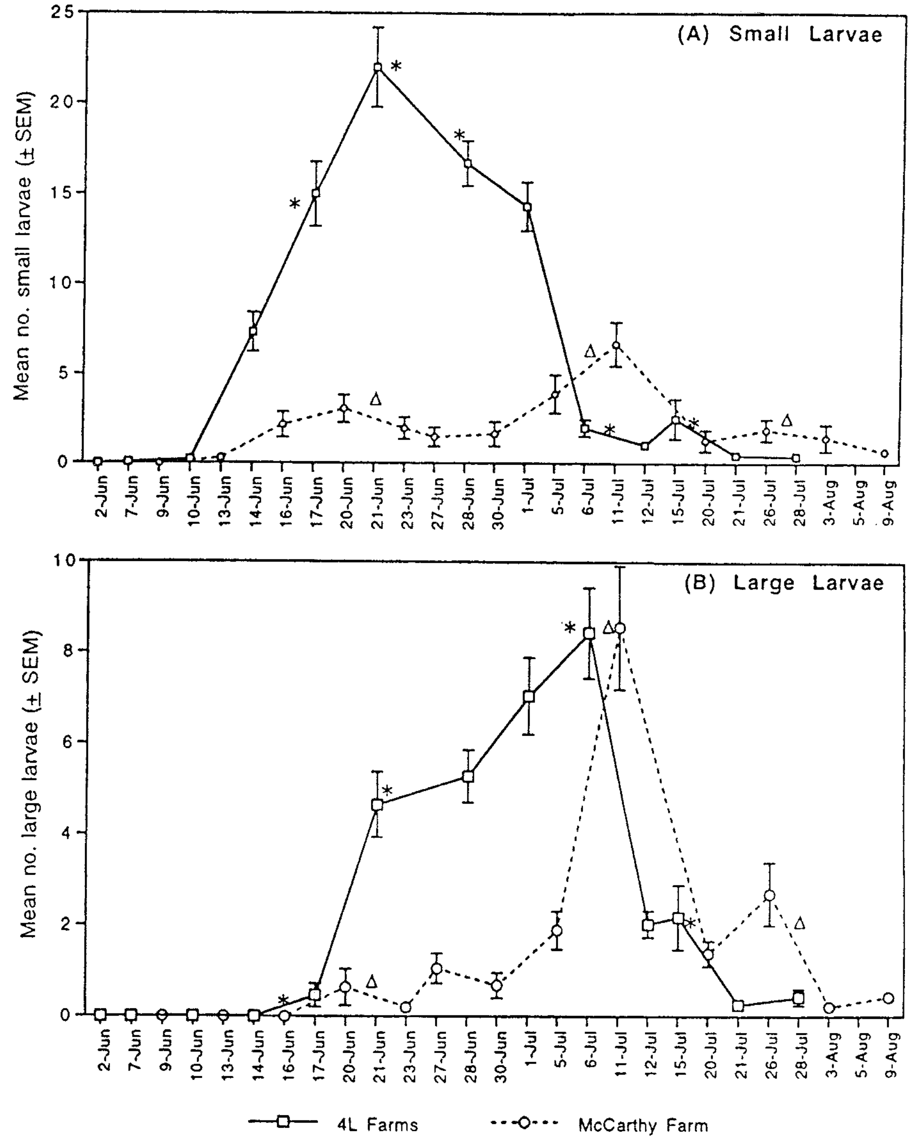


Fig. 3. 4L Farms: Proportion of type of predator occurring on plants on each sampling date.

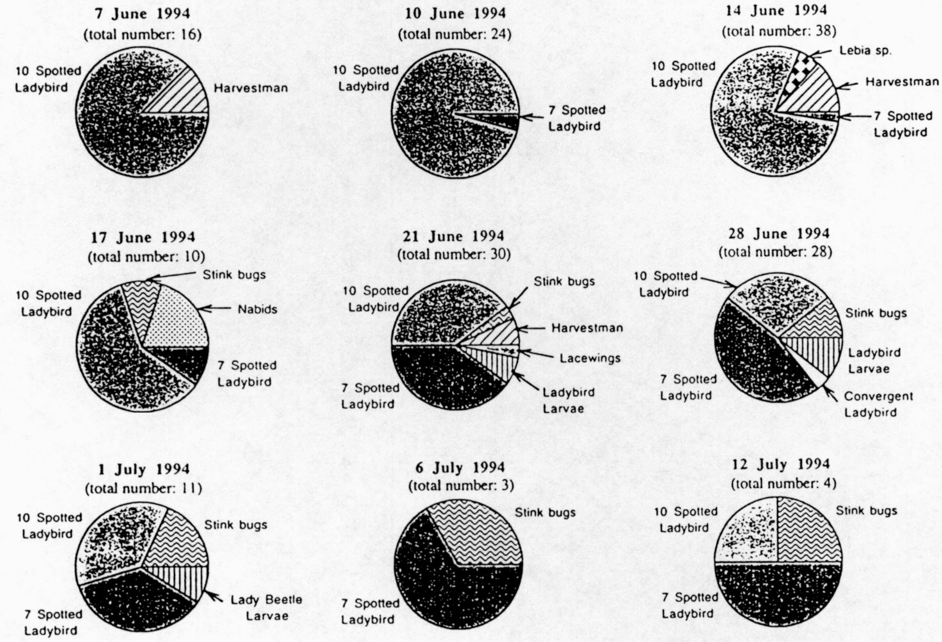


Fig. 4. McCarthy Farm: Proportion of each type of predator occurring on plants on each sampling date.

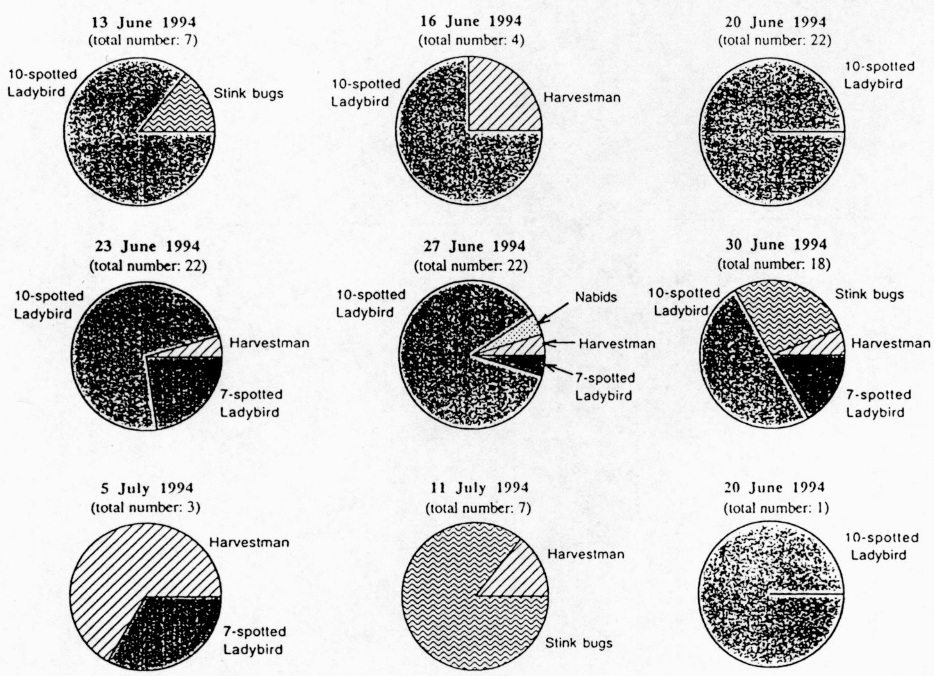


Fig. 5. Temporal distribution of 3 species of ladybird beetles in potatoes.

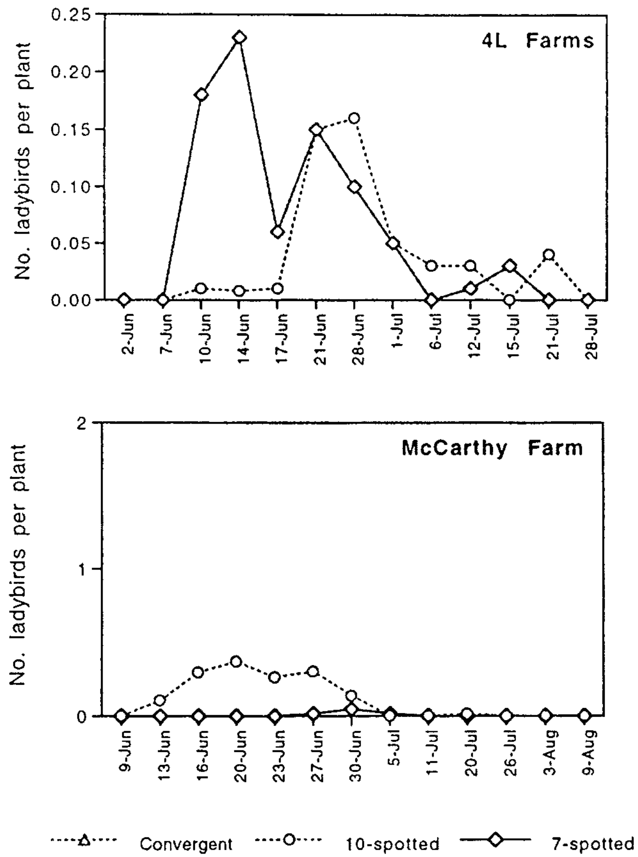


Fig. 6. Relationship of the temporal distribution of 10-spotted ladybird beetles and Colorado potato beetle egg masses found during plant sampling.

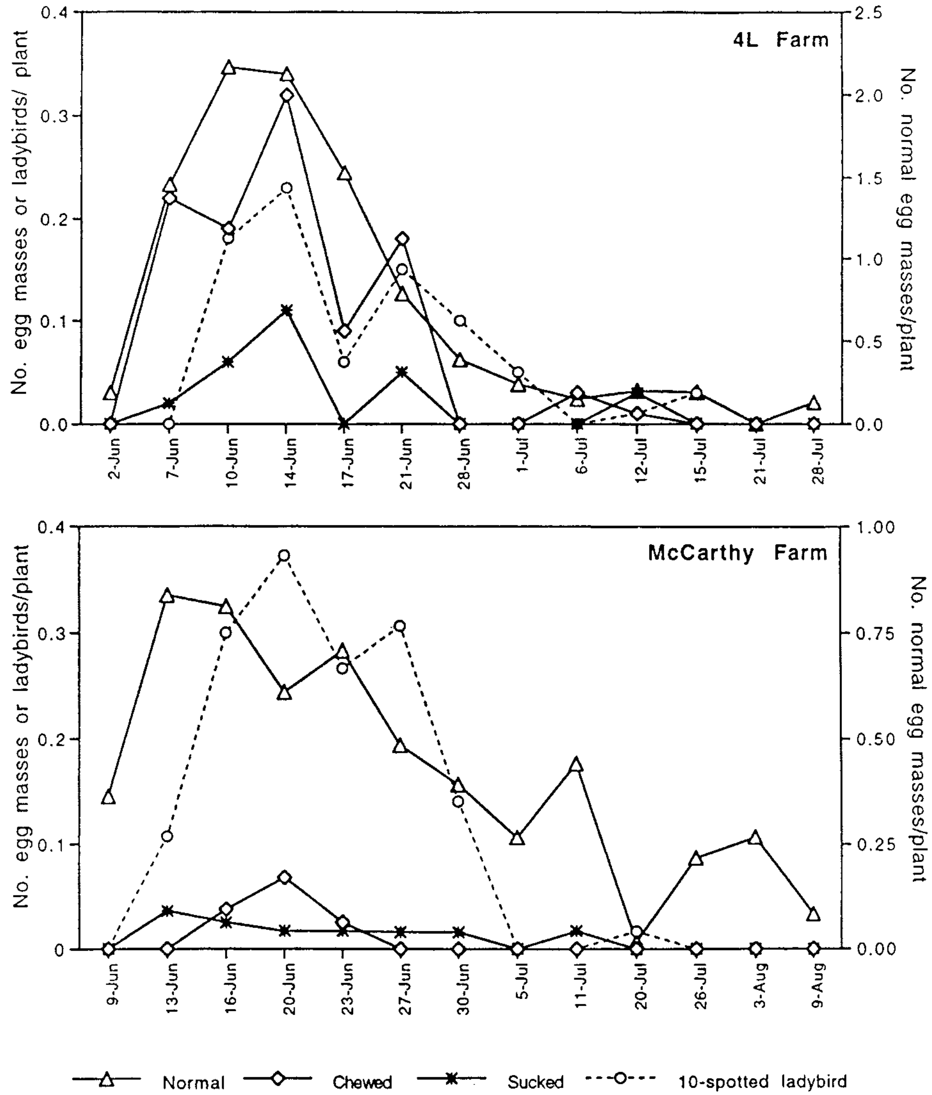


Fig. 7. Temporal distribution of harvestmen and Colorado potato beetle larvae.

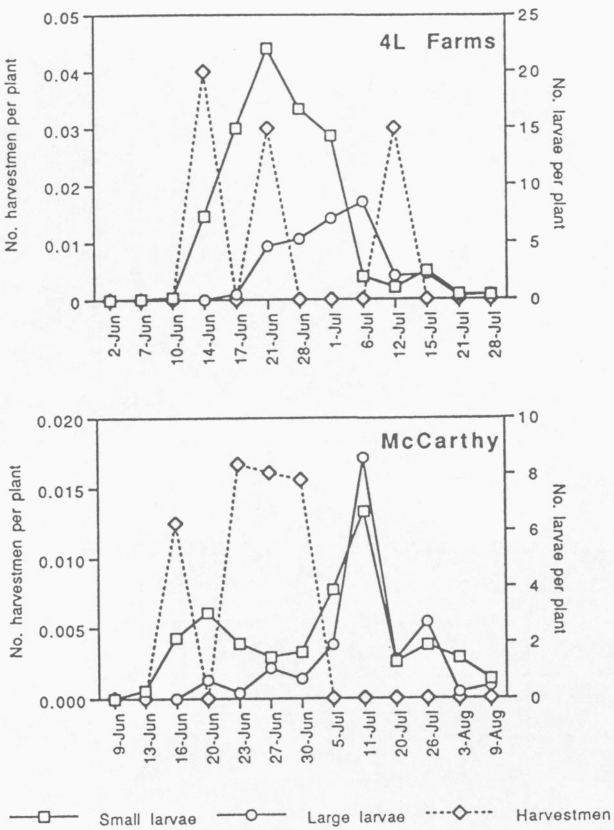


Fig. 8. Temporal distribution of harvestmen and normal and prey-damaged Colorado potato beetle eggs.

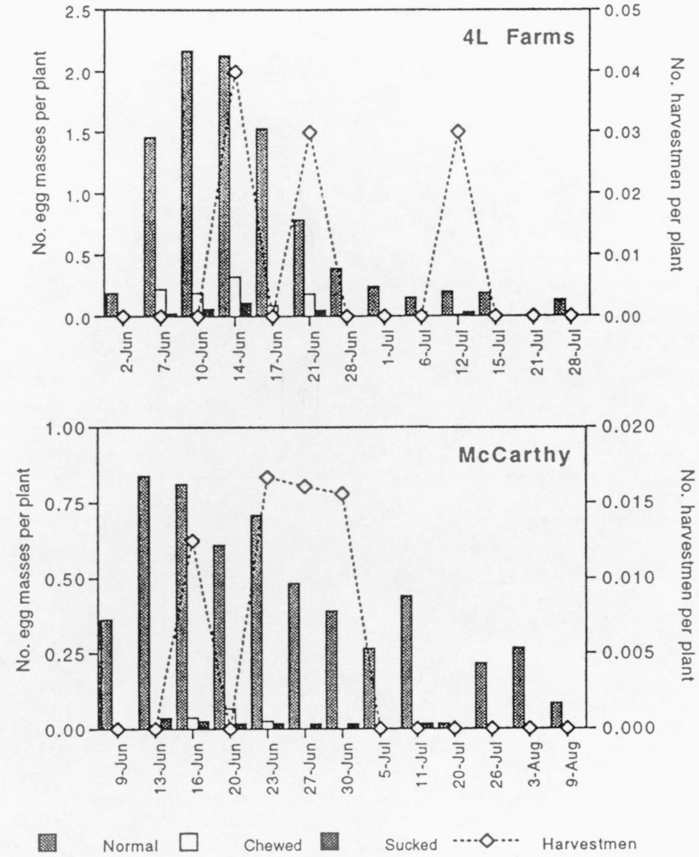


Fig. 9. Temporal distribution of stink bugs and normal and prey damaged Colorado potato beetle eggs.

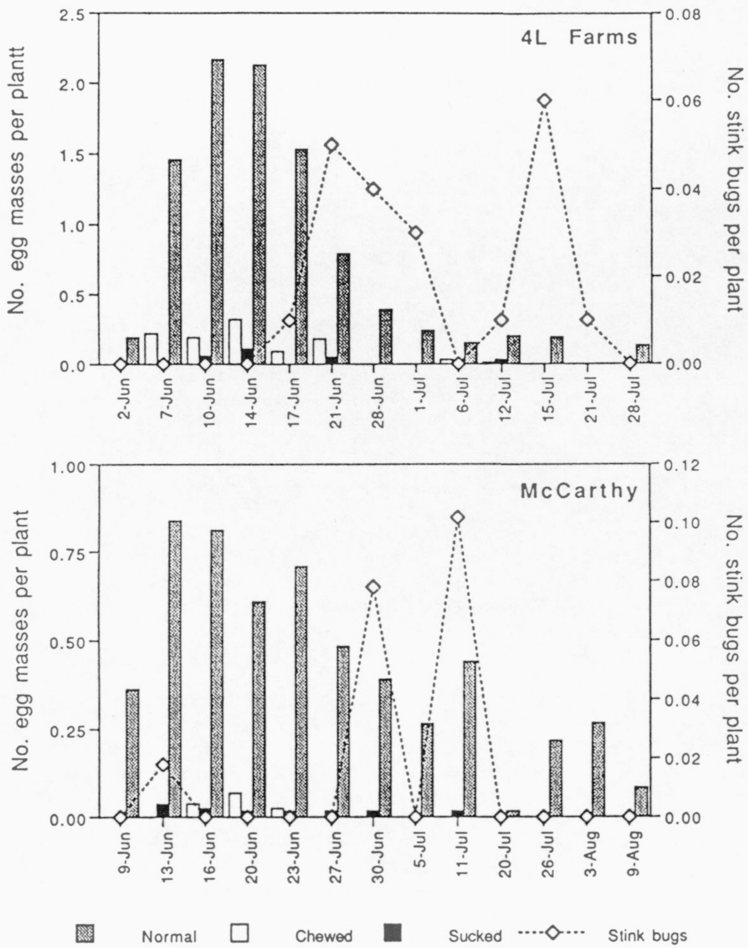


Fig. 10. Temporal distribution of stink bugs and Colorado potato beetle larvae.

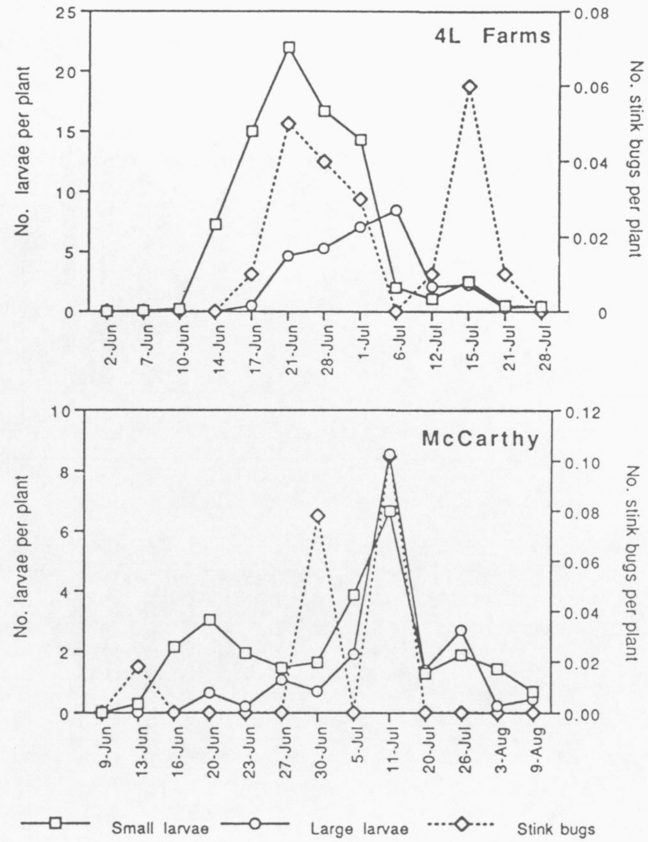


Fig. 14. (A) Mean number of CPB larvae attacked per day by ground beetles according to the number of days the beetles survived in the laboratory. (B) Proportion of CPB larvae provided that were attacked (completely or not completely eaten)by ground beetles.(25 July & 1 August: N=1 each at 16+ days)

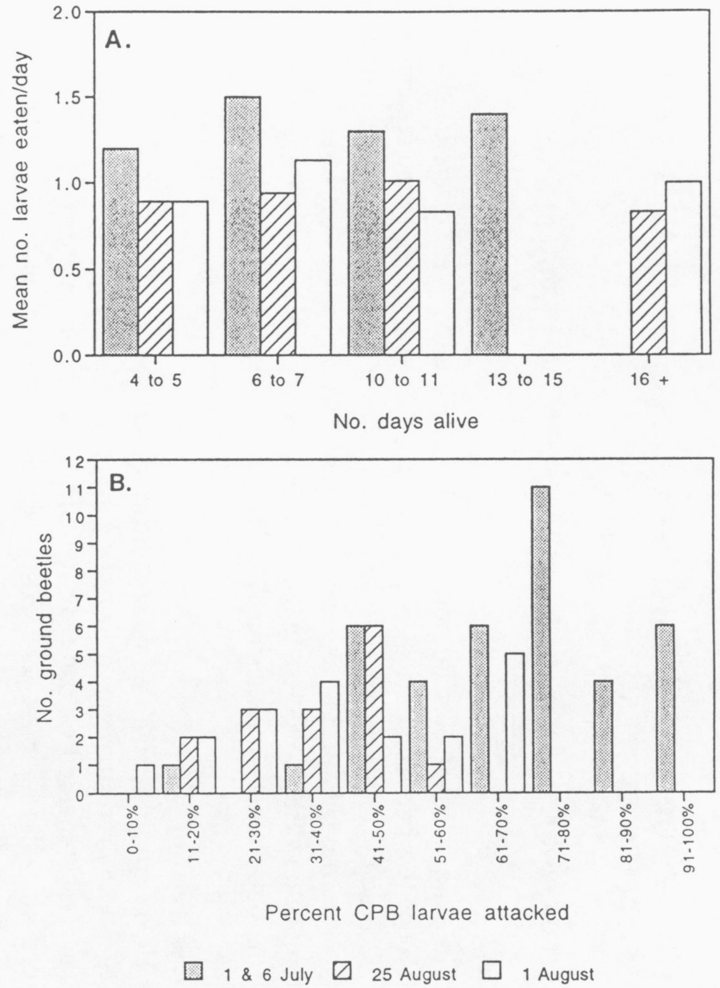
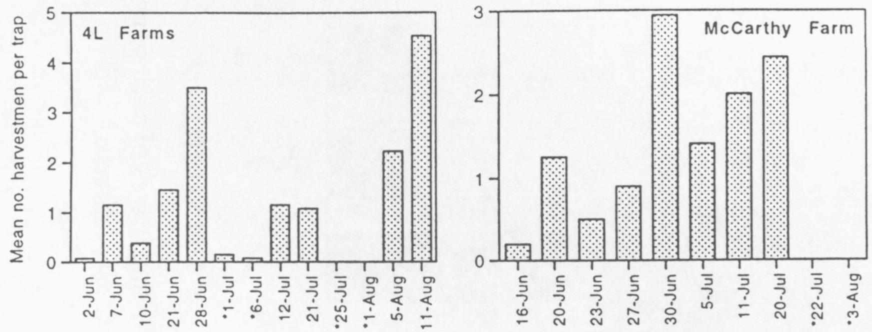


Fig 13. Mean number of harvestmen caught in pitfall traps. (*, dry traps)



Funding: Fed. Grant

Annual Research Progress Report to USDA/ARS
FY 1994

Title: THE USE OF TRANSGENIC POTATOES IN SIMULATED TRAP CROPPING SYSTEMS

Investigators: M. E. Whalon, E. J. Grafius, and M. R. Bush

Objectives 1 & 2

In petri plate arenas, Colorado potato beetle (CPB) adults were offered a six-way preference test between the leaves of different potato varieties. Initial results indicate that CPB adults preferred snowdon and onaway over russet burbank and the other potato varieties (Figure 1). In greenhouse plots, we will assess the effect of variety preference on CPB movement in trap cropping systems based on a transgenic russet burbank potato that expresses the *Bacillus thuringiensis* (*Bt*) toxin.

Objectives 3 & 4

The 1994 field study revealed no significant difference in CPB density or damage between trap crop strategies ("*Bt*-transgenic" russet burbank vs. conventional russet burbank, early-planted vs. planted simultaneously with main crop) or in the main crop adjacent to each trap crop. The "*Bt*-transgenic" potato crops were simulated by planting conventional russet burbank potatoes and spraying the plants 2-3 times per week with high rates of a *Bt* insecticide (M-trak). Due to a late planting date (wet spring, muck soil), CPB movement started prior to emergence of the trap crops. A late season frost affected our field study by reducing any potential effect of an early-planted trap crop. We will repeat this field study in 1995 with the following modifications: 1) new research plot location, 2) *Bt*-transgenic russet burbank potatoes will be used not simulated, and 3) width of each trap crop will be expanded from 4 rows to 12 - 20 rows.

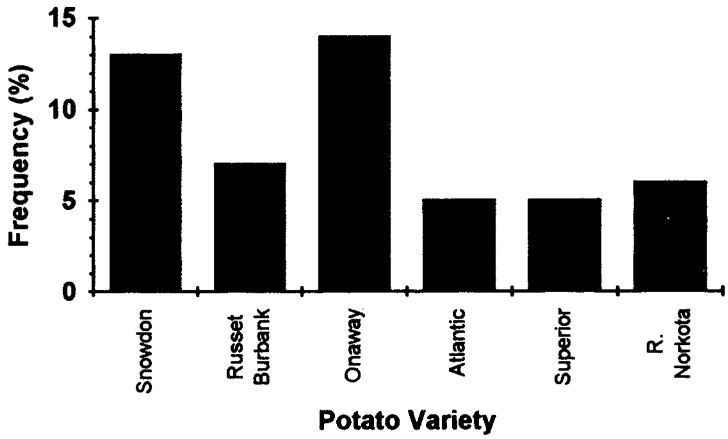


Figure 1. Frequency of CPB adults choosing leaves of each potato variety in a six-way choice test (n= 20 adults X 5 observations).

Funding: Fed. Grant

Annual Research Progress Report to USDA/ARS
FY 1994

Title: FIELD TESTING OF AN APHID RESISTANCE MONITORING TOOL FOR POTATO PRODUCTION

Investigators: M. E. Whalon & M. R. Bush

Objective 1: Development of Management Strategy- Alternating Pesticide Chemistries

Field trials were set up at five locations in Michigan (Figure 1) to evaluate alternative pesticide chemistries to control green peach aphid (GPA) resistant to organophosphate (OP) insecticides. Relative efficacies of each pesticide were similar at all locations (Figure 2). The OP insecticide, Imidan, provided little or no control of GPA. The addition of the insecticide synergist and esterase inhibitor, DEF, provided some control of GPA with Imidan. These observations suggest that OP resistance in GPA due to enhanced esterase activity is widespread throughout the major potato-producing regions of Michigan. We will explore the possibility of increasing the application rate of DEF to control resistant GPA without incurring potato phytotoxicity. Another OP insecticide, Monitor, provided adequate control of resistant GPA. Mocap and Admire were alternative chemistries that provided good control of resistant GPA at most locations. We are maintaining several colonies of GPA in the laboratory. We will perform bioassays on these GPA strains to identify an insecticide that provides enhanced control of resistant compared to susceptible aphids.

Objective 2: Development of a Resistance Monitoring Kit

In cooperation with the Neogen Corporation, we have produced a monitoring kit to detect esterase-based resistance in GPA. Initially the kit was effective in distinguishing resistant from susceptible aphids, but after one week that effectiveness was lost. This loss was attributed to oxidation of the color reagent. We will repackage the kit to include the color reagent in dry form and the user will have to add water to the color reagent to perform the test for resistance detection. GPA from several locations in Michigan and other states have been collected and frozen. These aphids will be used to test the effectiveness of the repackaged kit and confirm that GPA resistance to OP is widespread throughout Michigan and other states.

Figure 1. Location of aphicide efficacy trials performed for the green peach aphid on potatoes in Michigan. Organophosphate resistance was indicated at each location.

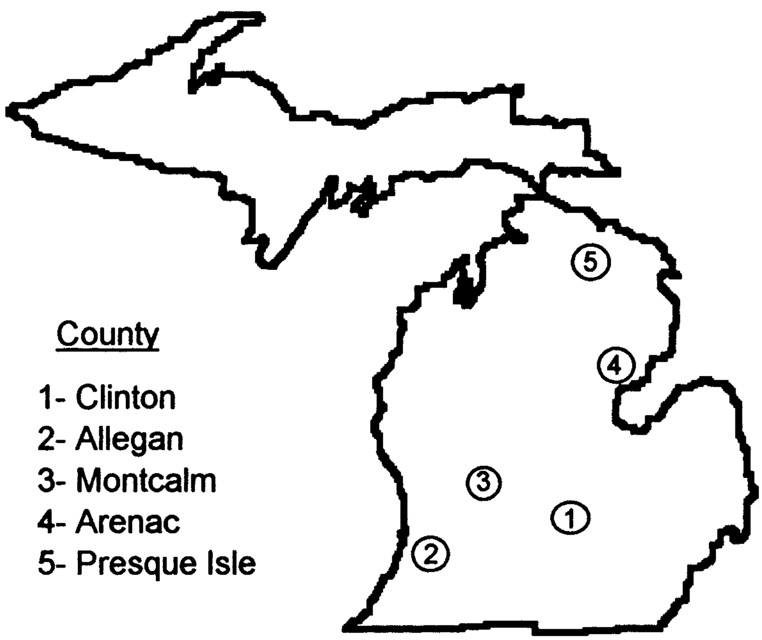
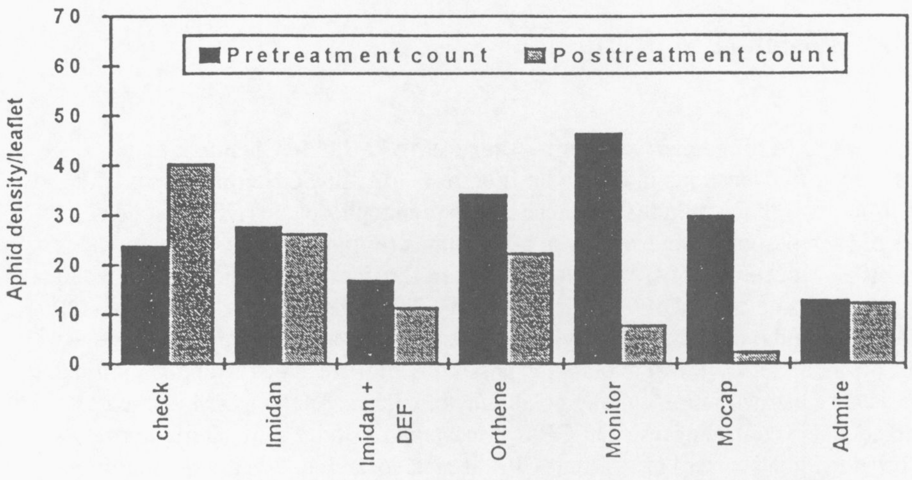
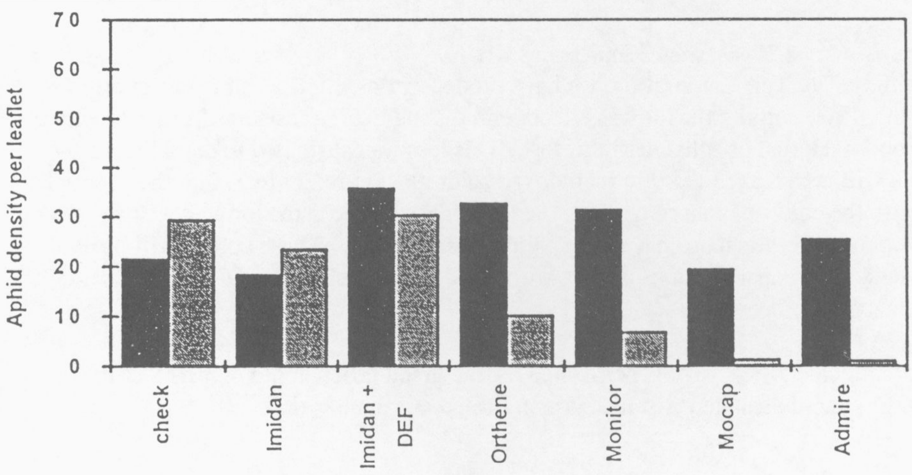


Figure 2. Change in green peach aphid density 24 hours after application of each insecticide to the potato foliage in three field tials. Insecticides were applied in 1.0 liter water over the top and sides of foliage with a CO_2 sprayer at 10psi. Application rates were as follows: Imidan 70WP- 1.13 kg/ha, DEF 6EC- 1.53 l/ha, Orthene 57S- 1.13 kg/ha, Monitor 4EC- 1.75 l/ha, Mocap 6EC- 9.5 l/ha, and Admire- 50 g A.I./ha.

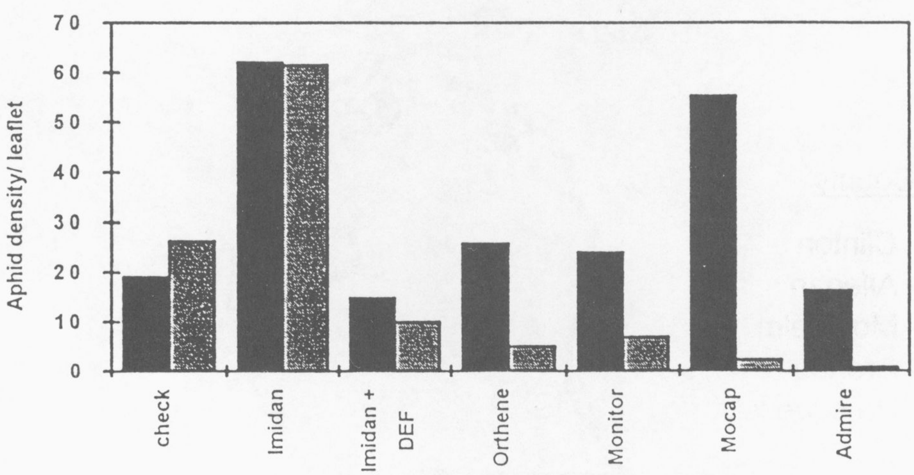
Allegan County



Clinton County



Presque Isle County



Funding: Fed. Grant/MPIC/Industry

INVESTIGATIONS OF BIOLOGICAL, CHEMICAL AND CULTURAL TACTICS FOR CONTROL OF ROOT-LESION NEMATODES IN MICHIGAN POTATO PRODUCTION

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Introduction

Successful management of plant-parasitic nematodes usually requires an integrative approach. Management of the root-lesion nematode, Pratylenchus penetrans, is no exception. The research reported on here are independent investigations of biological, chemical and cultural tactics for control of P. penetrans in potatoes. All the trials were conducted at the MSU Potato Research Farm in 1994.

Biological Control

The fungus, Paecilomyces lilacinus, has been used to effectively control a number of plant-parasitic nematodes in field and laboratory trials in a number of countries. P. lilacinus has been demonstrated to be very effective for control of root-knot and cyst nematodes (these nematodes produce large numbers of eggs within a matrix or sac) but its effectiveness against root-lesion nematodes (lay eggs singly within root tissue) has not been well documented. The product used in this experiment was BIOACT, a strain of Paecilomyces sp., marketed by American Cyanimid.

This trial was established on May 25. Potato (Snowden) seed pieces were dipped into a suspension containing the fungus, were drenched with the fungus while in furrow, or treated using both methods of application. An untreated control was included as well as a Mocap 10G treatment, applied in a 5-7 inch band at planting. The design was a randomized complete block with 6 replications. Nematode samples were collected at planting, on July 2, and at harvest. The plots were harvested on Sept. 28 and the potatoes graded at that time.

The average yields in all the treated plots were higher than those in the untreated plots although the differences were not statistically significant ($p = 0.05$, Table 1). The yields were high in all the plots, total yields exceeded 400 cwt/A for all 7 treatments. P. penetrans numbers were below damage threshold levels at planting although the nematodes increased in numbers during the growing season (Table 1). At harvest, only the plots treated with Mocap 10G had lower P. penetrans counts than the untreated plots. However, these differences were also not statistically significant ($p = 0.05$). Differences in potato yields were probably not observed due the low numbers of root-lesion nematodes recovered at planting.

Chemical Control

A nonfumigant nematicide trial was established on May 16. The trial consisted of 13 treatments in a randomized complete block design replicated 4 times. Mocap 6EC and 10G, Vydate 2L and an experimental compound, PCC 515, were included in this study. The materials were applied: broadcast, just prior to planting, and incorporated with a rototiller; in furrow at planting; in a 5-7 inch band at planting; or over the row at hilling. The potato cultivar Superior was used during this study. Plots were harvested on Sept. 1. Nematode samples were collected at planting, on July 6, and at harvest.

Yields of U.S. No. 1 tubers ranged from 262-347 cwt/A for all 13 treatments (Table 2). The highest yields were associated with the Vydate plots. These yield increases may have been due to insect control (insects were not monitored on a plot-by-plot basis) because root-lesion nematode numbers were low at planting and still fairly low within root tissue sampled on July 6. Differences between plots in numbers of root-lesion nematodes on both reported sampling dates were not statistically significant ($p = 0.05$). Therefore, it appears differences between treatments were due to other causes and not population densities of root-lesion nematodes. P. penetrans counts were below damage threshold levels at planting in all the plots.

The harsh winter of 1993-94 apparently had an impact on root-lesion nematode populations at the Research Farm. The research sites were selected based on results from nematode samples collected in the fall of 1993. The ones chosen for Nematology Research all had the highest counts of P. penetrans at that time. Counts of these nematodes exceeded 300 per gram root tissue at the time of sampling. These levels would be considered to pose high risk to a potato crop the following year. However, based on the low numbers of nematodes recovered at planting in these field trials, indirect evidence suggests that the low temperatures experienced during the winter were responsible for high mortalities of root-lesion nematodes.

Cultural Control

Ten-Year Potato Rotation Trial

A multi-year potato rotation trial was established at the Potato Research Farm in 1991. The cropping sequences, potato yields and midseason nematode counts for 1994 are shown in Table 3.

Potato (Russet Norkotah) yields have typically been poor at this location and 1994 was no exception. However, when yields are examined on a relative basis (Table 4), it is very obvious that the highest yields are always achieved when potatoes are grown following 2 years of alfalfa. The more often potatoes are grown, the more yields decline. This phenomenon has been documented in the past.

A possible explanation for the low potato yields was the low sap nitrate levels observed on July 12. Sap nitrate levels in the petioles ranged from 100 to 470 ppm (potatoes preceded by 2 years of alfalfa) on the July 12 sampling date. These levels are at least 700 ppm below the adequate range for potatoes in July. Potash, 200 lbs/A, was applied in April, but no nitrogen was applied to these plots, obviously explaining the low sap nitrate levels. The benefits of utilizing alfalfa in rotations with potato for providing nitrogen are apparent when examining sap nitrate levels within petioles.

Root-lesion nematode counts were quite low within potato roots on July 6 (Table 3). However, counts averaged 228 root-lesion nematodes/g rye root tissue on April 27 in the potato plots. Therefore, root-lesion nematodes probably also attributed to the low potato yields observed. However, whereas root-lesion nematode numbers decreased on potatoes, they typically increased on green peas (Table 3). In addition, peas supported more root-knot nematodes than potatoes. This is further evidence that green peas are excellent hosts for both of these nematodes.

Potato-Carrot Rotation Trial

Another rotation experiment was initiated at the Research Farm in 1994 investigating potato-carrot rotations. The main crop grown in 1994 was green peas to increase numbers of root-lesion and root-knot nematodes. Nematode numbers were extremely high, averaging 1367 root-lesion and 1424 root-knot nematodes per gram green pea root tissue on July 6. Carrots were not grown in any of the plots in 1994, but potatoes (Russet Norkotah) were included. The yield of U.S. No. 1 tubers was 171 cwt/A. In contrast to the counts within green pea roots, root-lesion and root-knot nematodes averaged 75 and 185/g potato root tissue, respectively, on the July 6 sampling date. The primary objectives of this research are to examine the influences of root-lesion and root-knot nematodes on potatoes and carrots grown in mineral soil. These nematodes will be managed with and without the use of nematicides and attempts will be made to correlate yield responses with nematode numbers.

Cover Crop Study

A number of crops were planted as fall covers on Aug. 30 to investigate them as potential hosts for *Pratylenchus penetrans* and to examine their benefits as green manure crops preceding soybeans. Fall covers/green manure crops were also investigated in the fall of 1992 and potatoes planted in 1993 to determine if they provided benefits for root-lesion nematode management and potato yield increases. It was discovered in 1992, that all the cover crops utilized, rapeseed, canola, rye and oats were excellent hosts to *P. penetrans* and subsequent potato yields were not increased compared to the rye (used as the standard), unless the plots were also treated with Vapam. The crops utilized in 1994 and the counts of *P. penetrans* obtained this fall are shown in Table 5. For comparative purposes, the numbers of nematodes recovered in the fall of 1992 are also displayed. The wide disparities in the numbers found in 1994 compared to 1992 are excellent indicators of the annual variabilities associated with nematode populations. Although soybeans, and not potatoes, will be grown in these plots in 1994, this information should still be of interest to potato producers because utilizing fall cover crops that are poor hosts to *P. penetrans* should lessen the dependence on nematicides. All of these crops were amended to the soil during the last week of Oct., 1994.

Futuristic Approaches to Nematode Management

Four experiments were conducted in 1994 examining "futuristic" approaches to nematode management in Michigan potatoes. Inter- or companion cropping, and the uses of compost and animal manure were the treatments examined in these studies. Nematode data are not available at this time however, the potato (cv. Snowden) yield information for the garlic-onion-potato study is presented in Table 6, the flax-lentil-potato study in Table 7, the compost study in Table 8 and the manure study in Table 9. In all 4 studies, the differences in yields observed between treatments were not statistically significant ($p = 0.05$).

Total tuber yields obtained in the garlic-onion-potato (Table 6) and the flax-lentil-potato study (Table 7) all exceeded 320 cwt/A. Companion cropping with garlic and/or onions and flax and/or lentils provided no yield benefits. The best yields were ca. 25 cwt/A (onion-potato treatment) higher than the potato only plots (checks).

The use of compost provided no potato yield increases in this study (Table 8). These results were somewhat anticipated because evidence suggests that compost is best applied in the fall preceding a potato crop for maximum benefit. Excluding the results obtained for treatment 5 (compost applied at 40 T/A), a negative correlation existed for quantity of compost applied and tuber yields, as compost tonnage increased, yields decreased. Although, it's difficult to draw conclusions from this experiment regarding the benefits of compost, its use did increase the incidence of potato scab. Tubers were rated from 1 (0-20% of tubers with scab lesions) to 4 (75-100% of tubers with scab lesions) as they were graded. In the plots where no compost was applied, the scab rating was 1.00. The rating was 3.25 for plots where compost was applied at 40T/A. The ratings for the other treatments were between these 2 values. The rate of compost applied explained 26% of the variability in the scab ratings when using regression analysis.

The uses of animal manure and tarp resulted in drastic, although statistically not significant ($p = 0.05$), yield increases. The combination of manure plus tarp resulted in a total tuber yield increase of 100 cwt/A (Table 9). With no other information available at this time regarding nematode levels, etc., it's difficult to explain why yields increased so dramatically. However, this approach should be investigated again in the future in an attempt to reproduce these results.

Table 1. BIOACT for control of *Pratylenchus penetrans* in Michigan potatoes, 1994.

Treatment	Yields (cwt/A)		*P. penetrans*		
	No. 1	Total	May 25[1]	July 2[2]	Sept. 28[1]
Untreated	358.06	407.04	7.50	29.00	128.17
Mocap 10G	413.24	449.93	6.17	48.83	58.17
BIOACT tuber dip (40 g/L) + soil drench (2 kg/ha)	416.56	471.01	7.50	79.33	148.33
BIOACT tuber dip (80 g/L) + soil drench (4 kg/ha)	415.33	462.61	3.83	63.33	161.00
BIOACT tuber dip (160 g/L) + soil drench (8 kg/ha)	378.81	422.84	11.33	124.00	114.17
BIOACT tuber dip (160 g/L)	384.91	434.14	14.33	37.33	147.33
BIOACT soil drench (8 kg/ha)	389.13	442.97	12.17	44.83	138.67

[1]Root lesion nematode counts per 100 cc of soil at planting (May 25) and at harvest (September 28).

[2]Root lesion nematode counts per gram root tissue (July 2).

Table 2. Control of the root-lesion nematode, *Pratylenchus penetrans*, with nonfumigant nematicides in Michigan potatoes, 1994.

Treatment	Yields (cwt/A)		*P. penetrans*	
	No. 1	Total	May 16[1]	July 6[2]
Mocap 6 EC: 6 lbs ai/A PPI	317.43ab	336.49ab	6.75	7.75
Mocap 6 EC: 6 lbs ai/A IF	306.96ab	323.13ab	7.00	28.00
Mocap 6 EC: 9 lbs ai/A PPI	319.36ab	338.03ab	10.50	0.00
Mocap 10 G: 3 lbs ai/A at planting	270.85ab	288.56ab	21.75	37.25
Untreated	298.38ab	310.50ab	15.75	42.25
Vydate 2L: 4 gal/A PPI	328.60ab	344.38ab	12.75	16.25
Vydate 2L: 2 gal/A PPI	347.08 b	363.44 b	5.00	6.00
Vydate 2L: 2 gal/A IF	323.98ab	341.11ab	14.75	16.00
Vydate 2L: 1 gal/A IF	305.69ab	323.40ab	16.25	22.25
Vydate 2L: 2 gal/A at hilling	331.49ab	348.62ab	17.25	22.67
PCC 515: 178 lbs/A PPI	261.99a	282.98a	15.00	34.50
PCC 515: 268 lbs/A PPI	318.40ab	335.33ab	7.25	25.75
PCC 515: 357 lbs/A PPI	308.96ab	325.33ab	9.25	14.00

[1]Preplant densities of root-lesion nematode, 100 cc of soil.
[2]Nematode counts per gram root tissue.

Table 3. Crop Rotation Trial, 1994.

Crops[1]				Yield (cwt/A)		Nematodes/g of root tissue	
1991	1992	1993	1994	No. 1	Total	RLN	RKN
P	P	P	P	18.25a	37.81a	10.88	0.00
A	P	P	P	20.50a	42.44a	36.38	5.13
A	A	P	P	35.00b	61.56b	9.00	1.25
OT	A	A	P	61.72c	88.59c	12.13	2.38
OT	P	P	P	19.31a	39.81a	15.13	14.50
OT	S	A	A	---	---	107.88	6.00
OT	S	LRK	A	---	---	92.50	98.88
OT	S	LRK	GP	---	---	421.25	16.13
OT	S	LRK	GP	---	---	717.38	6.50
OT	S	LRK	GP	---	---	398.50	268.25

[1]P = Potato; A = Alfalfa; OT = Oats; S = Soybean; LRK = Light Red Kidney Beans; GP = Green Peas.

Table 4. Cropping Sequences and Relative Yields of Russet Norkotah Potatoes in Rotation Trial, MSU Potato Research Farm, 1991-1994.

Cropping Sequences[1]				Relative Yields, U.S. No. 1[2]			
1991	1992	1993	1994	1991	1992	1993	1994
P	P	P	P	1.00	0.65	0.34	0.29
A	P	P	P		1.00	0.54	0.34
A	A	P	P			1.00	0.57
OT	A	A	P				1.00
OT	P	P	P		0.96	0.53	0.32

[1]Crop Symbols: P = potatoes; A = alfalfa; OT = oats

[2]Relative Yields calculated by giving the highest annual yield a value of 1.00 and dividing the other yields by the highest value.

Table 5. Fall Cover/Green Manure Crop Trial, MSU Potato Research Farm, 1994.

Fall Cover/Green Manure Crop	Root-lesion nematodes/g root	
	Oct. 25, 1994	Nov. 4, 1992
Annual Ryegrass cv.	11.6	
Black Lentil	110.4	
Canola	--	1179.2
Green Peas cv. Sugar Ann	91.6	
Hairy Vetch	106.8	
Marigold cv. Crackerjack	13.4	
Oats cv. Heritage	--	1072.0
Rapeseed cv. Askari	21.6	1764.0
Rapeseed cv. Bridger	24.4	1037.5
Rapeseed cv. Sollux	18.4	1087.2
Rye cv. Field Grade	38.0	1251.0
Spring Barley cv. Bowers	45.8	

Table 6. Onion-Potato Companion Cropping Study, 1994.

Treatment	Yield (cwt/A)	
	No. 1	Total
Check	282.58	336.79
Check + Onions	297.02	364.69
Check + Garlic	252.43	322.03
Check + Onion + Garlic	270.71	334.86

Table 7. Flax-Lentil-Potato Companion Cropping Study, 1994.

Treatment	Yield (cwt/A)	
	No. 1	Total
Check	254.03	329.73
Check + Lentils	275.52	331.98
Check + Flax	279.05	343.84
Check + Lentils + Flax	265.26	335.83

Table 8. Use of Compost in Michigan Potatoes, 1994.

Treatment	Yield (cwt/A)	
	No. 1	Total
0 tons	320.11	346.09
5 tons (7.5 lb/row)	312.41	335.18
10 tons (15 lb/row)	297.98	321.39
20 tons (30 lb/row)	266.22	297.02
40 tons (60 lb/row)	350.26	374.00

Table 9. Use of Animal Manure in Michigan Potatoes, 1994.

Treatment	Yield (cwt/A)	
	No. 1	Total
Check	223.88	254.03
Tarp	299.07	352.31
Manure: 10 tons/A	302.15	329.41
Manure + Tarp	325.56	355.39

Funding: Fed. Grant/MPIC

Fusarium Dry Rot Research

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Fusarium dry rot, caused by *Fusarium sambucinum* is a problem in the storage of potato and in seed piece decay. Part of the problem is related to the development of resistance of this fungus to thiabendazole and to thiophante methyl. These two fungicides are used in post harvest control and as a seed treatment, respectively.

Surveys of *F. sambucinum* throughout Michigan indicates that the isolates resistant to both fungicides dominate the pathogen populations.

Last year we determined that the pathogen was still sensitive to other chemical used as seed treatments (e.g. Dithane, captan). Thus, we tested these chemicals as seed protectant as compared to thiophante methyl. In addition, we have known for several years that proper wound healing will protect the tubers against infection, and that this resistance was correlated with the onset of a group of enzymes known as peroxidases that are involved in suberization. Our second objective was to make transgenic potato that expressed higher levels of peroxidase to determine if these plants were more resistant to dry rot. Finally, we have started to evaluate the nature of resistance in two lines of potato received from the USDA potato breeding program at Aberdeen, Idaho and have initiated studies to determine why *F. sambucinum* is pathogenic on potato.

Objectives

1. Test standard seed treatments

2. Begin to develop transgenic potato that have potential for enhanced wound repair and resistance

3. Evaluate the nature of resistance to *F. sambucinum* in resistant germplasm.

4. Initiate studies on the nature of pathogenicity in *F. sambucinum*.

Procedure

1. Seed treatment. Potato tubers of the varieties Atlantic and Snowden were cut and immediately treated with recommended rates of Dithane M45, captan, Tops-2.5D, or left untreated. Tubers were then planted and stand counts made after emergence. In addition, tubers were also cut, treated with mancozed, thiosphante methyl, or left untreated and then inouclated with a TBZ resistant strain of *F. sambucium* underlaboratory conditions. Tubers were rated as decayed or not decayed.

2. Development of transgenic potatoes. A peroxidase gene thought to be involved in resistance of cucumber to fungal pathogens was used to transform potato by standard means using Agrobacterium tumefaciens-mediated transformation. In brief, a peroxidase gene that we previously cloned from cucumber expressing general disease resistance was used to transform potato with a constitutive promotor that should allow for the continual expression of this gene in the plant. Attempts at transformation of several cultivars were made.

3. Two lines reported to be resistant to *F. sambucinum* are being studied. Tuber tissue of these lines were prepared and inoculated with the pathogen. Variables that are being monitored include disease progress in the tissue, and peroxidase activity and phenoloxidase activity in both infected and healing tissues.

4. factors causing *F. sambucinum* strains to be pathogenic and the behavior of these strains on tuber tissue is being studies in two ways. In the first case, different strains are inoculated onto tuber tissue and the response of the plant and disease development over time is being monitored. Host responses include peroxidase and phenoloxidase, and the synthesis of antibiotic terpenoids by the host tissue. In addition, we have started to study the control of pathogenicity in the fungus. We have made a number of crosses between different isolates of the pathogen that exhibit different degrees of pathogenicity. Analysis of the offspring of these crosses should allow us to determine how many genes control pathogenicity in the fungus and will help us to identify why the pathogenic strains are more virulent than the non-pathogenic strains.

Results

1. Seed piece treatments: All treatments resulted in the same degree of stand. No major difference were seen between the fungicides or the non-treated controls. In laboratory tests, however, mancozeb provided much better control than did thiophante methyl or the non-treated controls when treated tubers were inoculated with thiabendazole resistant *F. sambucinum*.

2. We have successfully transformed the peroxidase gene into three

lines of potato. These plants are currently being grown to maturity to allow testing of the tubers for enhanced resistance and/or suberization potential. In addition, these plants will also be tested for enhanced resistance to *Phytophtora infestans*.

3. In the potato lines that are resistant to *F. sambucinum*, we have noted that the progress of the disease is much slower. Biochemical analysis of tissue indicates that the resistant lines have a higher phenoloxidase and peroxidase level than the susceptible checks. We have also found evidence for the production of a new peroxidase that is only in the resistant line. The enzyme appears after two days, but this may be earlier enough to play a role in the confinement of the pathogen.

4. Inoculation of potato with a number of different isolates of *F. sambucinum* have yielded difference in the production of resistance-related enzymes (peroxidase and phenoloxidase), antifungal terpenoids and phenolic compounds. No clear pattern, however, has been seen as of yet. Non-pathogenic and pathogenic strains of *F. sambucinum* have been crossed and fruiting structures (perithecia) obtained from these crosses. The spores that are produced in the perithecia are being isolated. Re-inoculation of potato with these progeny spores followed by assessment of the amount of disease will help indicate how many genes are involved in pathogenicity. If the number is one or a few, it may be possible to identify these genes and develop control measures that act by interfering with the action of these genes.

Funding: MPIC

IDENTIFICATION AND DOCUMENTATION OF THE MOST PROMISING COVER CROPS AND ROTATIONS FOR MICHIGAN POTATO PRODUCTION

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The purpose of this study is to document actual producer practices and perceptions of crop rotations and cover crops in potatoes grown in Michigan. Current information on cover crops and rotations used in Michigan potato production is lacking. Such information should be useful in planning strategies for potato rotation and cover crop research.

We are still in the process of contacting growers who have not returned surveys yet in order to strengthen the survey information. Therefore, a report with complete results will be included in next years research report. A very brief summary of selected information is given below.

Potato growers were surveyed during the summer of 1994. Returned surveys from growers represented 40 percent of the acreage grown in 1994.

Thirteen potato crop rotations were identified. Seven of the rotations consisted of a legume crop. Ninety five percent of the respondents indicated planting some kind of cover crop. Growers indicated the cover crops were used primarily for reducing soil erosion but also included improving soil tilth, fertility, and nematodes. The most popular cover crop was rye, however, other cover crops used included oats, red clover, barley, alfalfa, and wheat.

Funding: Fed. Grant

POTATO STORAGE RESEARCH

MPIC/MSU Experimental Storages
1994 Harvest Season

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GOAL: to develop guidelines for long term storage management of chipping potatoes in Michigan

OBJECTIVES

- monitor the effects of various cooling rates and low temperature storage limits on chip quality
- monitor the effects of early storage season temperature stress on seed performance
- monitor the effects of early storage season temperature stress on chip quality
- monitor the response of selected varieties to low temperature storage

INTRODUCTION

Reducing sugar content is important in potatoes used in any process which involves frying. Darkening of potatoes due to the Maillard reaction can substantially reduce the value of the finished product. Glucose and fructose, the reducing sugars in potatoes, are produced during storage from starches which compose 60-80% dry weight of the tubers. Sugar content in potatoes differs among varieties. Sugar levels can be monitored by measuring glucose content in potato juice and by color evaluation of chips.

EFFECT OF COOLING RATES AND LOW TEMPERATURE STORAGE LIMITS ON THE LONG TERM STORAGE OF SNOWDEN POTATOES

During the summer of 1993, MSU researchers began working with Bishop Potato Farms of Pinconning, MI to develop four new experimental research bins, which were incorporated into a new potato storage building. These storage bins are approximately 10 ft. square with walls on three sides that slope slightly inward and have a capacity of 500 cwt. each. There are two Fancom ESUS-4 potato storage controllers, each providing independent environment control to two storage bins. Due to construction delays, the bins were not filled during the 1993 harvest season. They were finished and ready for the 1994 harvest season.

For the 1994 harvest season, the MPIC Storage Committee develop a protocol for management of these bins:

bin 21	filled with W870 potatoes harvested Oct. 14; goal is to find a temperature level where sugar levels start to rise; cooling rate to be 0.4°F per day down to 50°F and then 0.2°F per day for cooling to lower temperatures
bin 22	filled with Snowden potatoes harvested Oct. 14, 1994; these were grown in the same field as the W870 potatoes in bin 21; goal is to cool potatoes to 42°F; cooling rate to be 0.4°F per day down to 50°F and then 0.2°F per day for cooling to lower temperatures
bin 23	filled with Snowden potatoes on Oct. 4; goal is to cool potatoes to 45°F; cooling rate to be 0.4°F per day down to 50°F and then 0.2°F per day for cooling to lower temperatures
bin 24	filled with Snowden potatoes on Oct. 4; goal is to cool potatoes to 45°F; cooling rate to be 0.8°F per day down to 50°F and then 0.4°F per day for cooling to lower temperatures

All bins were treated with an application of gaseous CIPC on Nov. 8. Cooling began Nov. 14, with actual cooling rates of 0.42, 0.42 and 0.64°F for bins 21-24, respectively, for the next two week period. Figure Figure 1 presents data on temperature, sucrose levels and glucose levels of samples from the four experimental bins for the fall harvest, 1994.

EFFECT OF EARLY STORAGE SEASON TEMPERATURE STRESS ON THE STORAGE OF SELECTED CHIPPING VARIETIES

The Snowden variety has become a common variety for chipping potatoes in long term storage in Michigan. However, the grower and research communities are evaluating promising new varieties. For varieties that show commercial potential, it would be desirable to generate information on sugar changes during long term storage to help in evaluating samples in the Michigan bin monitoring program.

Varieties W870 and E5535 were grown at Sackett Potatoes and L. Walther & Sons, respectively. These varieties were each separated into four lots. The initial temperature for the samples was 50°F. The temperature was decreased 0.5°F per day until the desired level was obtained. Lots 1 and 2 were stored at 45°F and 50°F respectively. Lot 3 was stored at 65°F for 1 month and then stepped down to 50°F in increments of 0.5°F per day. Lot 4 was stored at 65°F for 2 months and then stepped down to 50°F in increments of 0.5°F per day.

The potato storage experiment started December 6, 1993 after suberization time for the two varieties and concluded April 25, 1994. Juice samples of each variety and each storage temperature condition were taken at 1 week intervals to evaluate sugar content. Juice from 200g of potato centers was diluted with water to 430 ml. A small sample of this was analyzed with the YSI glucose analyzer.

Potato slices were fried each month to evaluate chip color. Potato chips were fried in canola oil for 1 minute and 55 seconds at a temperature of 360°F. chip color based on Snack Food Association fry color standards, was measured by a panel of three with experience in color reading.

A comparison of W870 tubers stored at 65°F for 0 and 1 months shows that both maintained a very low sugar content (glucose <0.01%), with chip colors mostly 1-2. However, the tubers stored for 2 months at 65°F experienced an increase in sugar content in the final month of the experiment, with chip color increasing to 4.

The W870 and E5535 potatoes stored at 65°F for 1 and 2 months experienced physical deterioration beginning in mid-February. This was the most obvious in the tubers stored at 65°F for 2 months. There was no evidence of differing deterioration levels among varieties. This deterioration continued into March to the point where the tubers were beginning to give off a rotten odor. These tubers were removed from the experiment and discarded at the beginning of April.

Storage of tubers at 65°F for an extended period of time (>1 month) may be too far out of the normal storage temperature regime. The high temperatures seemed to physiologically deteriorate the potatoes at a much faster pace than other storage temperatures in the experiment (50-55°F). There does not appear to be any difference between 0 and 1 month of high temperature treatment on glucose levels for either variety, as illustrated in Figure Figure 2.

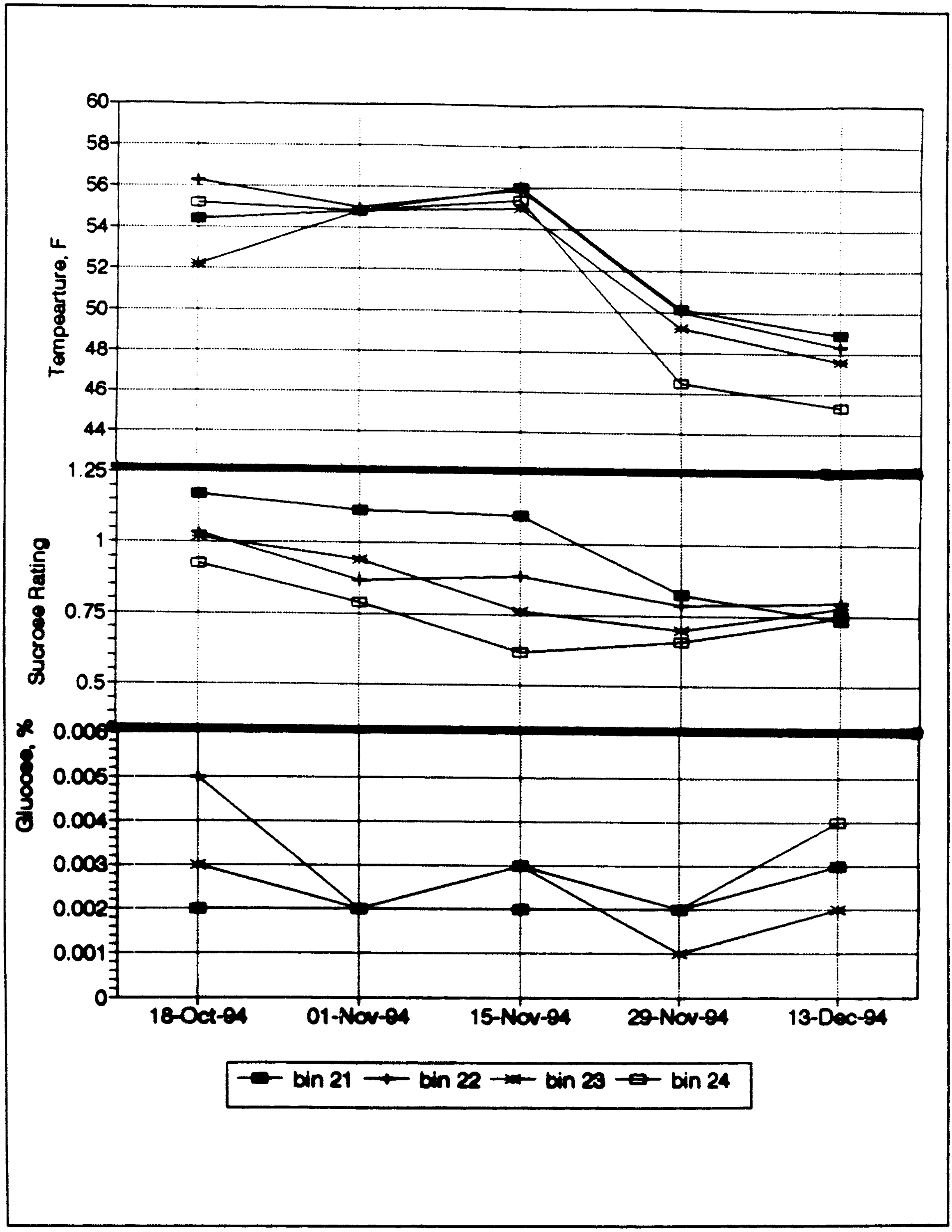

Figure 1. Temperature, sucrose and glucose data for the four MPIC / MSU experimental potato storage bins for fall harvest, 1994.

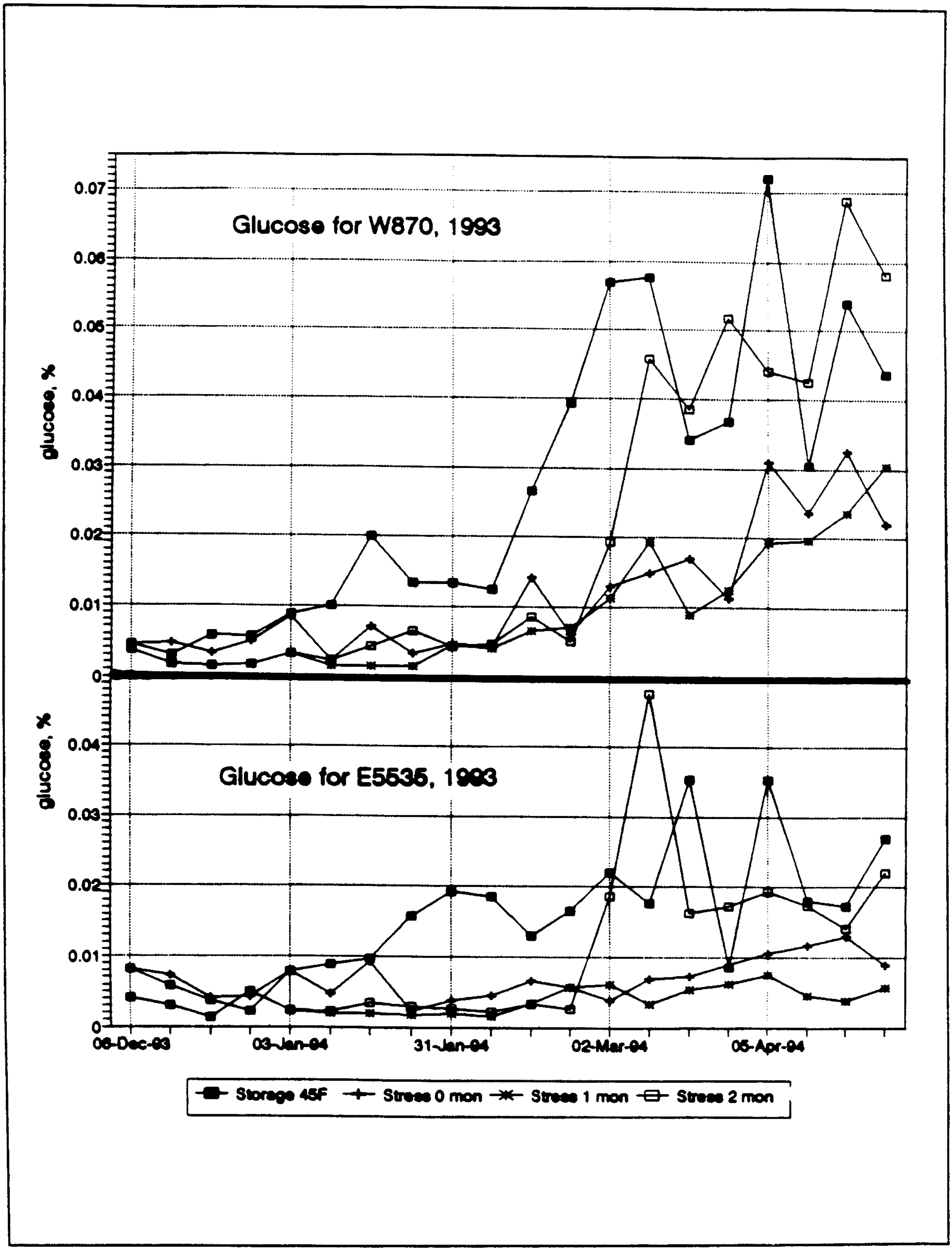

Figure 2. Glucose levels for varieties W870 and E5535 for 1993/94 storage season.

EFFECT OF EARLY STORAGE SEASON TEMPERATURE STRESS ON SNOWDEN SEED POTATOES

Snowden variety potatoes were loaded in the MSU experimental storage in Kalkaska on Sept. 13, 1993. The storage holds approximately 350 cwt of potatoes. The temperature of the experimental storage was managed to approximate the temperature in the commercial storage for the purpose of comparing storage performance (see Figure 3).

During loading, sample bags were placed at two levels in the experimental storage. Additional sample bags were filled for placement in the commercial storage surrounding the experimental storage. These samples were used to estimate weight loss during the storage season, and for seed performance studies outlined below. The resulting weight loss for the experimental storage and the commercial storage are presented in Table I.

Weight loss (%) for seed potato samples during long term storage research, Snowden 1993 harvest, presented as percent weight loss with averages in the last row.

top layer weight loss, %	bottom layer weight loss, %	commercial storage weight loss, %
9.5	9.4	8.6
9.2	10.5	8.8
9.6	9.9	
9.4	**9.9**	**8.7**

Additional sample of the potatoes were transported to the MSU campus for an experiment on the effect of early storage season temperature stress on the performance of seed tubers. These tubers were divided into four sub-samples. The first was decreased in temperature at 0.5°F per day until reaching 40°F. The other two sub-samples were stored at 65°F for one, two and three months respectively, before being cooled at 0.5°F per day to 40°F.

These tubers remained in storage until early May, 1994 when they were cut into seed pieces for planting. At that time, the sample bags from Kalkaska were retrieved and also cut into seed pieces. These seed pieces were planted at the Montcalm research farm in four replicated seed plots per treatment, with 23 seed pieces planted in each plot. Due to problems with suspected cross-contamination of these samples with CIPC in the on-campus storage cubicle, this phase of the experiment was terminated in June after checking plant emergence.

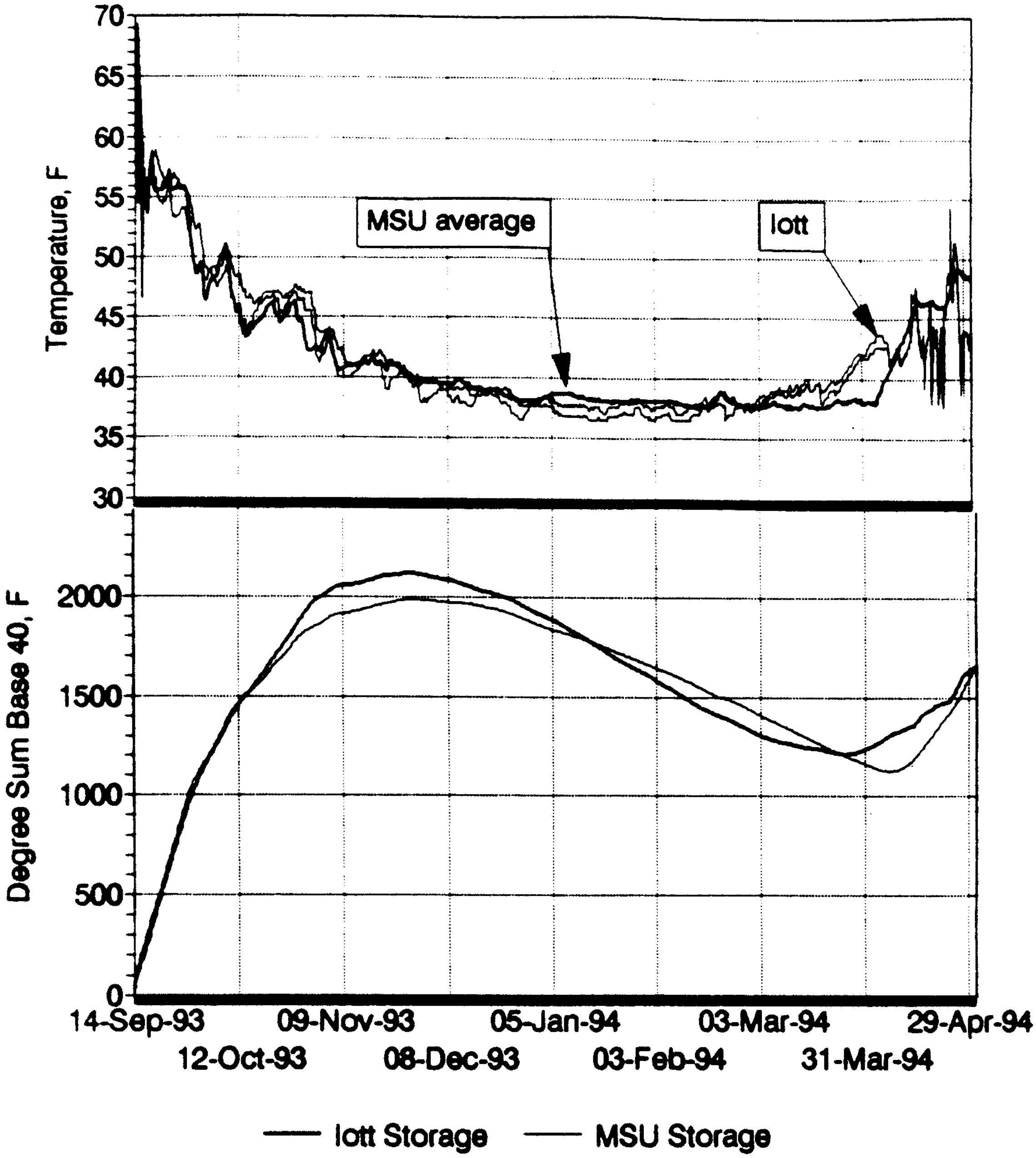

Figure 3. Temperature and degree sum information for the MPIC / MSU experimental potato storage in Kalkaska Co., 1993/94 storage season.

RESPONSE OF SELECTED CHIPPING VARIETIES TO LONG TERM, LOW TEMPERATURE STORAGE

Eleven varieties of potatoes were grown in clay conditions at V&G Farms in Stanton, MI. The harvest date of the potatoes was October 11, 1993. The tubers were stored at the Montcalm Research Farm until October 26 for suberization. Upon the completion of suberization, they were dipped in a Sprout Nip solution, dried in the sun and transported to the Food Science Building at MSU for the storage experiment. The tubers were stored in temperature controlled enclosed cubicles. They were initially stored at 50°F. This temperature was decreased 0.5°F per day until a final storage temperature of 45°F was achieved; the humidity was held at 95%.

Sub-samples of tubers for varieties Snowden, NDA2031-2 and Norchip were initially held at 50°F. This temperature was decreased at 0.5°F per day until a final storage temperature of 40°F was reached.

The potato storage experiment started October 27, 1993 and concluded April 25, 1994. Juice samples of each variety and each storage temperature condition were taken at 1 week intervals to evaluate sugar content. Juice from 200g of potato centers was diluted with water to 430 ml. A small sample of this was analyzed with the YSI glucose analyzer.

Potato slices were fried each month to evaluate chip color. Potato chips were fried in canola oil for 1 minute and 55 seconds at a temperature of 360°F. chip color based on Snack Food Association fry color standards, was measured by a panel of 3 with experience in color reading.

There was a large difference in sugar content among the varieties stored at 45°F (see Figure 4). The varieties which sustained the lowest sugar content throughout the experiment were Snowden, E5535 and NDA2031-2. Some tuber varieties such as NY95 and A80559-2 experienced sharp rises and falls in sugar content during storage, but overall had a high level. Some of the variation in sugar levels was due to the small tuber size (and probable immaturity of the tubers).

The Snowden variety started with fairly high glucose levels (>0.05%) but consistently decreased during 45°F storage to an ending level of about 0.01%. NDA2031-2 had a low sugar content at the beginning of storage and maintained this low level throughout the experiment. The chip color was also desirable indicating a low sugar concentration. The Norchip variety had a consistently rising sugar content though out the storage period. The highest quantity was in the final month of storage where the glucose content was over 0.1%. The variety had an unacceptable dark color in it's chips.

The potato varieties stored at 40°F (Snowden, NDA2031-2 and Norchip, illustrated in Figure 5) were reconditioned beginning in early March in an attempt to lower the high glucose levels. The reconditioning process involved raising the temperature from 40°F to 55°F at 1°F per day.

The sugar levels in the NDA2031-2 and Norchip varieties did not substantially decrease after reconditioning by raising the temperature from 40°F to 55°F. However, the sugar levels did not continue to rise at 55°F as they had at 40°F; chip color remained at the 4-5 level. The Snowden variety responded to the reconditioning with a large drop of sugar levels from it's peak of 0.068% glucose down to 0.010%; chip color improved to 2-3.

The sugar content data had large variations in weekly juicing evaluations. The normal tuber sample size in this procedure is 10-15. However, there were not enough potatoes in each variety for such a sample size this year. The tubers were also small in size. The low number of weekly samples in

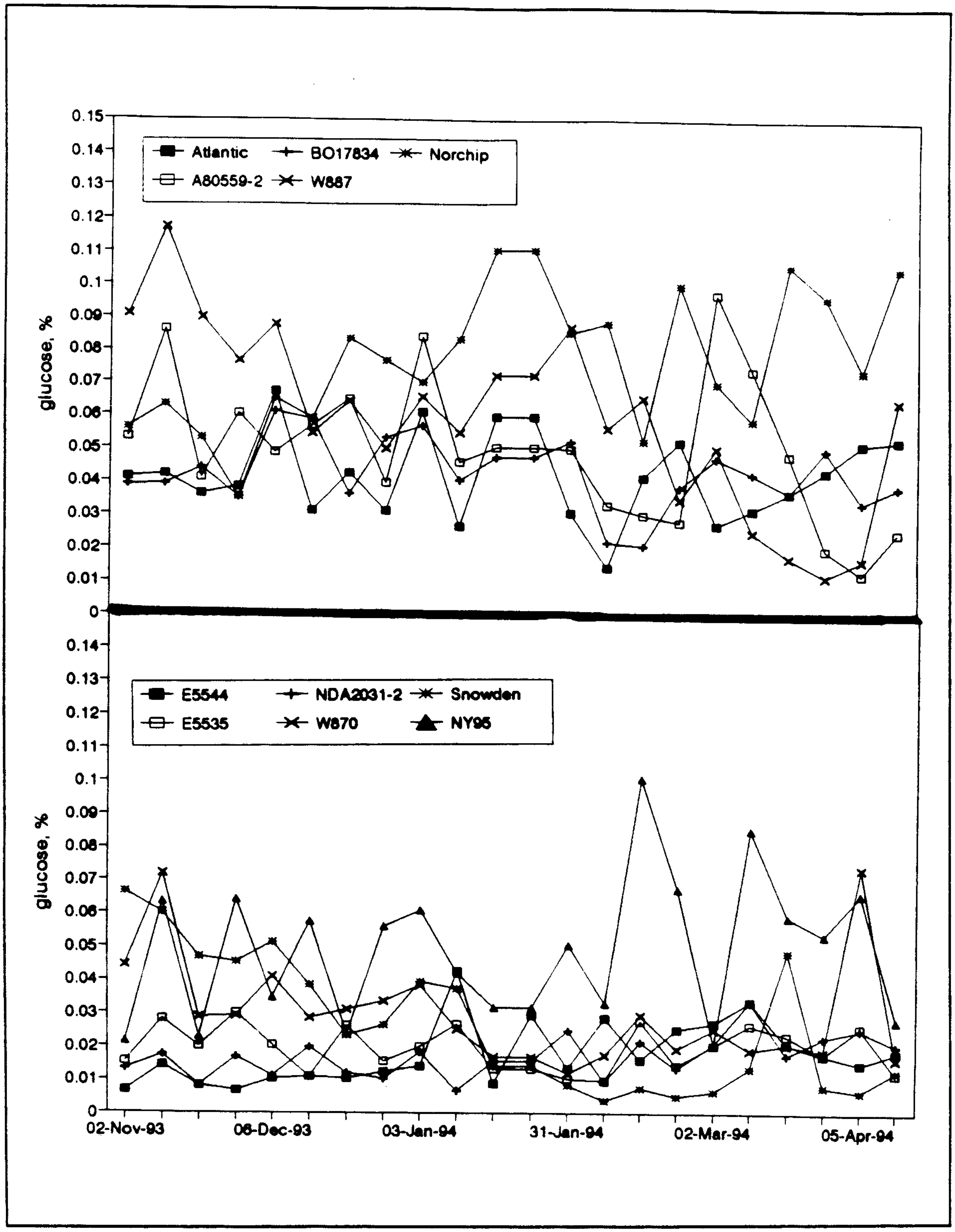

Figure 4. Glucose levels for varieties from the Snack Food Association variety trial plots, 1993/94 storage season.

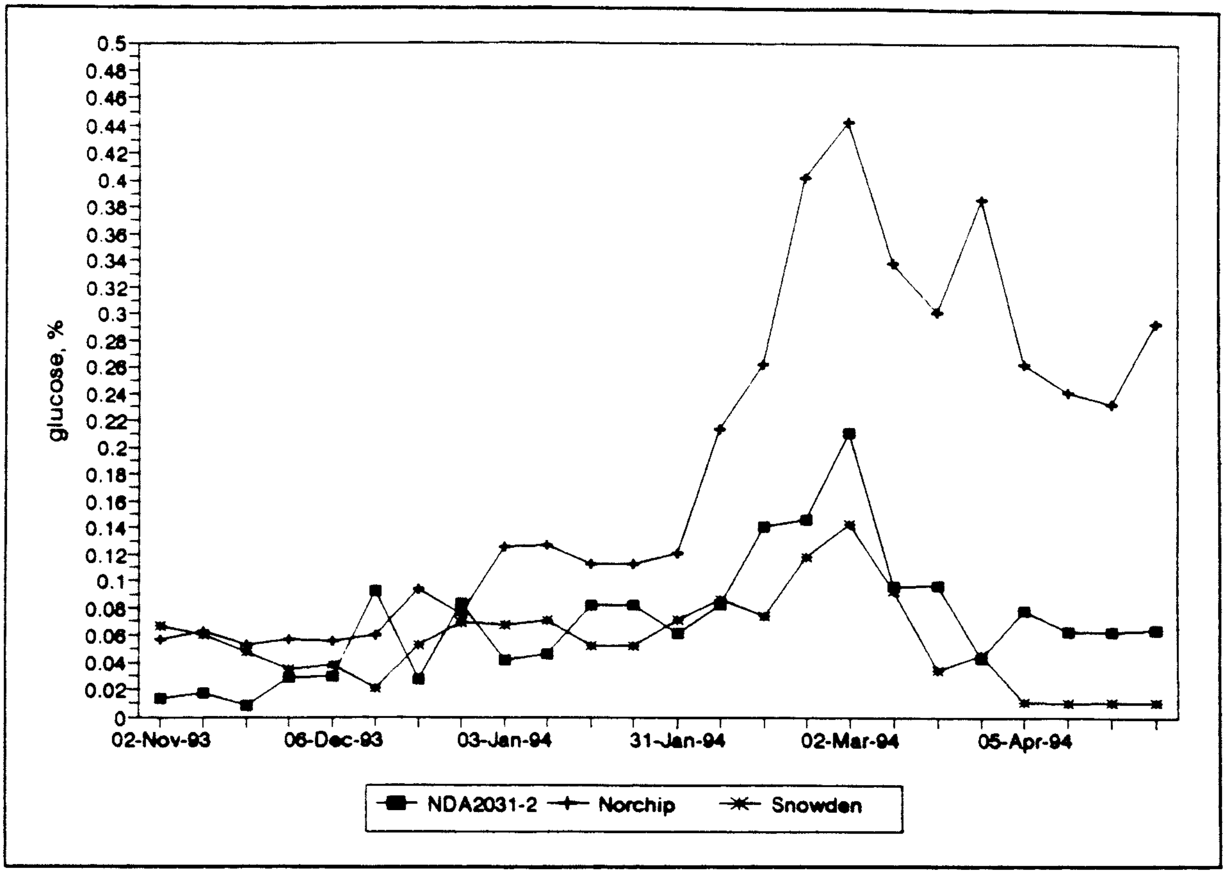

Figure 5. Glucose levels for varieties from the Snack Food Association variety trial plots storage at 40°F, 1993/94 storage season.

addition to the small size and probable immaturity is believed to be the reason for high variations.

Some of the large tubers stored at 45°F had hollow heart. The variety that was the most susceptible to this condition was A-80559-2. The A-80559-2 variety also had noticeable wounding on it's surface. As the study progressed, the wounds seemed to allow the tubers to be susceptible to mold growth. The A-80559-2 variety had a high sugar content.

The NDA2031-2 variety performed very well in storage at 45°F and should be utilized in future storage research at different temperatures.

The Snowden variety proved to maintain a low sugar content at 45°F as well as responding favorably to reconditioning after storage at 40°F. Because of this and it's growing important in the Michigan potato industry, Snowden should be utilized in future storage studies.

The response of varieties which maintained a low sugar content in 45°F storage should in included in the 40°F storage experiments. These varieties should include E5544, NDA2031-2 and E5535.

HUMIDIFICATION STUDY

After consultation with the commercial cooperator on this project, we decided not to attempt the experimental comparison of humidifier systems this year because of the blight pressure. It was thought that the humidification systems would not be run in an attempt to limit the spread of late blight in storage. The experiment will be attempted during the 1994/95 storage season with existing funding, assuming that weather and storage conditions are conducive to operation of humidification systems.

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